SAFE WATER AND WASTE DISPOSAL FOR RURAL HEALTH:

A PROGRAM GUIDE

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SAFE WATER AND WASTE DISPOSAL FOR RURAL HEALTH: A PROGRAM GUIDE

PREFACE

This book, *Safe Water and Waste Disposal for Rural Health: A Program Guide,* is part of the "Water for the World" series prepared by National Demonstration Water Project under contract to the U.S. Agency for International Development. The "Water for the World" materials are all focused on providing concrete assistance to the developing nations in planning and implementing programs and projects in rural water supply and sanitation. This program guide was written for people in the developing nations who have, or are interested in having, the responsibility for addressing rural water and waste disposal problems through a comprehensive countrywide program.

In addition to this guide, there are three "Water for the World" policy perspectives intended for policymakers: one summarizes this guide, one addresses planning of water supply and sanitation programs, and the third deals with implementing these programs. The final component of "Water for the World" is a series of about 160 technical notes written for people working in rural villages on water supply and waste disposal projects. Each technical note addresses a narrow technical aspect of such projects. A full list of technical notes may be found in Appendix Two of this book.

Many people participated in the preparation of this program guide. Special thanks are due to the editorial advisory board listed on the preceding page which exercised oversight of the entire project and reviewed the materials prepared as part of it.

These individuals and institutions contributed to the preparation and review of preliminary information documents which were valuable in the writing of this guide and other "Water for the World" materials:

Environmental Services Corporation,
Chapel Hill, North Carolina

Institute for Rural Water,
Washington, D.C.

National Environmental Health Association,
Denver, Colorado

John H. Austin,
Washington, D.C.

Emil T. Chanlett,
Chapel Hill, North Carolina

Daniel Dunham,
New York, New York

James Lamb,
Chapel Hill, North Carolina

Thomas C. Orihel,
New Orleans, Louisiana

George Reid,
Norman, Oklahoma

Gerald Rohlich,
Austin, Texas

Joseph Salvato,
Albany, New York

Everett Schiller,
Baltimore, Maryland

Charles Senn,
Los Angeles, California

Morris Shiffman,
Chapel Hill, North Carolina

Mark Sobsey,
Chapel Hill, North Carolina

Sources used for the manual were personal communications and materials prepared by the following persons:

John H. Austin, Washington, D.C.

Rifat Barokas, Washington, D.C.

Emil T. Chanlett, Chapel Hill, North Carolina

Edwin L. Cobb, Washington, D.C.

John K. Densham, Wetherby, Yorkshire, England

Mary Elmendorf, Washington, D.C.

Eric Greig, Wetherby, Yorkshire, England

Dennis B. Warner, Washington, D.C.

Overall editorial supervision was the responsibility of Mary E. Morgan. Gerald F. Winfield served as general consultant on this guide and made many contributions toward improving it.

National Demonstration Water Project bears full responsibility for the content of this manual. It does not represent the formal or informal policy of the U.S. Agency for International Development. For further information about it or about other parts of the "Water for the World" series, contact the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

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INTRODUCTION

Safe Water and Waste Disposal for Rural Health: A Program Guide is written for people in the developing nations who have the responsibility for developing and implementing water supply and sanitation programs for rural areas. Its purpose is to provide that audience with an overview of the information it will need to promote, design and carry out such a program.

The book is organized in three parts: Part One: Water Supply and World Health; Part Two: Water Supply and Waste Disposal Systems; and Part Three: Effective Water Supply and Sanitation Programs. Part One provides an overview of the relationship between water supply, sanitation and health and basically defines the problems that safe water and waste disposal systems can help to solve. Part Two presents solutions to those problems from a technical viewpoint, explaining the major technologies in water supply and waste disposal that are appropriate for use in the rural areas of the developing nations. Part Three describes how to go about establishing and implementing a program that matches technical solutions to water and sanitation problems in an efficient and effective manner.

A word about the organization of this volume: At the end of each chapter, there is a list of sources that were used in preparation of the chapter. In most cases, these sources are also a good place to start to find more detailed information on the subjects covered. Also at the end of each chapter is a list of the technical notes from the "Water for the World" series (see Preface) that are most relevant to the material in that chapter. These technical notes can also be used for more detailed information on the topics included in each chapter.

Appendix One is a glossary of terms, most of them technical, that, although explained in the text, are used multiple times. Readers may find the glossary useful in refreshing their memories as to the meaning of terms as they are encountered after the initial explanation. Appendix Two is a full listing of the technical notes prepared in the "Water for the World" series.

There is probably no more urgent need facing the developing nations than the provision of adequate water supply and sanitation to their citizens. This need has been recognized by the United Nations with the designation of 1981–1990 as the International Drinking Water Supply and Sanitation Decade with a goal of providing access to adequate water supply and sanitation facilities to all the world's peoples. This volume may provide some small measure of assistance in meeting that goal.

Water flowing from a bamboo pipe is a water system in many parts of the world.

PART ONE. WATER SUPPLY AND WORLD HEALTH

CHAPTER ONE
THE PROBLEM IN THE DEVELOPING NATIONS

SUMMARY

In the developing nations of the world in 1981, about 50 percent of the people did not have reasonable access to a safe water supply; roughly 75 percent did not have adequate santitation facilities. Improvements in water supply and santiation facilities that have been made in recent years have not even kept pace with population growth so that more people are unserved today than in 1970, even excluding figures for China. The heaviest concentrations of unserved people are in rural areas.

The principal result of inadequate water supplies and sanitation is a heavy burden of disease, a burden that is greatest on children. Third World nations have a high mortality rate among infants and young children. Half of all deaths in developing nations are among children under five, with malnutrition and infectious disease the principal causes. The disease that is most often involved is diarrhea—caused by a lack of clean water and sanitation. Many other diseases, unknown or already eliminated in developed nations, are also prevalent. Examples from Kenya, Colombia, and India illustrate some of the problems.

Improvements in water supply and sanitation in developing countries increase the well-being of the people of those countries. Such improvements promote economic and social as well as human development and are, accordingly, a desirable investment for the countries needing improvements, for other countries wishing to be of assistance, and for international agencies.

Open wells usually are contaminated.

CHAPTER ONE
THE PROBLEM IN THE DEVELOPING NATIONS

Clean water that is close at hand and a safe and convenient way to dispose of human excreta are all too frequently luxuries in developing nations. In the earth's geographic "South," the political "Third World," much water is not clean and sanitation is not adequate. Rural people use water mostly from contaminated shallow wells and surface sources; their excreta is disposed of more or less haphazardly in the fields. Millions of city people are also poorly served.

The health of the people in the developing nations reflects this situation. They do not live as long nor as well as those in the developed countries. While bad water and sanitation are certainly not the only causes of poor health, they are important contributors.

This chapter describes the problem in the developing nations in terms of:

Poor sanitation conditions contribute to poor health.

- present access to safe water and sanitation;
- present health conditions;
- examples from three countries;
- the impact of water supplies.

Access to Safe Water and Sanitation

It is 1981. Assume that we travel any road in the Third World outside China—the Western Hemisphere below the Tropic of Cancer; the continent of Africa; the land masses and islands of Asia. We meet ten people. At least five of them will not have safe water to drink; seven or eight of them will have no effective sanitation. If we are on a city street, the people will be better off. Only two or three will be without clean water and fewer than five will lack adequate sanitation. But if we are on the unpaved tracks of the rural areas, seven of the people will not have clean water and nearly nine of the ten will have inadequate sanitation.

These figures are based on the most minimum standards of adequacy for water and sanitation. In the eyes of the World Health Organization (WHO), a rural family has "reasonable access" to safe water if a member of the household, usually the woman, does not have to spend "a disproportionate part of the day" in fetching water that is not contaminated. Adequate sanitation is often merely a latrine of some sort. In congested areas, however, most latrines do not meet minimum health standards, and they are often designed so that children do not have access to them. Pit privies, another type of "adequate" sanitation, if improperly located may contaminate nearby shallow wells.

In urban areas, the standard of adequacy may be piped water supplies, but the use of the word "adequacy" is probably misleading. A 1970 survey found urban supplies to be "intermittent" about half the time. In other words, the pressure in the pipes failed every other day on the average, with the result that contamination was sucked in from the outside. Probably no more than ten percent of the people in the Third World, urban or rural, have indoor plumbing that works consistently, the common standard in developed nations. When the percentages are converted into numbers of people, the magnitude of the problem becomes even clearer.

WHO figures, derived from information supplied by governments, show the following numbers of people in the developing world without clean water and sanitation in 1980:

Table 1. Unserved Population in Developing Countries

	Population (millions)	*Population (millions) without clean water*		*Population (millions) without adequate sanitation*	
		Number	*Percent*	*Number*	*Percent*
Urban	703	177	25	331	47
Rural	1612	1143	71	1399	87
Total	2315	1320	57	1730	75

The population without clean water—1.3 billion—is greater than the *total population* of the developed world—North America, Europe and the Soviet Union, Japan, and Australasia. The population without sanitation is roughly the same as the entire developed world *plus Africa*. To get a true world picture of the needy population, a portion of the population of China should be added to the total. All in all, the number of people without adequate water and sanitation today approaches the total population of the earth in 1960.

For many years, the developing countries have been aware of the problem, and a lot of work has gone into making improvements. But improvements have not kept pace with population increases so that more *people* are unserved today than in 1970, even excluding figures for China. WHO statistics since 1962 reveal the following:

Table 2. Percentage of Population Adequately Served in Developing Countries

Year	*Urban population supplied with water*	*Rural population with reasonable access to water*	*Total population adequately served*
1962	58	—	—
1970	67	14	29
1975	77	22	38
1980	75	29	43

But consider rural water supply. This one area shows a clear percentage improvement over the last decade. Only 14 percent of the Third World population had access to safe water in 1970. This figure rose to 22 percent in 1975 and more than doubled to 29 percent in 1980. Despite the percentage increases, WHO reports also show that the number of rural people *without* access to safe water remained the same—about 1.1 billion in 1975 and 1980. There were actually *more* people without rural sanitation in 1980—1.4 billion—than in 1975—1.2 billion.

For several reasons, water and sanitation figures for developing countries must be used with caution. First, definitions used in gathering information are not always the same. For example, WHO's 1980 survey showed a major drop in the percentage of the urban Third World population with adequate sanitation—from 75 percent in 1975 to 53 percent. WHO believes that this drop reflects different definitions of adequate facilities. Second, government figures supplied to WHO are not always reliable. Did 100 percent of the urban residents of Algeria, Zambia, Cuba, and Jordan have reasonable access to safe water in 1980 for example? That is, did all of them reside within 200 meters of a standpost, as reported? It is highly unlikely. Even allowing for some unreliability, however, the basic message delivered by the figures is clear: despite hard work and many gains, an enormous number of the people in developing nations worldwide lack adequate water and sanitation, and the number is increasing.

The problem is greatest in the rural areas of the Third World, even though the standards of adequacy in water and sanitation are usually not as strict as for urban areas. Rural residents now account for nearly 70 percent of the population of the developing nations, excluding China.

Latin America illustrates the rural problem. Including the Caribbean, the region was home to 209 million people at the beginning of the 1960s. Of these, 68 percent lacked proper water supplies; 86 percent were not served by a sewage system. As bad as the overall figures were, they were not nearly as bad as those for rural people: almost none of them had sewerage and only 7 percent had safe water services.

In 1961, Latin American governments declared that within the next ten years they would provide water and sewerage to 70 percent of the urban population and 50 percent of the rural population. By 1971, the total population had grown 37 percent, from 102 million to 287 million. The urban water supply target had been met and the countries were over halfway to the urban sanitation goal. However, the rural picture was different. The water supply effort had fallen short by half and sanitation achievements were far from the goal—2 percent compared to 50 percent.

New goals were set: 50 percent of the rural population was to have both water supply and some type of sanitation service, although not necessarily sewerage. It does not appear that these targets have been met either. Only 34 percent of the rural people had potable water by the end of 1977 and only 3 percent had sewerage.

Here is a complete summary of progress in Latin America in the past twenty years.

Table 3. Water Supply and Sewerage in Latin America and the Caribbean
(Figures in Millions)

	1961	*1971*	*1977*
Total population	209	286	325
Without water	142 (68%)	134 (47%)	127 (39%)
Without sewerage	180 (86%)	224 (78%)	235 (73%)
Urban population	102	155	197
Without water	42 (41%)	34 (22%)	43 (22%)
Without sewerage	73 (72%)	96 (62%)	112 (57%)
Rural Population	107	131	128
Without water	100 (93%)	100 (76%)	84 (66%)
Without sewerage	107 (100%)	128 (98%)	124 (97%)

Source: Earthscan Press.

The effect of population increase can be clearly seen. Although the percentages unserved have generally declined, the numbers of people lacking adequate water supply and sanitation have not declined as much and in some cases have actually risen.

Health Conditions

The principal result of inadequate water supplies and sanitation is human suffering—stunted child growth and a heavy burden of disease. The burden is greatest on children. There is also economic suffering as poor health leads to decreased productivity.

The average person in the parts of the world that are now the developing nations had an estimated life expectancy of 38 years in the late 1940s. In 1981, life expectancy is thought to be about 58 years, a 53 percent improvement but still a far cry from the rate of 70-75 years found in the more developed countries.

The major factor in reduced life expectancy is a very high mortality rate among infants and young children. Half of all deaths in the Third World are among children under the age of five. If deaths in this age group could be reduced to the rates that exist in developed countries, life expectancy at birth in the developing nations would be only a few years less than in Europe or North America.

The majority of the children who die in developing countries fall victim to a combination of malnutrition and infectious disease. The disease that is most often involved is diarrhea—caused by lack of clean water, sanitation, and personal hygiene. Medically speaking, diarrhea is a minor disease, but it becomes a killer when combined with malnutrition. The child is caught in a vicious circle. A poorly-nourished infant is more likely than others to suffer an attack of diarrhea. Repeated attacks of this dehydrating and painful illness make the malnutrition worse. Children suffering from diarrhea eat less and have more trouble digesting the food they do eat.

WHO estimates that each year diarrhea directly kills six million children and contributes to the death of about 18 million others. This yearly toll is higher than the total number of persons, soldiers and civilians, killed in the First World War—which lasted four years.

There are many other water-related diseases (discussed in Chapter Two) that prey on adults as well as children in developing countries. Almost everyone in developed nations has heard of cholera and typhoid, but these diseases have been eliminated in those countries. They still occur in the Third World, although there are more cases of diarrhea in an hour than cholera cases in a year. There are other water-related diseases that are practically unknown in developed countries and are not often mentioned even by the media. An example is Guinea worm, which is found in rural areas of the Indian subcontinent and across Africa from the Sudan to Mauritania. The following sequence of events is not a pleasant story.

Children suffer most from poor health conditions.

A Nigerian woman, let us say, steps into a pond to draw water. A blister on her foot bursts and Guinea worm larvae are released into the pond. A neighbor draws water from the same source and later drinks it, taking the larvae, now living in barely visible water fleas, into her digestive system. The larvae move through her body. The adult female worm grows under the skin, causing a blister. Later the woman steps into an unprotected pond or step-well, and the cycle of infection begins again.

Guinea worms may grow to 80 centimeters in length beneath the skin. The infection rarely kills and the carrier will usually recover with no medical treatment. However, the painful ulcers that develop on the feet, legs or other parts of the body can last for months and cause disability, especially if there is more than one worm present. About one infected person in 20 is permanently disabled.

Guinea worm infection is easy to prevent by improvement of water sources. The improvement consists simply of replacing "step-wells" (wells or ponds into which people must step to draw water) with "draw-wells" (enclosed sources from which water must be drawn with a rope). Guinea worm was eliminated from parts of the USSR over 40 years ago with this method, and it also has been used successfully in India.

The Guinea worm story can be repeated with the substitution of several other diseases—except that they are not so easy to prevent. WHO estimates that 80 percent of all the sickness and disease in the world can be traced to bad water that either infects people directly, serves as a breeding ground for diseases and the insects that transmit them, or to a shortage of water that leads to poor personal hygiene and household sanitation practices.

How many people suffer from water-related diseases at any given time? Rather than citing the millions, let us imagine:

- the entire population of the Western Hemisphere above the equator with trachoma, which often causes blindness;
- all the people of the Soviet Union with elephantiasis, characterized by swollen legs;
- all of the United States of America ill from schistosomiasis (snail fever), a disease in which the patient urinates blood;
- the population of every island in Japan and the Philippines suffering from malaria.

The ratio of water taps to population may be the most important health statistic in the Third World, as Dr. Halfdan Mahler, WHO's Director-General, has suggested.

Water from open streams is usually unsafe to drink.

Three Country Examples

There is no "typical" developing country, but a closer look at one nation in each of the three major regions of the Third World—Latin America, Africa, and Asia—may help to sharpen understanding of the interaction between global water and health.

Colombia

The fourth richest country in the world in terms of water resources has a significant drinking water problem. Much of the population of Colombia takes its home water directly from rivers and streams. The waterways of this nation of 25 million people are heavily polluted.

The 250 people in the village of La Salada get all their cooking water from the Bogota River. This stream is pure when it rises in the Andes, but by the time it reaches Salada, it has absorbed municipal and industrial waste from dozens of small towns and the sewage of five million people in the capital city, Bogota. In Salada, the river is black, foam swirls on the current, and the stench of sewage and chemicals fills the air. The children in the village swim in the river; nearly all of them have skin sores and growths. The women use cactus juice to remove the worst pollutants from the cooking water; they do not boil it because boiling makes the smell much worse. The villagers use rooftop tanks or holes in the ground to collect water for drinking. Only during the rainy season do they see clean water.

There are no figures regarding illness and death in Salada, which has no doctor, but the area, including the nearby town of Tocaima, has one of the highest rates of parasitic disease and infant mortality in the country. Even the average height of the people using the river water has declined in the last twenty years.

A 1979 government report stated that 75 percent of Colombia's population had access to safe water and 62 percent had adequate sanitation. Even so, the Pan-American Health Organization (PAHO) says that water-related illnesses are the major cause of death in Colombia. At least 12,000 deaths each year are caused by diarrhea and enteritis alone. The infant mortality rate in Colombia—98 per 1,000 live births—is double the rate for Latin America as a whole.

As in other places, population increases have frustrated water and sanitation improvements. In the 1960s, nearly five million Colombians had no direct access to safe water. The figure topped eight million in the 1970s, and today stands at 12.5 million. In other words, three times as many people in Colombia are directly exposed to water-related diseases as twenty years ago.

Kenya

Mbere Division in Embu District is an arid region. For large parts of the year, stream beds, except for the Ena River, are dry. The search for water for household use is a major preoccupation of the people.

According to one study, each family in Mbere, on average, devotes 100 "woman- or child-days" a year to collecting water. The average distance that must be traveled in performing this task each day: eight kilometers.

The search for water has many socio-economic effects. Women are the primary source of agricultural labor; cultivation and planting are done during the dry season. Thus women must take time from working in the fields to fetch water for the household. Also, children lose time from school if they must replace the housewife as water-bearer. There are health effects as well. Since the water must be carried long distances, the amount used is small, and there is a high incidence of disease in the area, especially among the children.

At the end of 1980, 23 percent of the people in a population of about 15 million Kenyans had access to safe water. However, Kenya has given highest priority to water supply in urban areas where health hazards due to lack of clean water are the greatest. As a result, nine out of ten people in rural areas have no access to a proper water supply. National development plans call for the entire population to have enough water for domestic use and livestock by the end of the century.

India

Out of every three people in the Third World lacking clean water and adequate sanitation, one is an Indian. This vast nation of 650 million people shares the health problems of other developing countries, but its sheer size creates a new dimension. Pre-school children throughout the developing world die of diarrheal diseases. But in India, the number of children who die from diarrheal diseases other than cholera each year is about one and one-half million.

The sanitation problems of India's teeming cities were so great that Mahatma Gandhi, who led the country to independence, made it an important priority, and impressive strides have been made. Over 80 percent of the urban population is now estimated to have reasonable access to water supplies, either through house connections (42 percent) or public standposts. But even as citizen access to water has increased, the quality of water service itself has decreased. In the major cities, customers who had eight to ten hours of water service in 1970 were only served for two to three hours in 1975. In a number of Indian states, nearly all those served had only intermittent supplies. With the water pressure frequently off, the danger of sewage entering a water system is high.

Urban excreta disposal facilities have lagged behind water supplies. About 27 percent of the population was estimated to have sewer connections by the end of 1979. Nearly one-third of all urban Indian households today are still served by bucket latrine systems. In these systems, members of the household pass excreta in buckets. Scavengers go house-to-house and collect the buckets, depositing the contents in roadside pits for eventual trenching or composting.

As usual, the rural population lags behind the urban dwellers. Only 30 percent of India's rural population had access to water supplies in late 1979; only 2 percent had adequate sanitation.

About once every four or five years, drought returns to India to complicate the water and sanitation problem. The press once reported that young men in the state of Madhya Pradesh were having trouble finding brides. It seems that parents were unwilling to marry off their daughters for fear the girls would be forced to walk long distances to fetch water. The "drought-affected marriage" was thus added to the list of unpleasant side-effects of inadequate water supplies.

Children are often given the task of carrying water.

Droughts in India sometimes require young women to walk long distances to fetch water.

It is widely thought that improvement in water supply and sanitation in developing countries improves the well-being of the people in those countries. Such improvement promotes economic and social, as well as human, development and is a desirable investment for developing countries, for other countries wishing to be of assistance, and for international agencies.

Safe water supplies, combined with all-weather roads, electricity, and a skilled labor force, spur the development of trade, small industries, and crafts. They also allow an increase in economic productivity. If the work force is healthier, fewer work days are lost due to sickness and disability. Women and children, the chief "drawers of water" in developing nations, can spend more time in agricultural pursuits or other activities that produce income. For example, one study in Kenya revealed that female heads of households spent a third of their time bringing water home and only one-fifth in economic activities such as herding and marketing.

Water supplies also affect the economy by influencing settlement patterns, encouraging isolated rural and nomadic people to settle in one place where they may be better provided with services. Rural areas with adequate water and sanitation become more attractive places, and people can remain there and lead decent lives rather than streaming to the overcrowded cities.

From a social standpoint, improved water supplies affect family development. When women are freed from water-bearing chores, they have more time, not only for income-producing work but for child care and household tasks, training and educational programs, and leisure. The hours that children now spend carrying water can be spent in school instead. The school drop-out rate for girls is linked directly to domestic responsibilities.

Although many signs point to economic and social rewards from improved water supplies and sanitation, it is difficult to describe these rewards in exact "cost-benefit" terms. Too little is known about the ways in which the energy and time saved from disease and from the carrying of water is used. Studies that attempt to express the savings in monetary terms are usually based on assumptions, piled one on the other, that are themselves questionable.

In the end, it is the direct health impacts of water supplies that justify investments in them, whatever the ultimate social and economic consequences of these impacts. Most of the more serious diseases that plague the developing world have a close relationship with water. They both breed in its presence and thrive in its absence. Water carries disease from one person to another and from community to community. It is especially a factor in the gastrointestinal infections that are the chief causes of death and disability among infants and a major cause of illness among adults.

Time spent by women and children in drawing water could be better used for other activities.

Children usually benefit most from improved water and sanitation facilities.

Recognizing the importance of water to health is not a difficult matter; deciding what type of remedial action is best is a more complicated affair. The *quality* of water—expressed in terms such as clean or dirty, safe or unsafe, potable or nonpotable, pure or polluted—is surely a starting point. For example, a chart presented at a recent PAHO conference, summarizing information from 23 Latin American countries, showed a close correlation between lack of potable water and infant deaths due to diarrheal diseases. However, there were some notable exceptions. Guatemala and Honduras, adjoining countries, had the same percentage of people provided presumably potable water, but the infant mortality rate in Guatemala was four times worse than in Honduras. Paraguay had the same infant mortality rate as Honduras, 200 deaths per 100,000 people, with only one-third as much "safe" water service available. Cuba, with one of the lowest percentages of people served by clean water, surprisingly had one of the lowest infant mortality rates.

Having a sufficient *quantity* of water is at least as important as having good quality. Many diseases are not only contracted through drinking or cooking with dirty water but through lack of bathing, hand washing, unwashed dishes, and inadequate household cleaning. Water for these purposes need not be of the same quality as that which is drunk. In practice, of course, simply boiling a small quantity of water for drinking is not likely to solve a water supply problem. In the first place, the fuel cost involved in boiling water is high. Secondly, children are likely to drink from whatever container is handy, even if it contains impure water that adults know is to be reserved for cleaning. But however pure a household's water, there must be enough of it to accomplish numerous tasks that are related to health.

Water sources must be both *accessible* and *reliable.* There is evidence, for example, that diarrheal infections are highest in homes that are farthest from the water source. If people must walk long distances for water, or must stand in line to get it, there is a strong temptation to use a source that is closer at hand, even if it is polluted. And the source must be accessible on a regular basis. Pure streams that are dry several months in the year or water taps from which water flows only a few hours a day are not adequate sources. People dependent on these sources may be listed among those with "access to safe water," but unreliable water sources do not provide health protection.

Finally, water must be used and protected. If people do not understand the importance of washing and cleaning or if they are careless about excreta disposal in relation to water supply, their health is not likely to improve, even though water is available. Traditional beliefs and practices that lead to repeated contamination of water sources must be changed.

The most widespread feeling among experts today is that health problems in developing nations cannot be overcome by a single remedy, such as improved water quality. Instead, a combined approach is required, an approach that includes:

- improvement in water facilities, resulting in accessible and reliable water supplies that are of good quality and sufficient quantity;
- improvement in excreta disposal facilities, leading to better sanitation;
- education in water use practices, leading to better personal and household hygiene.

If they are to be truly effective, improvements in water and excreta disposal facilities must occur at the community as well as the household level so that the risks of infection in public areas can be reduced.

Standing water in a cistern is an inviting breeding place for insects.

Human health in the Third World, as in developed countries, extends beyond water and sanitation. Good health requires good nutrition, decent housing, basic immunizations, and primary health care. But the water supply is fundamental and a good place to start.

Education programs are needed to explain the connection between hygiene and public health.

SOURCES
CHAPTER ONE

Most of the water supply, sanitation, and health statistics are from World Health Organization studies as reported in "Water and Sanitation for All?" Earthscan Press Briefing Document No. 22, London, November 10, 1980. The three country examples are from "Water and Sanitation in Three Countries: Colombia, India, Kenya," Earthscan Press Briefing Document No. 23, November 10, 1980. Current population figures were drawn from "Population, Per Capita Product, and Growth Rates," *1980 World Bank Atlas*, Washington: World Bank, 1981.

Sources used for analysis and point of view were: *Water Supply and Waste Disposal*, Poverty and Basic Needs Series, Washington: World Bank, September 1980; "A.I.D. Water and Sanitation Policy Paper," Washington: Agency for International Development, July 28, 1980; Mary Elmendorf, "Women, Water and Waste: Beyond Access," July 1980.

CHAPTER TWO
A SURVEY OF WATER-RELATED DISEASES

SUMMARY

Intervention in the area of water-related diseases makes a health difference, as the experience of developed and many developing nations shows. The intervention may be by improved water supply, sanitary excreta disposal, better hygiene education, or a combination of these. In order to effectively program for interventions, there must be an understanding of the principal water-related diseases and the way each is transmitted, because it is at the transmission stage that most interventions can occur. The most important of these diseases may be classified as:

Category	*Transmission*	*Specific Diseases*
Water-site-insect carried	Disease-carrying insects breed in or near water.	African trypanosomiasis Onchocerciasis Malaria Arboviruses Filariasis
Water contact	Disease transmitted by direct contact with water.	Schistosomiasis
Water quality/microbiological	Disease transmitted by consumption of microbiologically contaminated water.	Cholera Typhoid fever Diarrhea Dysentery Guinea worm
Sanitation-related/water hygiene	Disease transmitted by inadequate use of water.	Shigellosis Trachoma and conjunctivitis Ascariasis Scabies

Conditions like these invite the occurrence of water-related diseases.

CHAPTER TWO
A SURVEY OF WATER-RELATED DISEASES

In London in 1854, a case of cholera was reported at No. 40 Broad Street. Within a 17-week period, over 700 people had died from the disease. Dr. John Snow began to search for the cause. He found that most of the victims had used water from a pump on Broad Street; he found a leaky sewer in the immediate vicinity of the well from which the water was pumped; he found that the same sewer served the house at 40 Broad Street that was the site of the first cholera case. The circle of water supply, excreta contamination, and disease transmission was complete.

As water supplies and sanitation practices improved in the industrializing nations in the mid-nineteenth century, diseases associated with poor facilities declined and lifespans increased, even without planned interventions for health reasons. Although the work of Dr. Snow and his contemporaries had laid the basis for intervention, there was no real attack on water-related diseases until Louis Pasteur and others demonstrated that specific diseases were caused by specific germs, or pathogens.

With the germ theory of disease came attempts to trace the routes germs follow in entering the human body. Human excreta (feces) was often the source, and the mouth was a frequent point of entry. Thus the "fecal-oral" cycle was established as a likely place for intervention in disease control.

Many developing nations are at about the same place today that countries such as the United States and Great Britain were 50 to 100 years ago. Water-related diseases are common and are among the leading causes of illness and death. The decrease in such diseases in developing nations following water supply improvements is similar to the U.S. experience. For example, one study of 20 American cities showed a 65 percent reduction in typhoid deaths following the introduction of water supply filtration. A half-century later, a study of 14 towns in India that began water purification reported a 63.6 percent drop in typhoid mortality.

Intervention in the area of water-related diseases does make a difference, as the experience of both developed and developing nations shows. The intervention may include improved water supply, more sanitary excreta disposal, better hygiene education, or some combination of these. If interventions are to be well planned, there must be an understanding of the diseases that are to be prevented or controlled.

This chapter provides a survey of the principal water-related diseases that are a problem in developing nations. In particular, the way in which each disease is transmitted is described because it is at the transmission stage that effective intervention can most frequently occur. Methods for treatment of patients will not be considered.

The fecal-oral cycle of disease transmission can be interrupted by good hygiene practices.

Many diseases are associated with contaminated water supplies.

Types of Water-Related Diseases

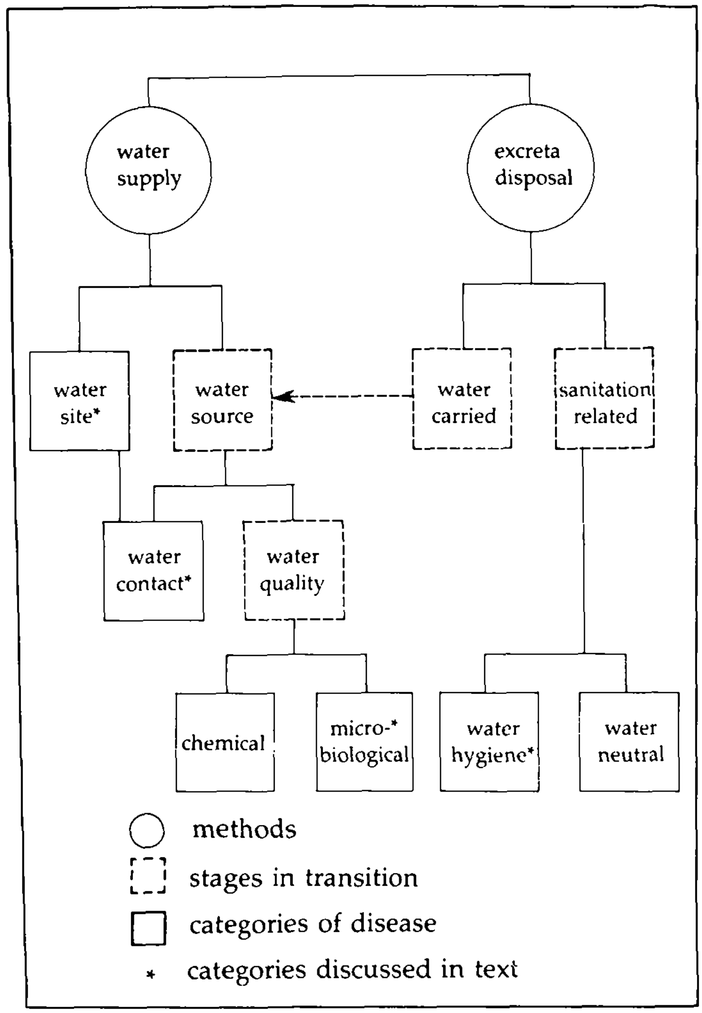
The concern of this guide is with improving health through better water and sanitation. The approach in this chapter—definitions and classifications—to the concept of "water-related diseases" reflects this purpose. A manual for medical practitioners would be concerned with curing diseases and thus would probably classify them in terms of the microbes that cause them. This guide is looking chiefly toward preventing diseases, so a classification based on methods of transmission seems more appropriate. Such a classification is well-suited for program design. The goal is a classification which accommodates the full range of diseases that are problems in developing nations and which clearly identifies the areas for appropriate intervention.

All human beings must take water into their bodies in some form and dispose of body wastes, or "excreta" (urine and feces). All persons, therefore, have *water supply* and *excreta disposal methods*. Dipping from flowing streams, drawing buckets from wells, turning water taps, and catching rain water from roofs are all water supply methods. Excreta disposal methods range from depositing urine and feces directly on the ground to flushing indoor toilets. People must also take in food, done primarily with the hands, either fingers or "substitute fingers" such as forks and spoons. These processes take place in an environment that includes many varieties of agents that can serve as links in a disease chain. Hundreds of varieties of flies and mosquitoes, for example, thrive in the tropical and subtropical climates of the less-developed countries. A number of aquatic (water-dwelling) organisms that do not occur in temperate zones cause problems in developing nations. The environment in these parts of the world is so important as a factor in illness that many water-related sicknesses are thought of, incorrectly, as "tropical diseases."

It is people, however, who are the chief agents in the spread of disease. When factories are built and agriculture is modernized, chemicals are dumped or flow into water supplies. As populations and cities grow and standards of living improve, people produce more household waste, and careless disposal of this "solid waste" produces breeding grounds for flies and rodents that carry disease. People often do not wash themselves or clean their houses enough, and when poor hygiene practices are combined with poor methods of excreta disposal, disease is often the result. However roundabout the route, when we retrace the steps of the cause of disease to the ill infant or adult in a developing nation, the trail often leads to a specific water supply.

Figure 1 shows generally the ways that water-related diseases are transmitted and provides a basis for classifying these diseases. First of all, it is useful to think of water-related diseases as originating either with:

Figure 1. A Typology of Water-Related Diseases



People are the chief agents in the spread of disease.

- water supplies or
- excreta disposal.

It is true that excreta disposal is not necessarily water-related, but excreta is so often introduced into water supplies that the connection should be established at the outset. From a disease control standpoint, water supply and excreta disposal are about equally important. These are the beginning points in the process of disease transmission.

A given water supply may cause disease due to the nature of:

- the water site or
- the water source (the water itself).

Many disease-carrying insects breed in or around water sites. People thus contract the disease by being bitten by the insects as they go to and from the site. What people do with or in the water is irrelevant; it is the insect, not the water, that is the immediate transmitter of disease, and people need not come into contact with water at all. Since the water is an indirect cause, however, diseases of this type are called water-related "insect vector" diseases. The need for drinking water is obviously a factor. Many insect bites are suffered by people who are fetching water for household use. However, many flying insect vectors are found a number of miles from their breeding site. The time of day affects the risk of mosquito bites, as many kinds of mosquitoes are most likely to bite at dusk, night and dawn in or near households. Mosquitoes breed almost anywhere there is water, including streams, ponds, roof tanks, hoof prints, and discarded cans or tires.

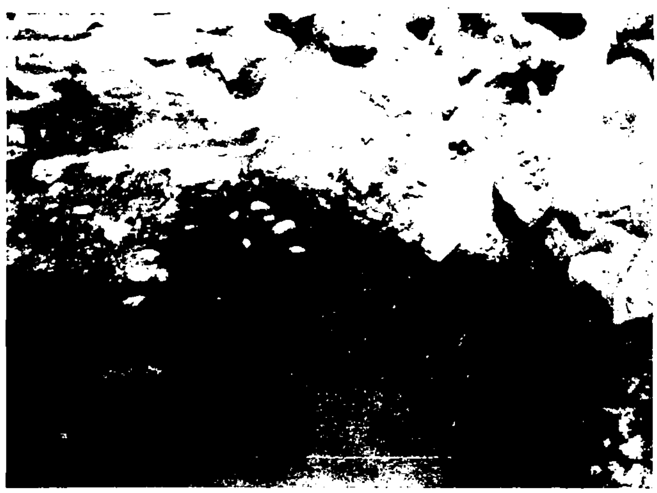
Another example is African trypanosomiasis, or sleeping sickness. The disease is passed by the bite of the tsetse fly, one species of which lives in rural areas near waterholes in most of tropical Africa. People fetching water from these locations are likely to be infected, particularly in the dry season when human contact with flies is most concentrated. A major urban problem in addition to outdoor water sites are water storage jars in which mosquitoes, such as those carrying yellow fever, breed. Large containers used for household storage where water is hauled or piped water supplies are unreliable are especially favored as mosquito breeding places. Onchocerciasis (river blindness), malaria, and dengue, the latter an influenza-like disease found especially in Asian cities, are transmitted by insect vectors.

Whether or not a water site furnishes breeding places for insect vectors, its use as a water *source* for people creates health hazards. Diseases may result from:

- contact with the water or
- consumption of the water.

Human beings fall victim to some diseases because their bodies come in contact with water containing a disease-causing organism. The water shelters an aquatic host of some sort which plays a necessary role in the life cycle of the disease-producing agent. In some cases, contact with the water is sufficient to produce the infection because the agent penetrates the skin, usually the feet, legs and hands.

Sometimes the water must be consumed if the disease is to be contracted. Again, the search for drinking water is one major reason people come in contact with water that causes disease; however, any contact, including swimming, fishing and irrigation farming, can result in infection. The two most noteworthy water-contact diseases, affecting hundreds of millions of people in developing countries, are schistosomiasis and Guinea worm. Schistosome eggs are found in human excreta. They hatch when they reach water. The resulting larvae, in order to survive, invade specific varieties of snail hosts. They multiply within the snail and then escape to swim in the water and penetrate available human skin. Since the schistosome worms can bore directly into skin, they are a danger to all who come in contact with the water, whether or not the water is drunk.



Consumption of water from unprotected sources such as this cistern often leads to ill health.

On the other hand, as described in Chapter One, Guinea worm larvae must be swallowed if the infectious process is to continue. They require a water-bound host, however, a small water flea in which to live after contact of an infected human has deposited them in the water.

Diseases contracted through the *consumption* of water—drinking, use in food preparation—are diseases of water quality. The quality is measured in terms of two types of contamination:

- chemical and
- microbiological (germ).

Waterborne chemical diseases are illnesses associated with ingestion (consumption) of water containing toxic substances in harmful ("poisonous") concentrations. The substances may be of natural origin or man-made and include metals (such as arsenic and lead) and organic chemicals. These diseases do not affect people on a broad geographic basis but are locality-specific. In some cases, contamination of water is caused by industrial wastes and drainage from fields containing harmful pesticides. In a global sense, these diseases are not yet major problems in most developing nations and will not be discussed in this guide.

Microbiological diseases, on the other hand, are a major source of concern, particularly those that follow the fecal-oral cycle. The connection between excreta disposal and water supply is thus established at the water source stage. There are other water-related excreta diseases of equal importance, however.

Most excreta-related diseases that affect people are fecal-oral in nature. In other words, the germ is present in human feces and enters the bodies of uninfected people through the mouth. In many cases, the entry is made in the water people consume. In many others, food or fingers are entry vehicles. Often these food and finger germs could have been eliminated if water had been used for washing or cleaning.

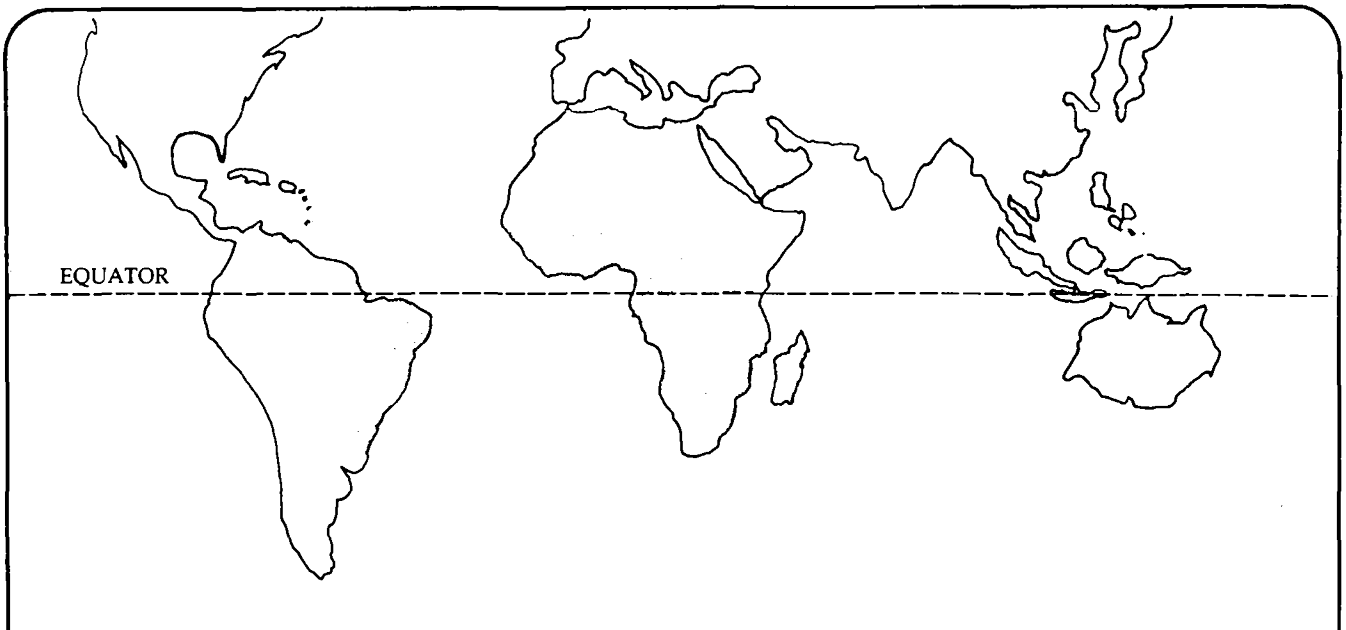
Water-related diseases traceable to excreta may thus be classified as either:

- water-carried or
- sanitation-related.

Some diseases that enter the water source infect people through water contact. Schistomiasis is an example. But in the great majority of cases, the germs must be ingested. The most important microbiological diseases contracted by water consumption are the water-carried fecal-oral diseases, such as amebic dysentery, bacillary dysentery, cholera, diarrheas, enteric virus, hepatitis, and typhoid fever.

The classical "waterborne diseases"—typhoid and cholera—are caused by fragile organisms whose only reservoir is man. They are highly infective and only a few are needed to produce disease. Since they are virulent and death is a frequent occurrence if the patient is not treated, they are illnesses that communities are particularly anxious to escape. They may occur dramatically as "common source outbreaks." A person suffering from or carrying typhoid or cholera contaminates the community water supply through excreta and many people become ill at the same time. The severity and sudden appearance of cholera and typhoid make them highly feared.

Most diarrheal diseases which are common and widespread in all parts of the Third World are associated with defective water supplies. The infections that can be spread from one person to another through water supplies can also be transmitted directly (hand to mouth, hand to food to mouth, flies to food to mouth) so that sanitation practices equal water quality as required health interventions. Sometimes the difference is between *epidemic* and *endemic* conditions. A



Geographical Distribution of Schistosomiasis

fecal-oral disease such as amebic dystentery is endemic when looked at from the standpoint of an individual village and may be transmitted in the village primarily through poor sanitation practices. Other villages need not be affected. If ameba cysts enter the water supply, however, it may become epidemic, affecting villages throughout a region.

There are some sanitation-related diseases where water plays a minor role. For example, human hookworms penetrate the skin directly from damp soil contaminated by excreta, and some disease-producing flukes (Clanorchis, Fuseiolopsis and Parogonimus) found in food are unaffected by changes in water supply.

A greater number of diseases are related to hygiene practices where water is a key element. Sanitation-related diseases may thus be classified as either:

- water neutral or
- water hygiene.

Many infections can be reduced in number if a plentiful supply of water is available and accessible. This applies particularly to diarrheas. Some studies of shigella infections in the United States have shown that making more water available tends to cut the frequency of infection in half. Some hygiene-related diseases affect the surface of the body and the eyes, making life miserable though rarely resulting in death. Examples are scabies and trachoma. Since proper washing is a big factor in controlling these diseases, they are sometimes classified as "water-washed."

How much water is needed for adequate personal hygiene? There is no really accurate answer to this question. As a practical matter, the best health conditions are achieved when water is readily available for use because it is piped into the home. However, this is probably a goal that developing nations cannot quickly achieve.

To summarize, water-related diseases are those traceable to water supply and excreta disposal methods. The most important of these diseases may be classified as:

• water-site-insect carried	disease-carrying insects breed in or near the water supply.
• water contact	direct contact with water is an important step in the transmission of the disease.
• water quality/microbiological (germ)	the disease is transmitted through the consumption of water that is microbiologically contaminated.
• sanitation-related/water hygiene	the transmission of the disease is permitted due to inadequate use of water.

The following is a list of the most significant individual diseases in each of the categories. Many diseases can be placed in more than one category. For example, most diarrheal diseases are related both to water quality and sanitation.

Water-Site-Insect Carried:

- African trypanosomiasis (sleeping sickness)
- Onchocerciasis (river blindness)
- Malaria
- Arboviruses (yellow fever and dengue)
- Filariasis (including elephantiasis)

Water Contact:

- Schistosomiasis (bilharziasis)

Water Quality/Microbiological:

- Cholera
- Typhoid Fever
- Diarrheal Diseases
- Dysenteries (Amebic, bacillary)
- Guinea worm (dracontiasis)

Sanitation-Related/Water Hygiene:

- Shigellosis (bacillary dystentery)
- Trachoma and Conjunctivitis
- Ascariasis (roundworm)
- Scabies

Water-Site-Insect Carried Diseases

Some of the Third World's most dreaded and economically destructive diseases originate at water sites because the insects that carry them—tsetse flies, black flies, mosquitoes—breed there. While piped water supplies would not eliminate the diseases (carriers breed in many collections of water not related to domestic water supplies and even breed in water storage containers), piped supplies in many situations would greatly reduce their incidence. Since universal piped water supplies are far in the future for many people of the developing nations, other prevention methods must be used. Attacks on carrier breeding places are prominent among these. The chief water site diseases are: African typanosomiasis (sleeping sickness), onchocerciasis (river blindness), malaria, arboviruses (yellow fever and dengue), filariasis (with accompanying elephantiasis).

The transmission of these diseases is complex because they involve at least three living things—a host (man and animals), a parasite that causes the disease (protozoan or worm), and a carrier (insect, fly or mosquito). This complexity makes these diseases difficult to understand and to prevent. The discussion of them must therefore be more extensive if it is to be helpful to those who must be involved in developing and implementing action programs to deal with them.

African trypanosomiasis (sleeping sickness)

Tsetse flies, of which there are many different kinds, carry the blood protozoan parasites (trypanosomes) that cause the disease known as trypanosomiasis. In English, it is often called "sleeping sickness" because of the symptons exhibited by the victims. Other names for it are "maladie du sommeil" and "souna bana." The trypanosomiasis that human beings contract is of two kinds, Gambian and Rhodesian. The disease also affects cattle, in which case it is usually called "nagana."

The tsetse fly is found only in tropical Africa, roughly in the four million square-mile belt south of the Sahara and north of the Kalahari. The presence of the flies places a tremendous constraint on the development of livestock and farming in tropical Africa. Large areas are totally unsuited for cattle raising because of the invariably fatal cattle nagana. The shortage or complete lack of livestock, with the consequent lack of draft animals and unavailability of manure with which to fertilize the soil, greatly affects agricultural development and productivity and the nutritional status of the population.

The direct threat to human life is also great. If untreated, the mortality rate from either Gambian or Rhodesian sleeping sickness is nearly 100 percent. Between 1896 and 1906, nearly a half million people died from the disease along the Congo River. An outbreak on the shore of Lake Victoria at the turn of the century was estimated to have killed two-thirds of the population. Ten thousand new cases of sleeping sickness are still reported in Africa every year, and many times that number probably go unreported.

From the standpoint of water-related disease, it is Gambian trypanosomiasis that is most significant because the fly that transmits the disease (*Glossina palpalis*) breeds in river areas. It thrives in high humidity and shady sites where the female lays not eggs but pupae; the adults feed on crocodiles, lizards, wild game—and man. Rhodesian trypanosomiasis occurs in drier savannah areas.

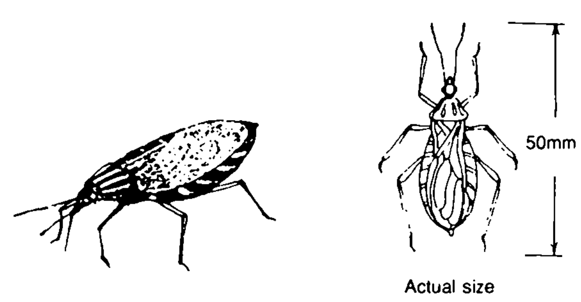
Tsetse flies are blood-suckers. When they bite infected animals or people, they suck the protozoa into their bodies where the parasites change and multiply. The tsetse flies pass them on by biting new victims. Only about 2 percent of the flies are infected. Two or three days after an infected tsetse fly bites, the bite area swells, itches, and becomes red and painful. About the sixth day, a round swelling with a red spot on top usually appears. The parasites are now in the blood. In the first stage of the illness, the patient has fever and perhaps swelling of the glands and spleen. In the second stage, the parasites are present in huge numbers in the blood vessels of the brain, heart, and other tissues, and constant drowsiness is the classic symptom. Eventually, the victim, if untreated, passes into a coma and dies. Death comes in three or four years if the sleeping sickness is Gambian; if it is the Rhodesian variety, it may come in a few months.

Short of moving entire populations out of an infected area—no easy task—the best way to achieve large-scale tsetse fly control is probably through chemical means. Applied either by aircraft or on the ground, compounds such as DDT and Dieldrin have proven effective in eradicating the flies. For river-breeding flies, insecticides applied to nearby shade-providing vegetation are usually effective as a control method. However, there are environmental costs to the use of insecticides, especially with repeated applications. DDT accumulates in the fatty tissue of many organisms, and Dieldrin is highly toxic for fish and the aquatic species they feed on.

As a rule, tsetse fly control should probably be integrated into an overall plan for water supply, economic development, and land use that takes local health structure, financial resources, and available manpower into account. Alteration of the fly habitat by bush clearing was among the first methods used in tsetse control after the link between the fly's breeding habits and vegetation was discovered. At first, the method was used to reduce man-fly contact at river crossings and watering places. Later, it was extended to savannah areas to promote the cattle industry. Gradually, bush clearing became more selective, and although the method is still used, it is usually undertaken in connection with other control methods.

Clearing can be done mechanically or by hand, the choice depending on available funds and equipment and the type of terrain. In barrier clearings, all of the tree-type vegetation is removed for the purpose of isolating an area that has been freed of tsetse flies so that reinvasion from a nearby fly-belt or the advance of the fly into new areas can be prevented. Such a barrier should be 500 yards or more in width, depending on local conditions. Also, clearings should be planned as a part of developing the land with regard to the potential for crop production or suitable grazing, so that land reclamation can have a dual purpose.

There is still the hope that scientists may someday discover a vaccine that will protect cattle and people from sleeping sickness, but no such vaccine exists today. Environmental measures and, of course, prompt treatment of those infected are the best available answers.



Reduviid Beetle (Vinchuga) Vector of South American Trypanosomiasis

Onchocerciasis ("river blindness" disease)

The rocks and vegetation in or near fast-flowing rivers and streams are the breeding grounds for blackflies (genus Simulium). The bite of the female fly is the starting point that leads to onchocerciasis and often to river blindness.

Onchocerciasis is caused by infection with thread-like roundworms that as adults live in nodules under the skin or in loose clusters deep in the body. They produce huge numbers of larvae that live throughout the skin of the patient but are more concentrated near the adult-worm-containing nodules. The disease affects from 20 to 30 million people worldwide, mostly in Africa south of the Sahara, southern Mexico, Guatemala, and northern Venezuela. In some localities, almost the entire population is afflicted so that from 5 to 20 percent of all adults have been blinded and many others are in the process of losing their sight. Itchiness, white skin patches, nodules under the skin, and sometimes swellings of the genitals or legs and arms are symptoms of the disease.

The larvae of the parasite are taken from the skin of an infected person through the bloodbite of the blackfly. They become infective in the fly and are passed to other people when the fly again bites. The parasite larvae mature, mate and produce additional larvae within the human body, which spread through the skin of that person.

Onchocerciasis can frequently be detected by the presence of nodules (lumps) on the bony parts of the human body—the head, the shoulders, the pelvis. Often, however, the worms are hidden, and the disease can only be confirmed by tests of skin snips under a microscope or eye examinations with special instruments. The diagnosis of "river blindness" disease is therefore a matter for health professionals, not laymen.

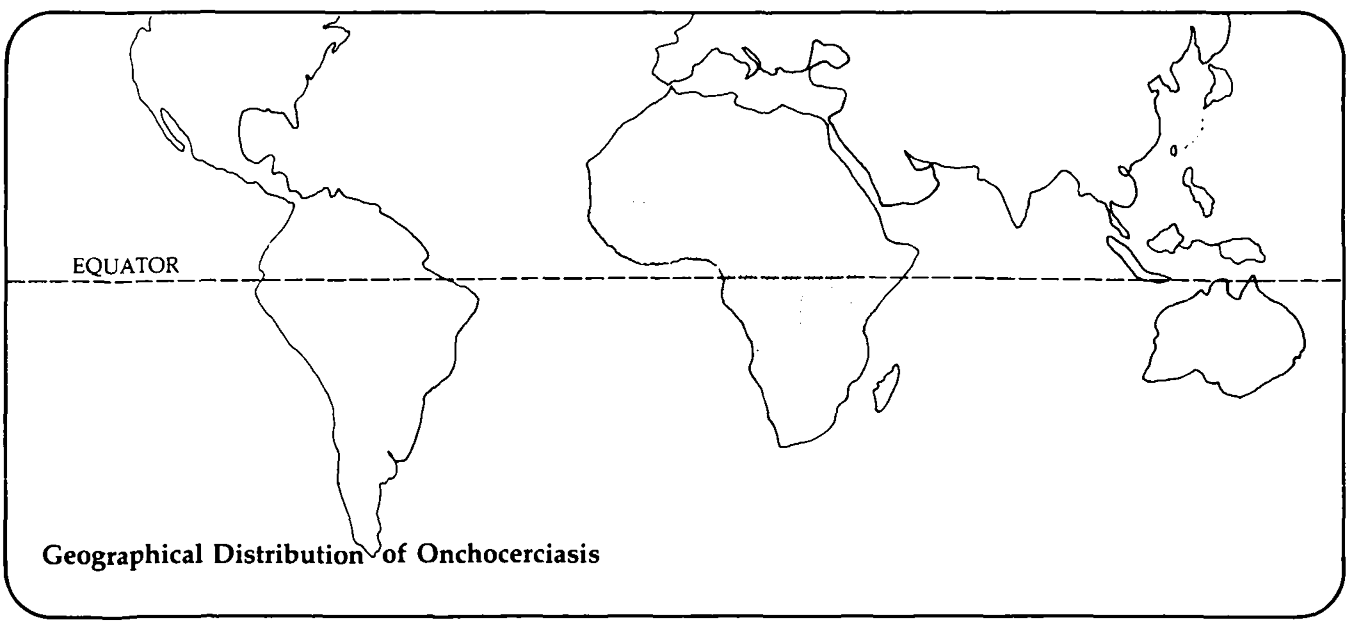
The disease causes blindness in the following way: Millions of tiny larvae produced by the adult worm die in the skin of the infected person because they can live only when sucked up by a blackfly. The human body tries to protect itself from the effects of the dead larvae by forming scar tissue around them. Over a number of years, many larvae die in the lens and other parts of the eyes. Finally, enough scar tissue forms in the eyes so that the infected person can no longer see.

For many years, onchocerciasis was fought, in some parts of the world, by campaigns to remove the nodules from under the skin and thus eliminate the adult worms that produce the larvae. However, worms may be deep within the body, not near the skin, or so many people in an area may be infected that operations to remove nodules are not practical.

Drugs have been used with mixed success. No drug kills both the adult worms *and* the larvae though some kill one or the other, and all drugs tested so far have dangerous side effects. In any case, drugs cannot repair the damage already done to eyes or other parts of the body. Given these drawbacks, the most promising approach, where large populations are concerned, is to focus attention on the water sites where they breed and attempt to eliminate the blackflies that serve as carriers for the disease.

Because blackflies require rapidly flowing water, stream modification can have a great influence on their reproduction. Dams eliminate breeding sites in the upstream flooded areas, but they also can provide good breeding sites in spillways and in fast water immediately downstream.

Blackfly breeding may be reduced if dams on rapid streams are constructed with this in mind. For example, if the spillways are built in a series of steps, the large area of water flow will provide ideal blackfly breeding conditions. There will be fewer blackflies if the spillway is on the vertical face of the dam. The blackfly population can also be reduced by dam con-



Geographical Distribution of Onchocerciasis

struction that releases water intermittently, thus interfering with the feeding of the blackfly larvae that may be present when the water flow stops.

If the breeding places themselves cannot be eliminated, chemicals may be used to kill blackfly larvae. Since DDT is dangerous to the environment, other chemicals have been developed. One is a preparation called Abate, applied from the air over blackfly-producing rivers. Methoxychlor is another chemical. While not as effective as Abate, it is about five times less expensive, an obvious consideration. The long-term effects on fish and other life of repeated use of either chemical has not been determined, although both appear to be safer than DDT. Other chemicals for blackfly control are being studied.

Malaria

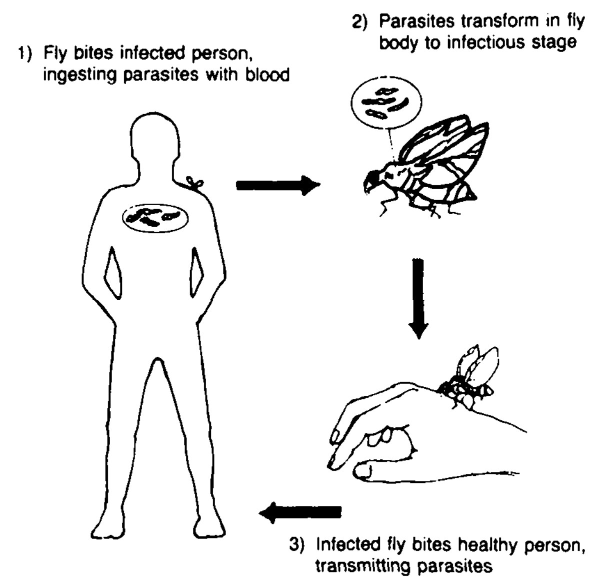
There are four varieties of protozoa that cause human malaria. Only one (malignant tertian malaria) is seriously life-threatening, with a death rate of about 10 percent among untreated children and adults who are not immune. The other three malarias, while generally not life-threatening, all cause severe illness with some deaths where the patients are very young or have another disease at the same time.

Malaria usually begins with the patient "feeling bad" for no specific reason. Chills, fever, headaches, nausea and heavy sweating follow. The cycle is repeated daily or every several days for weeks, months, or even longer if not treated. Relapses are common and may occur without warning for many years.

Malaria is transmitted by mosquitoes, females of many *Anopheles* species, using the same bloodbite with parasite change and multiplication as tsetse flies and blackflies. The mosquito-deposited parasites appear in the red blood cells of the victim from three to 14 days after malaria symptoms first appear.

Susceptibility to malaria is universal, and the battle against the disease has been going on for many decades. It has virtually been eliminated in temperate zone countries but continues to be a major problem in tropical areas of Africa, Asia and South and Central America. Even there, control programs have made great progress in lowering the number of malaria cases. Unfortunately, where control programs have been interrupted, malaria has again risen to epidemic proportions. Even more alarming is the fact that the parasites have recently shown high resistance to drugs and the carriers to insecticides long in use. The world situation with regard to malaria is thus a source of concern.

Malaria-bearing mosquitoes breed in a wide variety of aquatic habitats, including wet, swampy places; sanitary improvements, such as draining and filling, that reduce breeding opportunities are encouraged everywhere as a preventive measure. In addition, the spraying of walls in dwellings and other places where mosquitoes rest is an effective control device; DDT and Dieldrin are the most common insecticides used.



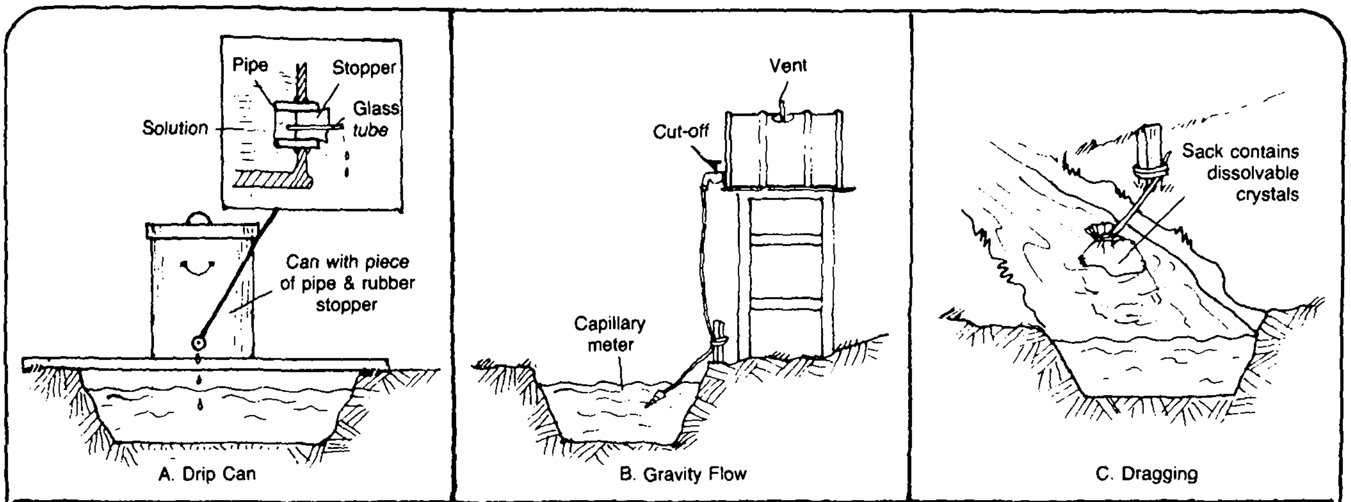
Transmission of Onchocerciasis

Several drugs administered directly to people suppress or cure the disease and are widely used by people traveling to malaria-prone areas. They are also used to treat the last cases in an area where control is well advanced. WHO is now supporting a worldwide anti-malaria campaign involving disinfection of aircraft, port sanitation, and administration of drugs to migrant workers.

Arboviruses (yellow fever and dengue)

There are many types of arboviral diseases, the most important of which are yellow fever and dengue fever. Both are transmitted by mosquito bites. The carrier mosquitoes are *Aedes aegypti* in urban areas but may be other *Aedes* species in rural areas or jungle settings. The mosquitoes breed in water, especially highly polluted water, so that improved water supplies and wastewater disposal can be important as control measures.

Yellow fever is an infectious disease of short duration, and the attack may be mild or severe. Common early symptons are fever, head and body aches, nausea, and vomiting. As the disease progresses, the pulse slows and weakens, and the passage of blood—through nosebleed, vomiting, or bloody stools—is common. Jaundice, the origin of the name "yellow fever," is moderate early in the disease but becomes more severe later. The death rate is only about 5 percent for people who live in places where yellow fever is common, but it may reach 50 percent among non-immune populations. If the patient recovers from yellow fever, immunity is permanent; second attacks are unknown.



Means of Applying Chemicals to Irrigation Ditches or Streams

Dengue has many of the same early symptoms—fever and aches—but is often accompanied by a rash. Patients recovering from dengue suffer fatigue for a long time. Epidemics of the disease are explosive, but deaths from it are rare.

Urban yellow fever has virtually been eliminated in the Americas, but there are still outbreaks in Africa in areas near rain forests where jungle yellow fever is prevalent. The jungle disease has occurred from time to time in most of Central and South America and in East and Central Africa. There is no evidence that yellow fever has ever been present in Asia. Dengue, on the other hand, is prevalent in most countries of tropical Asia, and epidemics have recently occurred in Polynesia and Micronesia. The disease is also well-established in Central and South America.

A vaccine has been developed for yellow fever, and this, combined with urban spraying of insecticides and a variety of international quarantine and reporting measures, has helped to bring the disease under control. There is as yet no vaccine for dengue, which must be attacked by identification and elimination of breeding places and by education of the public on personal measures for protection against mosquitoes, such as insect repellents and bed nets. A dengue vaccine now appears possible within the next five years.

Some diseases can be prevented by administering vaccines.

Filariasis (including elephantiasis)

Filariasis means infection of humans with one of several types of thread-like worms of the genus Filaria. The worms are transmitted primarily by mosquitoes, which may bite either in the daytime or at night, depending on the species. Filariasis is commonly a disease of heavily populated rural and urban areas with inadequate basic sanitation, a condition that favors breeding of the mosquitoes. At least one type of carrier is found in most of the warm regions of the world.

Early symptoms of filariasis are fever and inflammation of lymph nodes, where the adults frequently grow and live, or other parts of the body. If the infection is prolonged and repeated, lymph flow may be obstructed, leading to extreme enlargement of the limbs, breasts, or genitals. This is elephantiasis, a horribly disfiguring and handicapping disease.

In some developing countries, males with diseased genitals have been observed carrying them in wheelbarrows. Although only about 1 percent of the cases of filariasis result in elephantiasis, it is a much feared disease.

With no vaccination available, control of the filariasis-transmitting mosquito is the fundamental preventive measure. Even partial control may reduce or restrict the number of disease cases, so even small water breeding places such as in old tires, coconut-husks, tin cans and the like should be eliminated.

The reduction in water site diseases that might be expected with water supply improvements varies with the disease. One estimate is that piped water supplies would reduce Gambian trypanosomiasis by 80 percent. This is because journeys to obtain water would be greatly reduced, and this particular insect vector does not stray far from its river habitat. On the other hand, yellow fever would be reduced but 10 percent. The yellow fever mosquito breeds in water but rests far from its breeding place. Control measures will have to continue even after piped water supplies are in place.

Water Contact Diseases

In general, effective control of water site diseases requires country-wide if not region-wide efforts that extend considerably beyond water supply and sanitation. However, dramatic achievements with regard to water contact diseases can result from concentrating on water and sanitation alone. The most important water contact disease is schistosomiasis.

Schistosomiasis (bilharziasis)

Schistosomiasis is infection with blood fluke worms of one or more species of *Schistosoma*. *S. hematobium*, *S. mansoni*, and *S. japonicum* are the most common. The disease is also called "bilharziasis", after a physician who first diagnosed it, and occasionally "snail fever", due to the important role played by snails in its transmission.

It is commonly said that 200 million people worldwide are infected with schistosomiasis, and an additional 600-800 million are constantly exposed to the risk of infection. However, estimates vary widely because data available on the point are unreliable and incomplete. Little is known of schistosomiasis infections in mainland China, for example, and this figure could have a major impact on global estimates. Transmission of the disease is known to occur throughout the African continent, although tropical Africa is most strongly affected. It is rare in east and central Asia, except for China and the Philippines, but is found on the Arabian peninsula and parts of the Middle East. In the Americas, it is limited primarily to the west coast of South America, chiefly Brazil, and to Caribbean islands of the Lesser Antilles group. Infections are found in the United States and in Europe, but no transmissions are known to occur there.

There is little doubt that, on a global basis, schistosomiasis is one of the most serious tropical diseases, being found in seventy tropical or sub-tropical countries. Unfortunately, despite the fact that the disease is better understood and there are better means for its control than ever before, schistosomiasis infections worldwide are increasing largely due to the increase in irrigated agriculture.

Boiling the water will kill some disease-producing organisms.

While deaths directly from schistosomiasis are not common, the multiple long-term effects of the disease, and the large number of people infected, make it a staggering health problem. When the disease is first contracted, there are some immediate symptoms—an itchy skin rash, fever, a cough—that disappear in several weeks. The major damage to the human body comes two to five years later. It is caused by the eggs laid by the female worm in the blood vessels of the wall of the intestine and urinary bladder, the migration of the eggs in the body, and the response of the body to the eggs. Eggs lodging in body tissue may cause the development of tumors, lesions, ulcers, bleeding, and diarrhea. There can be damage to the abdomen, liver, or spleen. Occasionally, eggs contribute to brain, lung, and heart damage and even paralysis of the lower body. A strong connection between one type of worm (*S. hematobium*) and cancer of the bladder is suspected. The seriousness of infection in a given victim is proportional to the number of eggs that lodge in or cut through tissue and therefore to the number and length of time of infection by adult egg-laying worms. Infrequent infection by a small number of worms generally does not result in severe illness. Ordinarily, the disease develops slowly as more and more worms are acquired during childhood and the number of eggs causing tissue damage increases, with the maximum number being reached at 15-20 years of age.

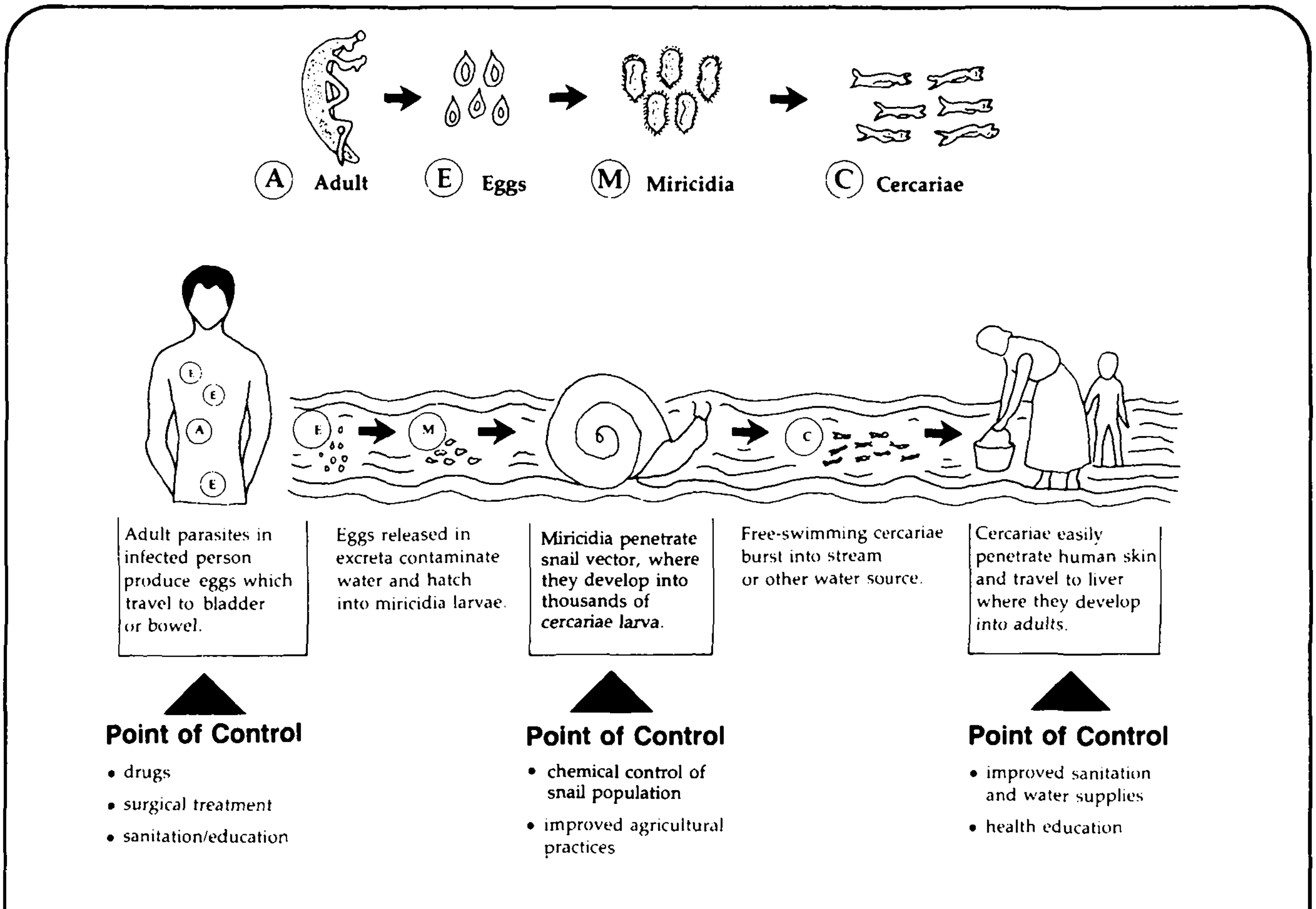
Schistosomiasis is transmitted by a process involving man, water, sanitation methods, and snails. Here are the steps:

1. An individual with schistosomiasis passes feces or urine containing schistosome eggs which reach a body of water.
2. The eggs hatch larvae known as "miricidia," which penetrate a suitable freshwater snail, develop in the snail, and produce larvae known as "cercariae" which, day after day, escape to swim freely in the water.
3. When given water contact opportunity, the cercariae penetrate human skin and travel to the blood vessels between the liver and the intestine and bladder where they grow to maturity.
4. The eggs laid in the wall of the intestine or bladder damage the human body but some work their way through the tissues to the feces and urine and are passed into water to continue the worm's life cycle.

The control of schistosomiasis can involve intervention at any or all of the steps in the transmission process. Specifically:

- Chemotherapy may be used to kill the adult worms in an infected individual.
- Better sanitation practices can prevent the contamination of water by feces and urine that contain worm eggs.
- Snails may be removed from the water or be prevented from entering the water or the miricidia and cercariae may be removed by water treatment.
- Human contact with the water may be reduced or eliminated so that cercariae cannot penetrate skin.

First, drugs can be used to treat schistosomiasis patients directly (chemotherapy). Such drugs have been available for many years, but many of them have serious side-effects and are quite expensive, in any case. Possibly the major problem with drug treatment is that drugs now available only kill the adult worm, not the eggs that do the real damage. In addition, if no environmental changes are made, drugs must be given over and over. At present, there is no drug to prevent infection.



Transmission Chain of Schistosomiasis*

*Schistosoma Hematobium

Secondly, the basic reason for the transmission of schistosomiasis is the low level of sanitation that allows eggs to enter water containing snails. It follows that if the safe disposal of human wastes could be accomplished, it would eliminate schistosomiasis, as well as other infections. In practice, however, improved sanitation alone is not likely to fully control the disease. Small children release excreta rather casually and some schistosomes are carried by animals. Better sanitation would be needed for fields and boats as well as homes. And even one human evacuation of waste may multiply into millions of cercariae.

Thirdly, if people have better water supplies, such as protected wells, for drinking, bathing, and washing clothes, they can avoid contact with contaminated water. Studies that have been done indicate that impressive results can be obtained in the transmission of schistosomiasis when adequate, reliable, and convenient water supplies are available. Of course, improvement in water supplies, even aside from the cost, would not provide total control because some persons, such as workers in irrigated fields, would still be exposed.

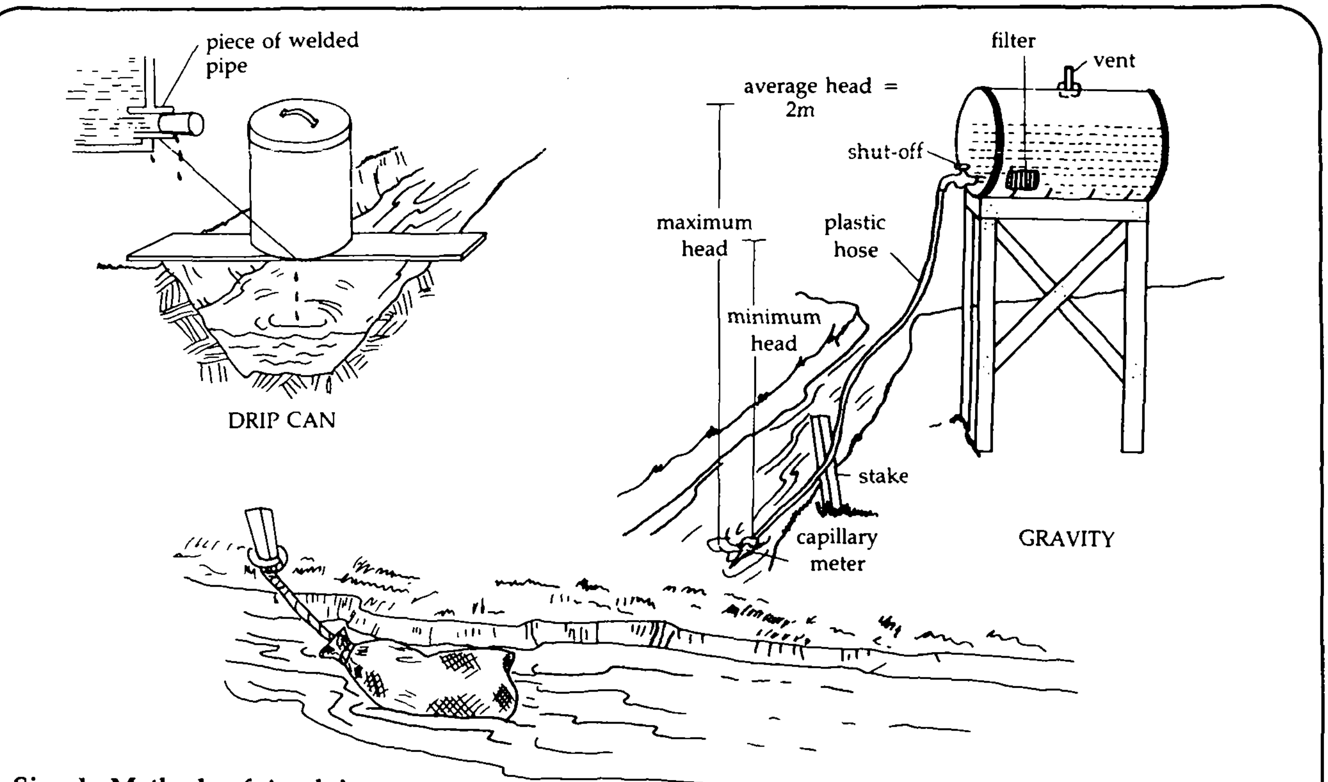
Finally, schistosomiasis control may center on the snail host. Water treatment—storage, filtering, disinfection—can prevent the miricidia from reaching their snail hosts or cercariae from reaching human victims. Rarely would water treatment be 100 percent effective, however. Another approach is to put chemicals in the water to kill the snails. The use of chemicals (called molluscicides) is a proven control method that can be followed by people who have little training.

But there can be problems with using chemicals for control. Usually, not all of the snails are killed and, even if they are, eventually snails from a neighboring untreated region will spread. A new snail population will begin to develop so the chemicals will always have to be repeated at intervals.

Some of the chemicals used to control the snails also can kill fish and plants living in or near the water. If the water where snails are found is running water, rather than standing water, this is less likely to happen. The chemical to be used must always be carefully selected, both to be sure that it will kill the type of snails that transmit the schistosomes and to make sure the least damage is done to fish and plants.

The amount of chemical needed to kill the snails depends on the amount of water present, how fast it is running, and the type of chemical selected. Equipment for putting the chemical into water is neither expensive nor hard to find, nor is the cost of chemicals prohibitively high.

In addition to molluscicides, the snail population may be attacked by a change in its environment. While water resource developments are essential for economic progress, they may prove to be a health hazard where schistosomiasis is a problem. Often, when better irrigation comes to an area, schistosomiasis follows, because snails breed in the new lakes and canals which are not protected from worm eggs from man or animals. But if irrigation methods are studied and improved, reducing the number of stagnant pools, ditches and seepage areas where snails live,



Simple Methods of Applying Molluscicides

there will be less disease. Sometimes using covered rather than open irrigation channels, rotating crops so that different water levels can be in use during the year, and stopping the common practice of leaving water to collect in reservoirs overnight can reduce the number of snails in an area. If there are fewer snails, there will be less schistosomiasis.

Reducing human contact with infected water also interrupts the transmission cycle of schistosomiasis. New settlements can be built away from irrigation canals and natural water courses and be provided with their own supply of safe water.

Environmental control is expensive, slow, and uncertain. It is used to supplement drug treatment of patients or chemical attacks on snails, rarely alone. Until rigorous, scientifically respectable analysis makes its outcome more predictable, the situation is unlikely to change.

Present knowledge of snail hosts is probably sufficient to guide engineering design of environmental control measures. However, such design is complicated by the great variation in natural environments and irrigation schemes. Furthermore, engineering measures affect agricultural productivity and project economics. There is little doubt that engineers could eliminate snails if unconstrained as to water or money. This complexity of requirements, some conflicting, has meant that environmental control has only rarely been the sole measure of an effective schistosomiasis control scheme. This situation seems likely to prevail in the future.

Water Quality/Microbiological Diseases

By far the major threat at present to water quality in developing nations is improper excreta disposal. Human feces contaminate water supplies and trigger a variety of diseases of a microbiological nature. These diseases are endemic in areas where excreta disposal is haphazard, forming an important part of the sanitation-related/water hygiene disease category. However, they are most feared when they surface through water consumption because it is in this way that the diseases are likely to achieve epidemic proportions. These are the classic and well-known "waterborne" diseases—cholera, typhoid fever, diarrhea, dysentery, and the less well-known Guinea worm.

Cholera

This dread intestinal disease strikes like the wind. The victim vomits and passes extremely watery stools. The body suffers dehydration, rapid acid build-up, and circulatory collapse, ending often in death. All this may occur within a few hours. In untreated cases, the death rate may exceed 50 percent; with treatment, which takes the form of intravenous fluid therapy, the rate drops to 1 percent.

Cholera has been known to exist in eastern India since the beginning of recorded history, but the first record of epidemics involving other parts of the world was in 1871. In the next one hundred years, there were six nearly universal cholera epidemics (pandemics) after which the disease retreated to its Asian homeland. Except for sporadic outbreaks (such as Egypt in 1947), the most terrifying disease of the nineteenth century seemed at that time to have vanished.

The causative agent in classic cholera is *Vibrio cholerae*. A new type of this strain, called El Tor, was identified in 1905, but the type was not thought to be epidemic. This hope was dashed in 1961 when the seventh pandemic, featuring the El Tor cholera, began. The newer strain is more resistant to environmental factors and to antibiotics than the classic strains, and the ratio of infected persons to clinical cases is higher. The symptoms of the disease are the same, however.

The seventh cholera pandemic has swept through Asia and Africa and has reached into Europe. Cases among air travelers have occurred in other parts of the world, including a few in North America. One case occurred in Texas in 1973 with no known source. In the affected countries, there has been a tendency for the disease to persist in an endemic form.

Cholera may be transmitted either from active cases or from carriers. All that is necessary, in both instances, is that food and water be contaminated and then be ingested. Carriers are particularly a problem since there is no practical way of identifying them in a transient population. Cholera patients excrete the infecting agents for only a few days, but carriers may pass them for up to a month and so be able to transport them over long distances.

There are vaccines for cholera, but ordinarily they are not considered a practical control measure because they are expensive and give only short-lived protection. The disease usually affects people of low socioeconomic status who live in unsatisfactory conditions including a lack of safe water and effective sanitation. Change in these conditions, beginning with water and sanitation, is the best long-run control measure.

Typhoid Fever

As the name suggests, typhoid fever is characterized by continued fever, headache and malaise. The spleen and lymph are affected, and there may be intestinal hemorrhaging in untreated cases. The victim is more likely to suffer constipation than diarrhea. The fatality rate for typhoid fever is about 10 percent, but this can be reduced to 2 percent or less with antibiotic treatment.

The typhoid bacillus, the infectious agent, is transmitted by food or water contaminated by the feces or urine of man, either a patient or a carrier. The typhoid patient is usually not infective before becoming ill. After the onset of the illness, the patient is usually too sick to go out and pose a threat to water supplies but faulty handling and disposal of patient excreta can be a threat. However, some persons who recover clinically continue to pass bacteria in their feces for years; they are the source of waterborne infections.

Typhoid is worldwide in its incidence, but it is most prevalent in the developing nations. Developed countries such as the United States report only a small number of cases, usually about the same from year to year. The availability of vaccines, which are effective in typhoid control, is an important factor. The common practice is to vaccinate persons likely to be exposed to typhoid through their occupations (e.g., food handlers) or travel and persons in institutions where sanitary arrangements may be less than satisfactory. As with cholera, water supply and hygiene improvements are the most effective preventive measures.

Diarrhea

The term "diarrhea" is used by laymen to describe a specific set of symptoms—watery stools and intestinal cramps often accompanied by malaise. There are many infectious agents that may produce these symptoms, however. Sometimes a specific infectious disease such as cholera, shigellosis (bacillary dysentery), or salmonellosis (intestinal inflammation) can be identified. Viruses loosely grouped as "enteric viruses" may attack the enteric or gastrointestinal (digestive) tract of humans. A subcategory of viruses, called rotaviruses, are considered a major cause of gastroenteritis, a type of diarrheal disease. So numerous are the possible causes of diarrhea that the specific agent is often not identified at all. In such cases, the diarrhea is referred to as "undifferentiated."

Whatever the specific cause, it is estimated that 500 million cases of diarrhea occur each year in children under five years of age in developing nations, with 3 to 4 percent of these ending in death. When diarrhea is linked to malnutrition, as it frequently is in the developing world, it becomes the leading killer of small children. Most high intensities of diarrheal disease are associated with defective water supplies and poor sanitation and hygiene practices.

Dysentery

The term "dysentery" applies to a variety of intestinal inflammations characterized by abdominal pains and intense diarrhea with bloody stools. One of the more troublesome types is amebic dysentery (amebiasis), an infection resulting from a protozoan parasite found outside the human body as a hardy cyst. Balantidial dysentery (caused by a protozoan widely found in swine) has similar symptoms, but humans appear to have a high natural resistance to this disease. The main epidemic danger comes when there is close and unhygienic association with swine. Shigellosis, discussed below, is also a form of dysentery.

Amebic dysentery infection is worldwide and, like other such diseases, is best addressed by sanitation practices and health education. In epidemics, the disease is transmitted primarily by water contaminated with feces containing the cysts of infected persons. There can be endemic infection by direct hand-to-mouth transfer of cyst-bearing fresh feces or raw vegetables. Flies and soiled hands and contaminated food are also means of transmission. Many persons who have the amebas in their intestines do not show symptoms of the disease, but for many years they may pass it on to others.

The protection of public water supplies from fecal contamination is the chief way of preventing amebic dysentery epidemics. Good sanitation practices, of course, contribute to this end, but some water treatment techniques are also effective. As generally practiced, chlorination does not kill the infecting cysts, but sand filtration will remove nearly all of them from the water. Diatomaceous earth filters remove them completely. Where water is being used in small quantities, as in canteens, treatment with high concentrations of chlorine or iodine are effective.

Guinea worm (dracontiasis)

It has been estimated that improved water supplies in the form of protection for water sources would eliminate 100 percent of the Guinea worms in the world. At present, the disease is very widespread—Africa, the Middle East and India. In the past, there have been cases in the West Indies and northeastern South America. For unknown reasons, there is great local variation in the disease. In some places, nearly everyone is infected; in others, very few people—mainly young adults—are.

Like schistosomiasis, Guinea worm depends on a water-dwelling host for survival—a water flea of the genus *Cyclops*. Larvae discharged into fresh water are swallowed by Cyclops, which becomes infective in about two weeks. When people drink water from this source, the infectious agent enters the stomach, and the larval worm begins to work its way to tissue just under the skin. The mature female worm, which may grow to a full meter in length, lies embedded under the skin with the opening through which larvae are discharged lying in a blister, usually on the foot, though they can be on any part of the body which is reguarly soaked in water.

Simple sanitation facilities like this privy may reduce sanitation-related diseases.

Persons infected with Guinea worm suffer from burning and itching of the skin near the blister, fever, nausea, vomiting, and diarrhea. Deaths are rare, but the long term effects can be crippling when several worms are involved, as is common, or when the long channels in which the worms lie under the skin are infected by bacteria. When the foot with a Guinea worm blister is immersed in water, the blister bursts and the worm discharges a large swarm of larvae which when eaten by water fleas continue the cycle of contamination.

There are no known immunizations for Guinea worm, which must be dealt with at the source. The infected *Cyclops* may be filtered out of the water with a fine mesh cloth. Or the water may be drunk if it is boiled first or treated with chemicals—chlorine or copper sulfate. A better prevention method is improvement of the water source itself. When the source is a step-well, there is obviously maximum opportunity for contamination to occur. Even when persons do not actually step in the water, infections may be transmitted if the shelf around the well slopes toward the water and allows spilled water to run back into the source. As noted earlier, the replacement of step-wells with better water sources seems to have eliminated Guinea worm in the Soviet Union some years ago, and the approach has also been used successfully in India.

Sanitation-Related/Water Hygiene Diseases

Some of the most common diseases in developing nations can be reduced, both in prevalence and in severity, if sufficient water is available for the improvement of personal and domestic hygiene. Obviously, disease reduction only occurs if there is enough health education being practiced to turn water *availability* into water *use*. Since the diseases stem basically from poor sanitation practices—that is, improper disposal of feces—improvement in these practices is also important. But water for washing must be readily at hand, whatever the sanitation facilities employed.

Most of the sanitation-related/water hygiene diseases can be transmitted through drinking water, but since their major routes of transmission are through food, hand-to-mouth contact, and numerous other means, it is well to discuss a number of them separately.

In addition to those that affect the intestinal system (example: shigellosis), hygienic diseases include those of the eyes (example: trachoma) and skin (example: scabies). Worms or lice may also be involved (examples: ascariasis and scabies, respectively).

Shigellosis

Shigellosis is a type of dysentery—bacillary—primarily involving the large intestine. The symptoms—diarrhea, fever, vomiting, cramps, sometimes constipation—are similar to amebiasis. The severity of the illness and the fatality rate vary with the patient's age, state of nutrition, and level of sanitation. When patients are not treated the fatality rate may exceed 20 percent.

The disease occurs worldwide. Two-thirds of the cases—and nearly all the deaths—are in children under the age of ten. However, it can occur in all ages among populations suffering from malnutrition and poor sanitation, especially where there are crowded conditions as in slum areas, city shantytowns, jails, institutions for children, and mental hospitals. Shigellosis is an important type of acute epidemic gastroenteritis among tropical populations, but where living conditions are poor, it strikes in temperate climates as well.

Shigellosis is contracted directly or indirectly from a patient or from carriers. The individuals most responsible for transmission are those who fail to wash their hands after defecation. They spread the infection by direct contact with others or by contaminating food. Outbreaks may occur when water or milk is directly contaminated with feces, but the hand-to-mouth transmission is more common.

Given the methods of transmission and the susceptibility of children to the disease, breast-feeding throughout infancy is recommended as a precaution against shigellosis. If milk and water are to be prepared for infant feeding, they should be boiled.

Trachoma and Conjunctivitis

The conjunctiva is the thin layer that covers the white of the eye. Conjunctivitis ("pink eye") is an infection of the conjunctiva that causes redness, pus and burning in one or both eyes. After sleep, the eyelids of a person infected often stick together. The disease is easily spread from one person to another.

Trachoma ("rough eye"), caused by a virus, is a chronic form of conjunctivitis that slowly gets worse over months or even years and may cause blindness if not treated. It begins with red, watery eyes, a condition similar to ordinary conjunctivitis. After a month or so, small pinkish-gray lumps (follicles) form inside the upper lid, and the white of the eye is mildly inflamed. The cornea, the clear layer that covers the iris and pupil, will appear grayish under a magnifying glass because there are many new tiny blood vessels (pannus) in it. When the combination of follicles and pannus appears, it is almost certainly trachoma. After several years, the follicles begin to disappear, leaving whitish scars. The scars make the eyelids thick and may prevent them from opening all the way. Or they may pull the eyelashes down into the eye, scratching the cornea and causing blindness.

Trachoma is the world's leading cause of preventable blindness. Approximately 400-500 million people are affected worldwide, with two million blinded and eight million at risk of blindness. As much as 3 percent of the population may be blinded in areas where the disease is endemic and uncontrolled. The worst affected areas are North Africa, the Middle East, and certain regions of Asia and South America. Although trachoma affects people worldwide, its absence in physicians and tourists suggests that long-term and repeated exposure is necessary to establish the disease.

Although no vaccine has been proven effective against trachoma, certain drugs retard the disease in the active stages. These may be oral tetracyclines, erythromycin or oral sulfonamides. Mass treatment with these drugs has sometimes been practiced in developing countries. Of course, prevention is better than cure. The best techniques are clean hands and cloths that touch eyes achieved by regular use of ordinary soap and water, combined with health education in the avoidance of practices that spread the disease, especially common-use towels.

Scabies

This is an infectious disease caused by a mite which penetrates the skin and deposits eggs. At the points of penetration, which can be on many parts of the body, the patient itches intensely, but unless the scratching causes secondary infections there are usually no complications.

The parasites are transmitted primarily by direct contact, particularly sexual contact, but there is some transference from underclothing and bedclothes used by infected persons. Scabies occurs worldwide and is common during war or social upheaval when personal hygiene is apt to be overlooked. In communities where frequent bathing is the common practice, the disease is rarely found.

Ascariasis

Ascariasis, or roundworm infection, is a common and worldwide condition that occurs most frequently in moist tropical regions where prevalence may exceed 50 percent of the population. Children of preschool and early school age are more often and more severely infested than older children and adults.

Symptoms of the disease are sometimes vague, mild, or even absent, and appearance of live worms in the stools is often the first sign of infection. However, heavy parasite burdens may cause malnutrition, digestive disturbances, abdominal pain, vomiting, restlessness and disturbed sleep. Serious complications among children, especially in unsanitary areas of tropical countries, include bowel blockage and occasionally death if the adult worms migrate to the liver, gall bladder, or appendix.

Ascariasis is not transmitted directly from man to man but by ingestion of eggs which have become infective by about two weeks of incubation in damp, warm soil. The unwashed hands of children that play in contaminated soil in and around houses where they are permitted to freely defecate is the principal source of infection. Salads and other foods eaten raw are a common vehicle. Contaminated soil may be carried long distances on feet or shoes into houses. Transmission by the ingestion of contaminated dust is also possible.

Ascariasis can be prevented by proper disposal of human excreta and by education of all persons, especially children, in handwashing and proper use of sanitation facilities.

SOURCES
CHAPTER TWO

A basic reference was Abram S. Benenson, *Control of Communicable Diseases in Man*, 12th ed. Washington: American Public Health Association, 1975. A number of materials prepared for the AID Knowledge Synthesis Project were used.

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RELATED TECHNICAL NOTES
CHAPTER TWO

DIS.G	Overview of Disease
DIS.1.M.1	Means of Disease Transmission
DIS 1.M.2	Methods of Improving Environmental Health Conditions
DIS.1.P	Planning Disease Control Programs
DIS.2.M.1	Methods of Controlling Schistosomiasis
DIS.2.M.2	Methods of Controlling African Trypanosomiasis
DIS.2.M.3	Methods of Controlling South American Trypanosomiasis
DIS.2.M.4	Methods of Controlling Enteric Diseases
DIS.2.M.5	Methods of Controlling Onchocerciasis

CHAPTER THREE
DEVELOPMENT AND USE OF WATER QUALITY STANDARDS

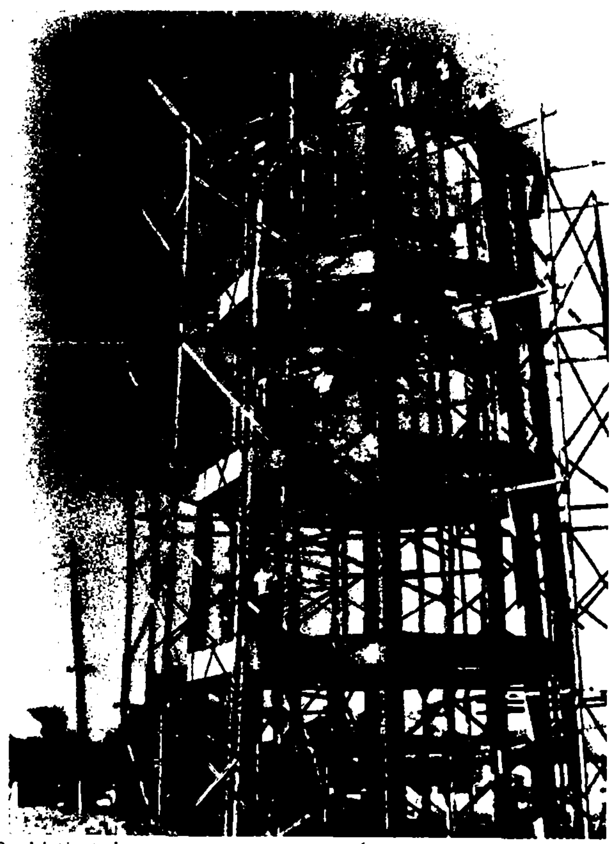
SUMMARY

Efforts at water supply improvement have usually been directed at achieving at least minimum adequacy in terms of both quantity and quality rather than through either alone. Developing nations today that want to attack disease and ill health through water improvements must surely develop water quality standards.

The current methods of assessing water quality were fashioned over the past two hundred years in the urbanizing areas of Europe and North America. While these methods may not be completely and automatically applicable to the Third World, this experience does offer valuable guidance. The standards with the most universal acceptance were formulated by the World Health Organization in 1971.

The test of water quality standards is their ability to correctly guide the evaluation of water supplies as a source of microbiological disease, the diseases of chief importance to developing nations. Indicator organisms, especially the coliform group, are widely used as tests to assess the possibility for these disease-producing pathogens to occur in a water supply. This approach is strongly endorsed by WHO.

Water quality standards should be applied as a means to better health, not as an end in themselves.



Sophisticated water systems are not always necessary to ensure good quality water.

CHAPTER THREE
DEVELOPMENT AND USE OF WATER QUALITY STANDARDS

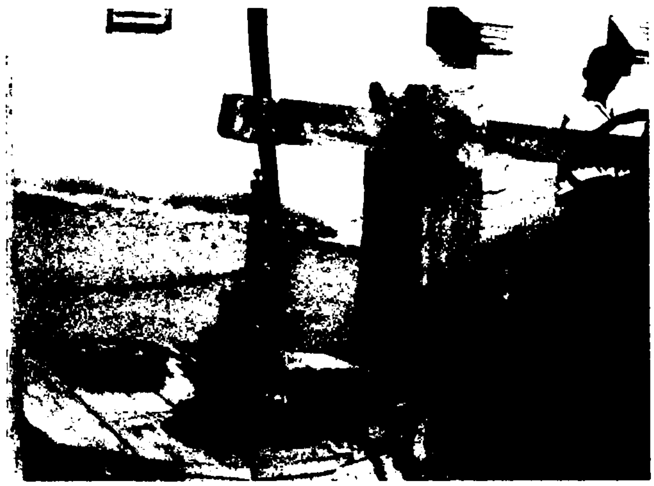
Improvement in water supplies, including their protection against contamination by excreta, can be a major factor in the prevention of disease. How much of a factor depends on the disease. Experts on safe water and sanitation have estimated that through water improvements the diseases discussed in the previous chapter could be reduced by the percentages shown in Table 4.

Table 4. Reducing Water-Related Diseases

Disease	*Percentage*
Trypanosomiasis (Gambian)	80
Onchocerciasis	20
Malaria	*
Yellow Fever	10
Filariasis	*
Schistosomiasis	60
Guinea Worm	100
Cholera	90
Typhoid Fever	80
Diarrhea	50
Shigellosis	*
Trachoma	60
Ascariasis	40
Scabies	80

*not estimated

Source: Feachem, *Water, Wastes and Health in Hot Climates*.



A simple hand pump with a protected water source is often enough to preserve water quality.

The question is "what water improvements?" As noted previously, the overall issue is one of the availability of water of sufficient quantity *and* good quality. With water site diseases, such as Gambian trypanosomiasis, it may be enough if water is readily available so people can avoid infected water habitats. With sanitation-related diseases, such as trachoma, an adequate quantity of water for washing may be sufficient, while for most diseases, it is the quality of the water that really counts. In an actual community, one water supply must meet all these needs.

Some water site diseases can be avoided if people do not have to visit infected water habitats.

Role of Water Quality Standards

Always there has been some controversy among concerned persons as to the relative emphasis that should be given to water quality improvements as a method of disease prevention. Some feel that those with detailed knowledge of the technical side of water quality, such as sanitary engineers, tend to assign undue importance to quality. Others argue that water for washing is so crucial to health that it should be provided in abundance and people educated in its use, even if the quality of the water is poor. In particular, costly improvements in water *quality* should not be allowed to stand in the way of water *quantity* improvements. If necessary, two sources of water, one for drinking and another for washing and household use, should be used.

Opponents of this view, which admittedly is oversimplified here, counter that two water sources will rarely be feasible. For better or worse, the choice will be between water that is contaminated and water that is not. If this is the choice, insisting on water of good quality is the wiser course, especially since ensuring such quality in a water supply will cost very little more. Enough water of good quality helps to prevent *all* the water-related diseases, both those that are hygiene-related and those that are water-carried and to some degree even the water site diseases. Impure water helps to prevent *only* those that are hygiene-related.

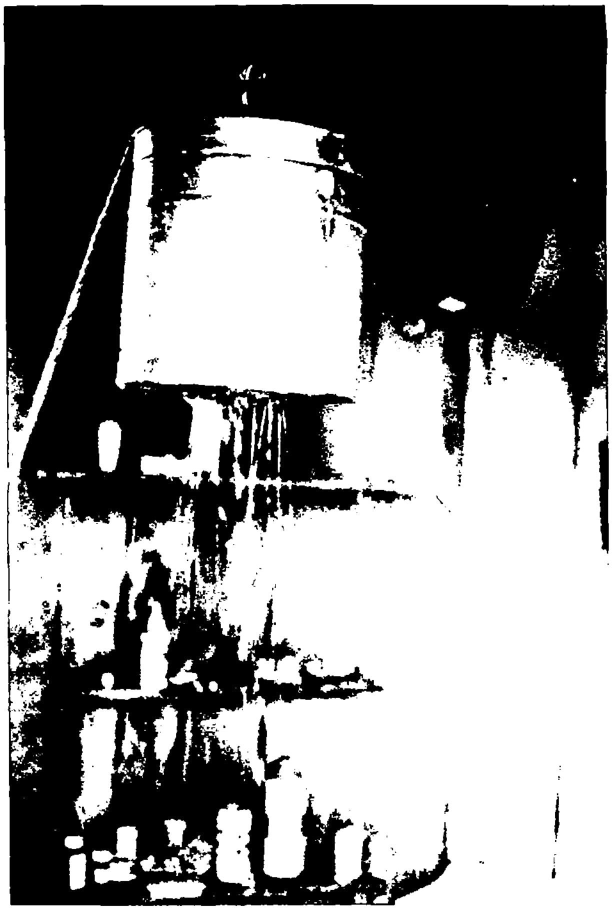
In practice, efforts at water supply improvement have usually been directed at achieving at least *minimum* adequacy in terms of both quality and quantity. In water program planning, the problem is likely to arise only at the extremes as *minimum* levels are being determined. No rational person would be content with a situation where water was plentiful but all of it was infected with Guinea worm. On the other hand, it would hardly seem wise to withhold water from needy people until every trace of chemical contaminant, no matter how mild, had been eliminated.

In sum, the quality-versus-quantity issue is essentially theoretical. In the real world, some degree of water quality is accepted as essential and meaningful debate is over the balance between quality and quantity. In developed areas with long histories of water supply improvements, some fairly exotic minerals may be cited to show poor water quality. In developing areas where water-related diseases are widespread, water that is simply free of contamination from excreta may be judged acceptable.

Developing nations today that want to attack disease through water improvements must surely develop and increasingly enforce water quality standards, not as an alternative to increasing quantity but as a prudent prerequisite to it. This chapter sheds some light on this process by discussing the historical context for water quality standards, the content of the standards that are widely accepted today, and the problems of applying modern standards in developing nations.

The term "water quality standard" refers to matters both of substance and procedure. As substance, a standard states what should not be found in water if it is to be judged acceptable in quality. As procedure, part of the standard specifies the means for determining what is in the water and how often these means are to be used.

No naturally-occurring water is completely "pure"; all water contains some elements that *could* be harmful to health. Thus all consumption of water involves some risk of an undesirable effect. A water quality standard is based on assessing the limits of acceptable risk. Water quality cannot be evaluated simply by determining the presence or absence of a disease-producing agent (germ or pathogen). The probability of



Such simple sanitation facilities as this shower (above) and bath house (below) are effective in preventing disease if water of good quantity and quality is available.

anyone's falling victim to water-related disease is a statistical question related to a number of things, particularly to the type and number of pathogens. Not all pathogens have the same capacity to produce disease. They do not have equal "virulence" and some may be rendered ineffectual by unfavorable conditions in the human intestine or for other reasons. For example, some strains of Shigella germs are highly virulent and cause infection when only a few cells are ingested; other Shigella strains require much larger doses for the same result. The probability of contracting disease generally increases as the number of pathogens ingested increases. To summarize, here are the chief factors influencing the water-disease linkage:

- the type of pathogen involved;
- the length of time infective agents can live outside the host;
- the virulence of the specific strain of organism;
- the number of cells ingested;
- the age of the potential victim (the very young and very old usually are more susceptible);
- the general health of the individual (those suffering from malnutrition, infection, or other debility are especially disease prone);
- the extent to which the individual may have acquired immunity through earlier exposure to small quantities of the pathogen;
- the presence of other factors, such as certain chemicals, that affect the relationship between the organism and the individual.

Despite the complexities involved, societies have long sought to define specific limits for permissible impurities in water and effective methods for discovering when the limits are breached. Most of the development of water quality standards has been in Western nations and has come about primarily since the Industrial Revolution.

The Historical Context

The current methods for assessing water quality were fashioned over the past two hundred years in the urbanizing areas of Europe and North America. Although there are many similarities between the Western nations in this period and the developing nations today, there are also many differences. The differences include variations in water resources, population size and growth rate, climate, available resources, economic and social organization, and important pathogens. In addition, Western standards were developed largely to meet urban problems while most developing nations' problems are rural. It is thus clear that methods developed in the Western context cannot be completely and automatically applied to the Third World. Nonetheless, the experience offers valuable guidance.

The association between filth, lack of water and the presence of disease was not new in the early nineteenth century when concern with water quality standards began to grow. What was new—at least it had been dormant since the Romans—was the notion that public projects should provide water and remove filth. Supported by this belief, sanitary reform gradually spread across industrial nations, especially Great Britain. Reform was speeded by increasing evidence, a lot of it gathered by the famous Dr. Snow, that cholera was transmitted through excreta in drinking water and by greater acceptance of the germ theory of disease. By 1860, the basic foundation had been laid for subsequent public sanitation work. At its core was the provision of a water supply that was convenient and free of contamination by excreta.

Still to be developed were methods for achieving the public health objective. The major institutional response was the public health board, the first of which had already been established in 1848 in Great Britain. Between 1869 and 1877, ten state health departments were established in the United States, but their functions were advisory and cooperative rather than regulatory, at least partly because it was not yet clear how freedom from contamination was to be achieved.

The first regulatory attempts relied on field investigations, or "sanitary surveys," to identify impure water. Some of the things considered in such surveys were: color and hardness in the water; presence of industrial activities; distance from wells to sources of pollution; and population of a drainage area. At the turn of the twentieth century, one writer summarized the "most advanced ideas" for establishing the purity of surface waters as a supply of high organic purity, a watershed as thinly populated as possible, and extensive storage capacity.

Gradually, laboratory analyses of both the chemical and bacteriological content of water began to be employed to supplement the sanitary surveys. The recommended tests usually included clarity, color, odor, total solids, volatile solids, chlorine, free ammonia, nitrite and nitrate, magnesium and sulfate levels, oxygen demand, and metals. With the growing recognition that diseases resulted from germs, specific microbiological tests assumed more importance. The greatest problem was in interpreting the results. Samples from the same well sent to five different analysts might be graded as anything from "unusually pure" to "unfit for drinking."

Given the variations in results, it is not surprising that laboratory analysis of water as a basis for purity judgments was suspect. As late as 1925, most sanitary scientists and engineers opposed widespread application of specific laboratory-based standards, fearing that "safe" supplies would be unjustly indicted. They continued to champion sanitary surveys as more reliable. Even today, in the United States, many communities complain of overly-strict national standards and insist that their water supplies are perfectly safe, even when they contain, by lab tests, high amounts of arsenic or other toxic chemicals.

Nonetheless, the drive for objective water quality standards proceeded. The first such set of limits with broad applicability was promulgated by the U. S. Department of the Treasury in 1914 under the authority of Interstate Quarantine Acts. The regulation required certification of the water supplies of railroads and ships involved in interstate commerce. A commission of fifteen sanitarians was appointed to recommend a standard of purity. The limits of purity were established solely on the basis of bacteriological laboratory analysis, using the "coliform count" for fecal contamination that was coming to be an accepted test. No physical or chemical limits were specified, nor was a sanitary survey required.

Despite criticisms, the U. S. Treasury standard had the virtue of being a measure of quality endorsed by an accepted authority. It eliminated personal judgment in the interpretation of laboratory results and could be easily administered. Therefore, the standard came to be widely accepted even where no interstate carriers were involved. Although sanitary surveys continued to be the most common basis for condemning water supplies at the state level, the principle of fixed laboratory standards was clearly established.

In 1922, a commission was appointed to formulate definite specifications that could be used by the U. S. Public Health Service (USPHS) in administrative action, and there were revisions to the original standard to meet technical criticisms. A satisfactory sanitary survey report was required and its characteristics were detailed; chemical standards were added; the maximum permissible fecal contamination was significantly reduced. The revised standard was issued in 1925, and there were subsequent revisions by the Public Health Service in 1942, 1946, and 1962. In 1975, the USPHS standards were superseded by the Primary Standards issued by the U. S. Environmental Protection Agency. These are the standards that presently govern public water supplies in the United States.

Current International Standards

The World Health Organization first issued its *International Standards for Drinking Water* in 1958. These standards were adopted, at least in part, by a number of countries as the basis for national standards and were cited in the International Sanitary Regulations as applicable in deciding what constitutes a pure water supply at ports and airports. A second edition of the standards was published in 1963, and the most recent version appeared in 1971. A new edition is scheduled for late 1982.

According to WHO, the current standards are based on: earlier editions of the *International Standards;* the 1970 edition of the WHO *European Standards for Drinking Water; The Bacteriological Examination of Water Supplies* published in 1969 by the Ministry of Housing and Local Government for England and Wales; the 1962 edition of *Public Health Service Drinking Water Standards,* issued by USPHS; the 12th edition of *Standard Methods for the Examination of Water and Wastewater,* prepared by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation; *Water Treatment and Examination,* edited by W. S. Holden; and the water standards of the Ministry of Health of the USSR.

The 1971 WHO publication is concerned primarily with methods of ensuring that supplies of drinking water are not a danger to the health of the users. It is divided into sections on bacteriological, virological, biological, radiological, physical and chemical examination and sampling. Section 2 on bacteriological examination is concerned with: the choice of organisms to be used as indicators of pollution; the methods that should be used for the detection of these organisms; and the standards of bacterial quality that might be set for supplies of drinking water. This is followed by Sections 3, 4, and 5 on virological examination, biological examination and radiological examination respectively.

Improved water supply systems with storage tanks are one way of reducing contamination.

Section 6 on physical and chemical examination is concerned primarily with the limits of concentration that should be set for certain toxic substances that may constitute a danger to health; methods are recommended for detecting and estimating these substances. Consideration is also given in Section 6 to the approximate concentrations above which other chemical substances may affect the health of the user. The "highest desirable" and "maximum permissible" concentrations of chemical substances that affect the acceptability of water for domestic use are listed. The methods that may be used in the estimation of these chemical substances are indicated. In the part of Section 6 dealing with chemical examination, it is suggested that certain methods should be used in the general examination of supplies for their aesthetic, physical, and chemical characteristics in order to make the results obtained in different laboratories more easily comparable.

In Section 7 on sampling, methods of sampling for purposes of bacteriological, virological, biological, radiological, and physical and chemical examinations are outlined, and advice is given on when and how frequently samples should be collected for each purpose. Some advice on the storage and transport of samples is also given.

To support the recommended laboratory standards, WHO gives a strong endorsement to sanitary surveys:

> No bacteriological or chemical examination, however careful, can take the place of a complete knowledge of the conditions at the sources of supply and throughout the distribution system. Every supply should be regularly inspected from source to outlet by experts, and sampling—particularly for purposes of bacteriological examination—should be repeated under varying climatic conditions, especially after heavy rainfall and after major repair or construction work. It should be emphasized that, when sanitary inspection shows that a water, as distributed, is liable to pollution, it should be condemned irrespective of the results of chemical or bacteriological examination. Contamination is often intermittent and may not be revealed by the chemical or bacteriological examination of a single sample, which can provide information only on the conditions prevailing at the moment of sampling; a satisfactory result cannot guarantee that the conditions found will persist in the future.
>
> With a new supply, the sanitary survey should be carried out in conjunction with the collection of initial engineering data on the suitability of a particular source and its capacity to meet existing and future demands. The sanitary survey should include the detection of all potential sources of pollution of the supply and an assessment of their present and future importance. In the case of an existing supply, a sanitary survey should be carried out as often as required for the control of pollution hazards and the maintenance of the quality of the water.
>
> It is considered that the responsibility of the surveillance authority goes beyond that of merely pronouncing that water as delivered satisfies, or fails to satisfy, a certain quality standard. Surveillance should include the giving of advice on how defects can be removed and quality improved.

Evaluating for Microbiological Disease

It is undisputed that the greatest danger associated with drinking water is that it may be contaminated by human excreta. If such contamination has occurred recently, and if it is caused partly by carriers of infectious diseases, the water may contain the living germs (pathogens) of these diseases. These are the diseases that are of most concern in developing nations. For these nations, then, the supreme test of water quality standards is their ability to correctly evaluate water supplies as a source of microbiological disease.

Techniques are available that can identify and enumerate most of the common types of pathogens in water. They have been employed in research on the occurrence and survival of those organisms and in studies conducted during outbreaks of water-related diseases. However, direct identification of pathogens is not used routinely because it involves many technical difficulties and because there are alternatives better suited to evaluation of the risk.

There is no single procedure to test for presence of pathogens. Each type of pathogen must be studied separately, using different laboratory techniques. Most of the available techniques are reliable only for grossly contaminated waters in which pathogen populations are high. Finding and enumerating the pathogens in a typical finished water supply is much more difficult, very costly, and quite unreliable.

Further, direct enumeration of pathogens is only capable of evaluating risk in samples actually containing the pathogens in question. It is highly desirable for risk evaluation to go beyond merely enumerating pathogens when they happen to be present—which would be rare in potable water—to provide a measure of the probability that pathogens might be present in that water supply on other occasions. Fecal contaminated water often may contain few or no pathogens simply because an active case of the disease may not be a contributor to the contaminating material at that time. Although the absence of pathogens would infer that the sample of water tested is safe, clearly the risk could increase quickly upon addition of a carrier to the contributing population. In summary, then, direct enumeration of pathogens is not useful to assess the safety of drinking water.

These limitations in attempting to evaluate public health safety of water through direct enumeration of pathogens have caused the water supply field to use "indicator organisms" instead. Indicator organisms do not have a direct relationship to the numbers of pathogens present in a water sample but are useful for assessing the degree to which that water may be polluted by fecal contamination from humans and other warm-blooded animals. Instead of attempting to determine the risk of contracting a specific disease through consuming the water, this test provides a measure of opportunity for transmitting *any type* of water-carried disease that might result from fecal contamination.

While there is no perfect indicator organism, effective indicators have been found. Basically, this is the "coliform count" referred to earlier. The organisms most commonly used as indicators of pollution are *E. coli* and the coliform group as a whole.

In 1884, studies by Escherich established that huge populations of certain specific bacteria were present in the intestinal tracts of humans and other warm-blooded animals. Subsequently, it was recognized that presence of those organisms (*Escherichia coli* or *E. coli*) in water may be regarded as evidence that the water has been contaminated with excreta. The total "coliform group" of bacteria includes *Escherichia coli* as well as numerous other bacteria originating in fecal discharges *and from many non-fecal sources*, as well.

For over 70 years, the coliform group has been employed widely to evaluate sanitary quality of drinking water. It should be emphasized that the rationale behind using this group of bacteria as "indicators" is not based on their potential for causing disease, although under some circumstances certain coliforms may cause infections. They are valuable as indicators simply because large numbers are present in fecal discharges and their numbers in a water sample show the extent of pollution by those discharges. Presence of the coliform group does not establish that pathogens are necessarily in the water. Their presence indicates contamination of the water with fecal matter which is a proven source for pathogens.

The total coliform group possesses some serious limitations. For example, the group includes many types of bacteria that may not originate in the intestinal tract of man and which have little or no relationship to the potential for presence of pathogens from that source. Also, many non-fecal coliform organisms are capable of multiplying under conditions present in streams or water treatment facilities. This can result in very high populations of coliforms having little or no sanitary significance because pathogens do not multiply under those same environmental conditions. Further, there are two accepted procedures for obtaining coliform counts: the MPN (Most Probable Number) and MFC (Membrane Filter tests). Each yields different results. Finally, coliform growth may be suppressed by high populations of other organisms.

Despite these limitations, the total coliform group remains the preferred indicator because of its origin, ease of detection and enumeration, survival characteristics, and long history of practical usefulness. Fecal coliforms (fecal bacteria and streptococci) are a subgroup of the total coliforms. Since they include organisms more likely to have originated in the intestinal tract, they represent better evidence of fecal contamination. However, testing for this subgroup has not been used much for evaluating the quality of drinking water because the total coliform group has proven more reliable for evaluating the adequacy of water treatment. Fecal streptococci have been used occasionally in stream pollution control investigations but have not been useful in evaluating the microbiological quality of finished drinking water supplies. Other organisms—for example, Clostridium and some Salmonella species—have been tried and found unsatisfactory. In short, although alternatives have been proposed and even used from time to time, no organism or group has yet been found that is clearly better than the total coliform group.

The 1971 WHO standards endorse *E. coli* and the coliform group as acceptable indicators of bacterial water quality, the presence of these organisms being sufficient grounds for condemnation of a water supply. They accept either the Most Probable Number or Membrane Filter tests as detection methods when they are properly conducted. With these procedural standards, WHO suggests the following substantive limits:

> **2.3 Standards of Bacterial Quality Applicable to Supplies of Drinking-Water**
>
> **2.3.1 Piped supplies**
>
> **2.3.1.1 Water entering the distribution system**
>
> (a) **Chlorinated or otherwise disinfected supplies.** Efficient treatment, culminating in chlorination or some other form of disinfection, should yield a water free from any coliform oganisms, however polluted the original raw water may have been. In practice this means that it should not be possible to demonstrate the presence of coliform organisms in any sample of 100 ml. A sample of the water entering the distribution system that does not conform to this standard calls for an immediate investigation into both the efficacy of the purification process and the method of sampling. It is important, however, in testing chlorinated waters, that presumptive positive tubes should always be subjected to appropriate confirmatory tests.
>
> (b) **Non-disinfected supplies.** Where supplies of this sort exist, no water entering the distribution system should be considered

satisfactory if it yields *E. coli* in 10 ml. If *E. coli* is absent, the presence of not more than 3 coliform organisms per 100 ml may be tolerated in occasional samples from established non-disinfected piped supplies, provided that they have been regularly and frequently tested and that the catchment area and storage conditions are found to be satisfactory. If repeated samples show the presence of coliform organisms, steps should then be taken to discover and, if possible, remove the source of the pollution. If the number of coliform organisms increases to more than 3 per 100 ml, the supply should be considered unsuitable for use without disinfection.

2.3.1.2 Water in the distribution system

Ideally, all samples taken from the distribution system, including consumers' premises, should be free from coliform organisms. In practice, this standard is not always attainable, and the following standard for water collected in the distribution system is therefore recommended:

(1) Throughout any year, 95% of samples should not contain any coliform organisms in 100 ml.
(2) No sample should contain *E. coli* in 100 ml.
(3) No sample should contain more than 10 coliform organisms per 100 ml.
(4) Coliform organisms should not be detectable in 100 ml of any two consecutive samples.

If any coliform organisms are found the minimum action required is immediate resampling. The repeated finding of 1 to 10 coliform organisms in 100 ml, or the appearance of higher numbers in individual samples suggests that undesirable material is gaining access to the water and measures should at once be taken to discover and remove the source of the pollution.

The presence of any coliform organisms in a piped supply should always give rise to concern, but the measures—apart from the taking of further samples—that may be considered advisable in order to safeguard the purity of the water supplied to consumers will depend on local conditions.

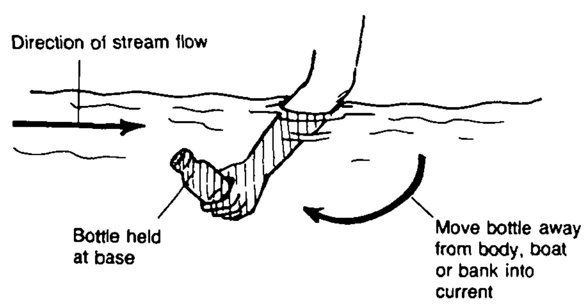
The degree of contamination may be so great that action should be taken without delay, even before the result of the examination of a repeat sample is known. This is a matter for decision by those who know the local circumstances and who are responsible for safeguarding the health of the community.

2.3.2 Individual or small community supplies

Where it is economically impracticable to supply water to the consumers through a piped distribution network and where reliance has to be placed on individual wells, bores, and springs, the standard outlined above may not be attainable. Such a standard should, however, be aimed at and everything possible should be done to prevent pollution of the water. By relatively simple measures, such as the removal of obvious sources of contamination from the catchment area and by attention to the coping, lining, and covering, it should be possible to reduce the coliform count of water from even a shallow well to less than 10 per 100 ml. Persistent failure to achieve this, particularly if *E. coli* is repeatedly found, should, as a general rule, lead to condemnation of the supply.

Evaluating Chemical and Physical Properties

Although the greatest threats to human health in drinking water are bacteriological, the chemical and physical properties of water are also significant. Many chemical substances are toxic, and physical characteristics may lower the acceptability of water for domestic use by affecting its taste, odor, or appearance. Where possible, chemical and physical properties of water should be evaluated through laboratory analysis and sanitary surveys. Such examinations are conducted much less frequently than those for biological disease—perhaps once a year rather than once a month (or even every day, depending on the size of the population involved).



Taking a Sample from Stream or Lake

Toxic Chemical Substances

A number of potentially harmful chemical substances enter the human body as it comes into normal contact with the environment. If they are also present in certain concentrations in drinking water, they are a danger to health. How great a danger depends upon the amount of water ingested, body weight, and amount of the substance obtained from sources other than drinking water. Assuming an average daily intake of water of 2.5 liters by a man weighing 70 kilograms, WHO's 1971 standards propose the following limits*:

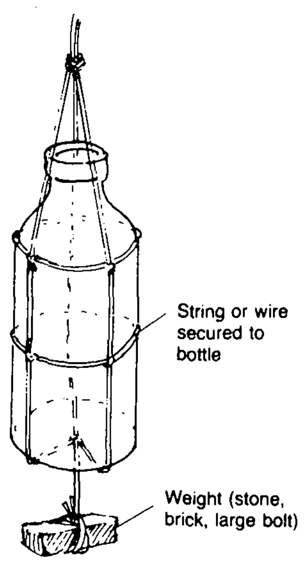
Table 5. Tentative Limits for Toxic Substances in Drinking Water

Substance	*Upper limit of concentration*
Arsenic (as As)	0.05 mg/l
Cadmium (as Cd)	0.01 mg/l
Cyanide (as CN)	0.05 mg/l
Lead (as Pb)	0.1 mg/l
Mercury (total as Hg)	0.001 mg/l
Selenium (as Se)	0.01 mg/l

*mg/l equals milligrams per liter

Other Chemical Substances

Contamination of ground or surface water with pesticides (a term that includes insecticides, herbicides, and fungicides) may be the result of intentional application (for example, weed or insect control programs), industrial pollution, or agricultural runoff. Although pesticides in water supplies generally make only a small contribution to the total daily intake for particular populations, they can create health problems. For this reason, WHO and the Food and Agriculture Organization keep pesticides under constant review, and there is at least one center in each country or region that can carry out investigations into pesticide residues in drinking water.



Weighted Bottle for Well Samples

Fluorides occur naturally in many public water supplies and are also found in foods. The average daily intake of fluoride may thus be substantial for some people. Fluorides may be beneficial (they prevent cavities in the teeth of children, for example) and, in the United States and Latin America, are typically added to drinking water when naturally absent. If ingested in excessive amounts, however, fluorides cause discoloration of teeth and even certain bone damage in children and adults.

WHO's 1971 fluoride limits, adapted from USPHS drinking water standards, are as follows:

Table 6. Recommended Control Limits for Fluorides in Drinking Water

Annual average of maximum daily air temperature in °C	*Recommended control limits for fluorides (as F) in mg/l*	
	Lower	*Upper*
10.0–12.0	0.9	1.7
12.1–14.6	0.8	1.5
14.7–17.6	0.8	1.3
17.7–21.4	0.7	1.2
21.5–26.2	0.7	1.0
26.3–32.6	0.6	0.8

Nitrates

Nitrates, if they are present in drinking water at concentrations higher than 45 mg/l, may be a health hazard to infants and possibly older children. Nitrates may cause methemoglobinemia, a blood disease. If a water supply contains nitrates higher than the recommended limits, an alternate source of drinking water for infants should be used.

Physical and Aesthetic Characteristics

Water supplies may have many chemical-related characteristics that are not linked directly to health in the same way that arsenic or nitrates are. However, they are linked indirectly because by affecting taste, odor, and appearance, they help determine whether people are willing to use the water. People may shun a water supply that is safe in favor of a source that is bacterially contaminated if the former is smoky in color (turbid) or fishy in smell and the latter is not. These "aesthetic" properties of water may be considered more important than health-related factors. For this reason, drinking water standards commonly include tests for these characteristics. The WHO 1971 standards are shown in Table 7.

The Application of Drinking Water Standards

Problems associated with the adoption and application of recognized water quality standards are, to some extent, caused by failure to understand what purposes standards serve and how they should be used. Standards are too often allowed to substitute for common sense and judgment. If these two ingredients are not left out of the mix, standards can play a useful role in public health protection.

A more legitimate concern is economic in nature. Poor nations fear that they will not be able to afford the laboratory tests and field surveys involved, and it is true that the total package of standards, controls, infrastructure, and equipment for an effective program can be expensive. Nevertheless, the usefulness of good bacteriological testing of water at all stages of its collection, storage, treatment and delivery is so great in assuring the quality of the consumed water that prudent but strong efforts should be made in the development of national or regional safe water programs to provide for bacteriological testing of water samples within the WHO quality standards for sampling and handling. In practical terms, this means providing bacteriological laboratories with the capability of doing total coliform and *E. coli* standard counts that are so located in relation to the systems being tested that tests can be begun within 24 hours after the samples are drawn. With such minimum laboratories in place, it should be possible for even the poorest country to increasingly enforce bacteriologically safe water standards.

Judgmental Factors

A review of the standards adopted by 18 countries and of the 1971 WHO recommended standards reveals a remarkable uniformity. Although differences occur in maximum permissible concentartions of a number of the chemical, physical, and bacterial limits, these differences are usually not large because most are based on WHO standards. With respect to bacteriological standards and quality, it is noteworthy that there is total agreement on use of coliform organisms and Most Probable Number or Membrane Filter counts as indicators of contamination of public health significance. In contrast, a wide spectrum of practice exists in the use and application of the standards. Many countries adopt WHO standards but fail to enforce them.

While there appears to be general recognition that standards serve a useful purpose, whether as goals or design specifications, people of differing disciplines have in the past frequently been critical of specific standards. A review of the standards and of the prob-

Table 7. Substances and Characteristics Affecting the Acceptability of Water for Domestic Use

Substance or characteristic	*Undesirable effect that may be produced*	*Highest desirable level*	*Maximum permissible level*
Substances causing discoloration	Discoloration	5 units*	50 units*
Substances causing odours	Odours	Unobjectionable	Unobjectionable
Substances causing tastes	Tastes	Unobjectionable	Unobjectionable
Suspended matter	Turbidity; possibly gastrointestinal irritation	5 units**	25 units**
Total solids	Taste; gastrointestinal irritation	500 mg/l	1500 mg/l
pH range	Taste; corrosion	7.0 to 8.5	6.5 to 9.2
Anionic detergents***	Taste and foaming	0.2 mg/l	1.0 mg/l
Mineral oil	Taste and odour after chlorination	0.01 mg/l	0.30 mg/l
Phenolic compounds (as phenol)	Taste, particularly in chlorinated water	0.001 mg/l	0.002 mg/l
Total hardness	Excessive scale formation	2mEq*'** (100 mg/l $CaCo^2$)	10mEq/l (500 mg/l $CaCo_2$)
Calcium (as Ca)	Excessive scale formation	75 mg/l	200 mg/l
Chloride (as Cl)	Taste; corrosion in hot-water systems	200 mg/l	600 mg/l
Copper (as Cu)	Astringent taste; discoloration and corrosion of pipes, fittings and utensils	0.05 mg/l	1.5 mg/l
Iron (total as Fe)	Taste; discoloration; deposits and growth of iron bacteria; turbidity	0.1 mg/l	1.0 mg/l
Magnesium (as Mg)	Hardness; taste; gastrointestinal irritation in the presence of sulfate	Not more than 30 mg/l if there are 250 mg/l of sulfate; if there is less sulfate, magnesium up to 150 mg/l may be allowed	150 mg/l
Manganese (as Mn)	Taste; discoloration; deposits in pipes; turbidity	0.05 mg/l	0.5 mg/l
Sulfate (as So_4)	Gastrointestinal irritation when magnesium or sodium are present	200 mg/l	400 mg/l
Zinc (as Zn)	Astringent taste; opalescence and sand-like deposits	5.0 mg/l	15 mg/l

*On the platinum-cobalt scale.
**Turbidity units.
***Different reference substances are used in different countries.
Source: *International Standards for Drinking Water*, World Health Organization, Geneva, 1971.

lems which motivated the criticisms reveals, among other things, that most of the trouble has occurred over bacteriological standards. Chemical standards have appeared to draw criticism only from those unable to distinguish between standards for toxic substances and those for such qualities as corrosiveness, hardness, and other characteristics having little to do with health.

Additional criticisms involve urban and rural application of standards. There seem to have been few challenges of the accepted standards (such as those proposed by WHO) in application to large urban water systems. The number of problems increases as the size of the systems decreases. It can be said with reasonable certainty that the problems of applying drinking water standards are essentially the problems of rural water supply quality. This does not mean that there have been *no* problems associated with application of the standards to large urban systems, only that urban problems can be more easily solved because of the greater resources available. The difficulty of applying broad policies and standards to numerous small systems makes the problem more complicated. It is here that judgment and technical competence in the interpretation of field and laboratory data is most important.

Economically, it is usually less expensive to make water bacteriologically safe to drink than to meet some of the chemical and physical standards, especially those concerning toxic substances. Fortunately, in most areas, the task is one of taking the present sources and, through construction and protection, making them capable of meeting the bacteriological standards without chemically altering a water which the people already are accustomed to drinking. In other words, prudent use of the standards means an emphasis on the important standards and a downgrading of those standards which are of no health significance. This assumes, of course, that the chemical levels are not toxic.

Cost Factors

The question is sometimes asked whether it would not be better to employ less strict standards and to use the savings to provide water to more people, to increase convenient access to the supply, or to expand the quantity available. The implication is that construction of supplies which produce water meeting the WHO or other recognized standards will increase costs substantially over those for less refined systems. Unfortunately, those who raise the question seldom indicate whether they would use another standard (e.g., one which permits twice as many coliform organisms, or twice as much arsenic, or three times as much nitrate) or none at all.

As noted, compliance with bacteriological standards is usually much easier and much less costly than meeting chemical and physical standards. Where all available sources of water nearby contain levels of toxic substances in excess of the standards, compliance will usually be costly, requiring extensive treatment or transportation. Fortunately, there are not too many areas of the world where such problems arise, although these do include portions of Argentina, Chile, Yemen, and Tanzania. In these areas, problems will have to be considered on a case by case basis, taking into account alternative sources, epidemiological evidence, and other factors.

Meeting most bacteriological standards should usually require no greater investment than that necessary to make the water simply accessible and palatable. In a few instances, it may involve the additional capital, operation, and maintenance costs of chlorination; in a few others, the costs of filtration.

Where ground water is available, it is almost always the best source of supply for rural areas. In most countries, properly located, constructed (i.e., protected), and maintained wells which are deeper than 4m and which take water from consolidated aquifers will provide water which, with few exceptions, will meet the strictest of bacteriological standards without need for chlorination or further treatment. Where wells and springs can be protected and made tight, reliance can be placed on good maintenance to yield water of high bacteriological quality. Routine laboratory testing or further treatment will normally not be required, and costs need be no greater than if no standards were to be met.

In rural areas where surface water is the only available source, some form of treatment will be necessary to meet safety standards. Treatment must include making the water acceptable for drinking by the people and should also include making it safe. The cost of doing both will usually be little more than for one. Depending on raw water characteristics, treatment to make surface water suitable for drinking can range from simple settling to chemical precipitation and filtration for reduction of turbidity. It may sometimes also include taste and odor removal and reduction of iron and manganese. Each of these processes directly concerns acceptability of the water for drinking. Some will affect usage. Where these capital and operation costs have been accepted, the cost of adding chlorination to any one of these steps required to make the water palatable involves such a small additional investment that it is usually insignificant.

In cases where the costs of meeting standards are high, questions of alternative uses of the resources are unavoidable. But even in those cases, the questions frequently arise from the misapplication of standards rather than from standards *per se*. Common sense indicates that condemning a *protected* well on the basis of a single sample showing 10 coliforms/100 ml is inappropriate, and that even where that level is consistently observed through an adequate sampling program, prohibition may drive users to *unprotected* and clearly contaminated sources. Water quality standards are a means to better health, not an end in themselves.

SOURCES
CHAPTER THREE

A basic reference was *Water Supply and Sanitation for the Decade (1980-1990): A Panel Report*, Washington: Agency for International Development, July 1979. This was used for discussions of the historical development and application of water quality standards. Current international standards, including tables, are drawn from *International Standards for Drinking Water*, 3rd ed., Geneva: World Health Organization, 1971. The discussion of indicator organisms is adapted from materials prepared for the AID Knowledge Synthesis Project. The table showing possible percentage disease reduction from water improvements is taken from Feachem, *Water, Wastes, and Health in Hot Climates*.

PART TWO. WATER SUPPLY AND WASTE DISPOSAL SYSTEMS

CHAPTER FOUR: WATER SUPPLY SYSTEMS
CHAPTER FIVE: WASTE DISPOSAL SYSTEMS

Part One described the relationship between water supply, sanitation, and health in developing countries, surveyed the principal water-related diseases found in those countries, and encouraged the establishment and use of sensible water quality standards as a means of preventing disease. The central theme of Part One is that improvements in water supply and sanitation facilities are necessary to create a better health situation in the Third World.

Part Two describes the nature of the improvements that can be made. Chapter Four gives details regarding the technology of water supply systems; Chapter Five does the same for waste disposal methods. The central theme of both chapters is the application of technology that is appropriate and available to developing nations at relatively low cost.

Improved water supply facilities include simple systems like this one.

CHAPTER FOUR
WATER SUPPLY SYSTEMS

SUMMARY

Although water has many beneficial uses, the domestic uses — drinking, cooking, cleaning, and bathing — are especially important because of their relationship to disease and health. Improvements in water supply generally occur through changes in the source of water and in the means of distribution to the users.

The technical steps involved in bringing water from its natural state to the user in acceptable quality and quantity are:

Step 1. Identifying a Water Source. Sources are either surface water or ground water.

Step 2. Retrieving the Water. This refers to the means used to retrieve the water from its source and bring it into the distribution system. Wells and intake structures are examples of retrieval methods. Retrieval also includes devices for moving the water, such as windmills and pumps.

Step 3. Treating the Water. This may not be necessary if there are no harmful contaminants in the water. If there are such contaminants, there are a number of treatment technologies available for dealing with them.

Step 4. Storing and Distributing the Water. Water may be distributed directly from the source without storage. Since people do not use water at a constant rate, however, it is usually better to have a means for storing water in quantity so that high-demand periods may be accommodated.

Rings to cap wells and other parts of water supply systems may be constructed locally.

CHAPTER FOUR
WATER SUPPLY SYSTEMS

The value of water lies in the ability of people to use it for beneficial purposes and, throughout history, people have been ingenious in devising ways to benefit from water as shown in Table 8. They use it *in place* for the propagation of marine life, for commercial navigation, for recreational pursuits and for its scenic value; they use the *flow* of water to produce hydroelectric power or to dispose of wastes; they *withdraw* water from the source to water their livestock, irrigate their fields, and operate their factories. And, individually or as groups, they withdraw water for domestic use—drinking, washing clothes, bathing, cleaning, and excreta disposal.

Here we are concerned with water for domestic use, because it is this use that is most directly related to human health. People can make personal use of water in its natural state—they can drink from lakes and bathe in streams. But much of the world's water is underground and not readily accessible, and the water that is on the surface is often neither safe nor conveniently located. Thus water often is unavailable for domestic and personal use without water supply systems.

An Overview of Water Supply Systems

In its simplest terms, a "water supply system" is a water source and a means of getting the water to the user. If a person walks a considerable distance to a stream, fills a jug with water, and returns home, this is a water supply system. If, in a city, water is pumped mechanically from a deep well, stored in a large tank, treated in an expensive plant, and distributed through pipes to kitchens and bathrooms in homes throughout the area, this is a water supply system. Improvements in water supply systems are made from a baseline defined essentially by the source of water and the means of distribution to the user. With the source, the important concerns are the quality and quantity of the water; with the means of distribution, the main considerations are protection from contamination and convenience to the user. Both are important from a health standpoint. If the water source is contaminated and the water is not treated, disease may result. Or if there is no storage and the quantity at any given time is not adequate, there may not be water for necessary washing. Whatever the quality and quantity of water, if it cannot be retrieved and protected, or if access to it is inconvenient, it may not be used and, again, water-related disease may be the result.

Table 8. Beneficial Uses of Water

Reason for Use	*Method of Use*		
	Withdrawal	In Place	Use of Flow
Water Supply			
Domestic (personal)	X		
Industrial	X		
Irrigation	X		
Stock and Wildlife	X		
Propagation of Marine Life			
Fish		X	
Shellfish		X	
Others		X	
Recreation			
Swimming		X	
Pleasure Boating		X	
Sport Fishing		X	
Other Water Sports		X	
Commercial Navigation		X	
Hydroelectric Power Production			X
Scenic Values		X	
Wastes Disposal			X

As Figure 2 shows, there can be a variety of water supply systems based on type of source and means of distribution, ranging from least desirable to most desirable from a health standpoint. In System 1, the source is "unimproved," i.e., highly susceptible to germ contamination. It may be a pond where schistosomiasis lurks, or it may be a step well containing Guinea worm larvae. Likewise, the distribution is inconvenient since each household must obtain the water directly from the source. Time is lost from other work and the water carrier may be exposed to water site diseases, such as trypanosomiasis.

In System 2, although water must still be carried to the household, the water source has at least been improved. This may be a natural spring that has been protected from surface contamination or a dug well with a handpump. In System 3, the means of distribution has also been improved. A small pipeline now runs out from the water source. Household carriers need not go as far to water because they only walk to a tap on the pipeline, not to the source itself.

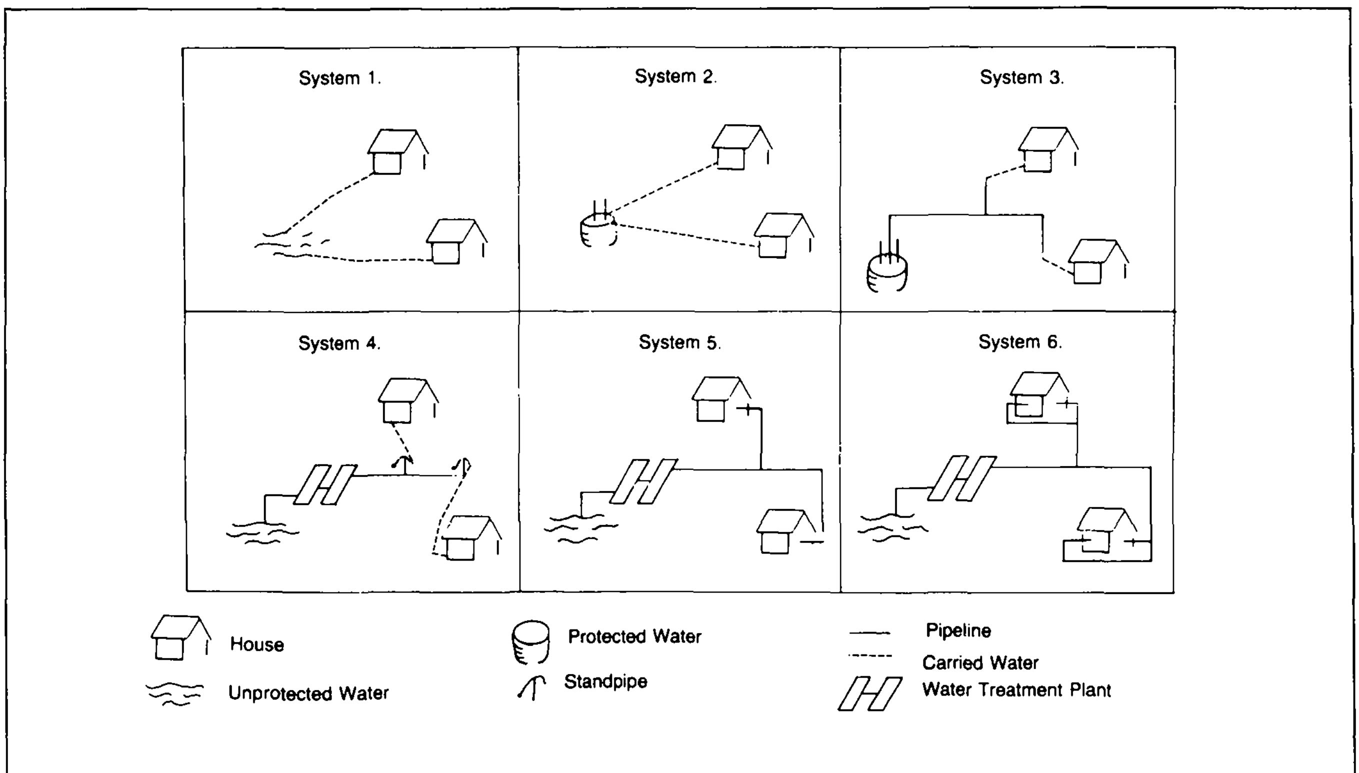
While Systems 1-3 assume a scattered population, System 4 assumes at least a cluster of households or a village setting. There is piped distribution to a central place from which all nearby households obtain water. In System 5, there is even better distribution because an outlet for water has been provided for each household. In this case, the water source has been further improved by the addition of a treatment facility. In System 6, the most desirable situation, there is an improved source and a treatment facility, and water is piped into each household, possibly to several taps.

In developing nations, the prevailing situation is still often System 1. Any improvement beyond that is desirable. The move to System 6 may well be too costly for many communities, and some intermediate stage will have to be accepted. A typical developing nation will have populations involved in all six situations. The announced goal of the International Decade for Water—universal access to safe drinking water by 1990—might be achieved if all people at least had System 2 by the year indicated. Many nations will probably want to do better than that.

The total activity necessary to move communities beyond System 1 may be described as a development process. The process typically includes an assessment of needs, usually in terms of existing facilities and the likely impacts of improved facilities and a strategy for meeting the needs; some type of community organization or other community involvement; arrangements for financing the facilities, including a plan for user charges for service; and the design, installation, operation and maintenance of the facilities themselves.

The first three elements of the development process—planning, community participation, and financing—are discussed in Part Three. The design, installation, operation and maintenance of water and waste disposal systems are the concern of this and the following chapter. As for water systems, their development occurs in four steps, each step representing a stage in applying technology to bring water from its natural state to the user in acceptable quantity and quality. The four steps are:

Figure 2. Water Supply Systems Based on Source and Distribution Method



Step 1. Identifying a Water Source. Sources are surface water and ground water.

Step 2. Retrieving the Water. The term "source development" also describes this step. It refers to the means used to retrieve the water from its source and bring it into the distribution system. Wells and intake structures are examples of retrieval means. Retrieval includes devices for actually moving the water, such as windmills, hand and electric pumps.

Step 3. Treating the Water. This may not be necessary if there are no harmful contaminants in the water. Frequently, there are such contaminants. Various technologies can deal with them.

Step 4. Storing and Distributing the Water. Water may be distributed directly from the source without storage. Since people do not use water at a constant rate, however, it is usually better to have a means for storing water in quantity so that high-demand periods may be accommodated. Storage is usually needed in sytems that must treat the water.

After water facilities have been installed, they must be operated and maintained if they are to perform reliably. Depending on the design, there may be tasks associated with the normal operation of the system, such as the addition of a chemical treatment agent on a periodic basis. Some maintenance tasks may be routine, such as the cleaning of a filter. In addition, all but the most primitive systems require repairs from time to time. The importance of this aspect of a water supply system should never be overlooked.

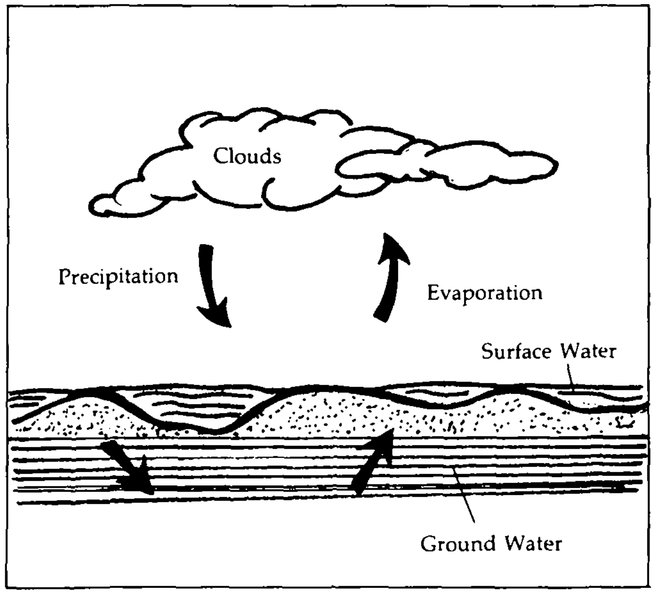
The operation and maintenance function relates to each aspect of the development process. It must be a part of planning because the human resource requirements of the system must be considered. It must be taken into account in financing because the cheapest system to install may not be the cheapest to maintain. It may be part of community participation because community residents may have to operate the system. It is, of course, a part of design because ease of operation and maintenance is a factor in the choice of all system components.

With this overview, the remainder of this chapter describes the basic technology of water systems. The discussion is organized by the steps in system development described above, concluding with a section on operation and maintenance.

Identifying a Water Source

There is enough water on the planet to meet all reasonable human needs for the foreseeable future. The Earth does not appear to be "drying up" by any natural process. However, water is not distributed evenly, either on the surface or beneath it. Africa, for example, includes both arid deserts and dripping rain forests. In addition, the things that people do in the conduct of their lives—irrigating crops, operating factories, building cities, maintaining livestock, installing plumbing—all have a tremendous impact on the available water. Any nation undertaking a plan for providing its citizens with safe water must first answer the question, "Where will we get the water?" To answer the question it is necessary to understand something of the sources of water in general and of the factors to consider in identifying specific sources.

Figure 3. The Hydrologic Cycle



The Hydrologic Cycle

The water of the earth is constantly moving and changing forms in a process known as the hydrologic cycle. The total quantity of water available at the earth's surface at any given time is substantially constant. Although minor amounts are contributed from volcanic sources, most of the available water is in constant circulation through three layers:

- the lithosphere (the crust of the earth)
- the hydrosphere (oceans and other bodies of surface water)
- the atmosphere (the air above the earth)

Huge quantities of water are temporarily removed from circulation because they are buried in sedimentary deposits or frozen as ice. (In fact, about 80 percent of the earth's total fresh water supply is in the form of ice.) The remainder is subject to evaporation, which may be taken as a beginning point in the cycle.

Approximately 95,000 cubic miles of water evaporate from the earth's surface to the atmosphere annually. The exact amount varies according to local temperature and wind conditions. Much of this evaporation forms clouds and returns to the ocean in the form of rain, snow, sleet, or fog. Other clouds, driven by regional wind patterns, move overland and precipitate on the land surface. Part of the precipitation evaporates directly back into the atmosphere, forming one of the many short-circuits in the hydrologic cycle.

Water falling on the surface of the earth can take several possible routes:

(1) It may evaporate directly. Some falling water collects on soil or vegetation from which it directly evaporates. For example, when the sun bursts out after a heavy rain, wet leaves will rapidly lose their moisture to the atmosphere.

(2) It may temporarily become surface water. Some water falls directly or flows overland into surface depressions, thus changing for the moment the volume of water stored on the surface. This is called surface water. Some of this water will be returned to the atmosphere through evaporation; the remainder eventually flows back into oceans where yet more evaporation may occur.

(3) It may become ground water. Much of the water falling to the surface penetrates the earth's upper soils, which are porous. The water then slowly works its way down to the lowest possible level, filling the tiny openings in the earth (pore spaces) and the cavities in rocks. This is ground water. The level below which all of the pore spaces are filled with water is known as the water table. The water is contained in "underground rivers" called aquifers.

The evaporation process does not end when the water enters the ground. Some of the water penetrating the earth is intercepted as it moves downward toward the water table and is brought back to the surface, where it evaporates, by a natural process called capillary action. Other water is intercepted by plants, which use some water to sustain themselves and pass the remainder back to the atmosphere through their leaves (transpiration). There is, of course, great variation in the amount of water used by plants and in the depth of the soil from which they draw water. Type of plant life thus has an important impact on water supply. Through all phases of the hydrologic cycle, water quality changes. As water evaporates from the ocean, fresh water lakes, streams and ponds, or as it is transpired into the atmosphere by plants, it is very pure. As it enters the atmosphere, it comes into contact with very fine-grained matter. This "particulate" matter may be natural (volcanic dust, salt crystals) or man-made (fly ash, smoke) and is instrumental in the formation of rain droplets or ice and snow. As a consequence of this atmospheric contact with particulate matter, precipitation, whether in the form of rain, ice, or snow, acquires minor quantities of chemical impurities.

As ground water moves through rock and soil materials, it becomes enriched in the various elements dissolved from the decomposing materials. The water tends to increase most commonly in hardness, alkalinity, carbonates, sulfates, chlorides, iron, and manganese. Water discharging from the ground into intersecting streams ultimately returns to the sea. The load of dissolved constituents, as well as the suspended load of clays and silt, is deposited in the sea and remains there as the water continues in the cycle.

Some water is stored underground and must be reached with a well (above) while some emerges naturally through springs (below).

Also, whether water is on the surface or in the ground, it may acquire man-made chemical or biological impurities.

In sum, the paths followed by water in the hydrologic cycle determine not only the quantity of water in a given place but also its quality. These paths also provide us with the most basic classification for water sources: surface water and ground water. Surface water consists primarily of flowing (rivers and other streams) and essentially non-flowing (lakes and ponds) bodies of water, but it also includes rainfall itself and springs. A spring is found where ground water naturally discharges to the surface.

Surface Water Sources

Streams may be either intermittent (they stop flowing during dry seasons) or perennial. Streams that depend entirely on direct runoff of rainfall for their source of supply will be dry when where is no rainfall. Streams that receive a significant portion of their flow from ground water, in the form of seepage along the course of the stream bed, or from springs, have much more reliable flow during periods of dry weather.

Where a stream is in contact with an underlying aquifer, composed of sand and gravel, limestone, or sandstone, there is direct exchange in the form of discharge or recharge between the stream and the aquifer. At the end of an extended dry period, groundwater levels in the aquifer will be low, with much of the shallow storage in the aquifer depleted. Water levels in the stream, rising in response to rainfall, will be higher than those in the ground and the stream will lose water into the aquifer, refill it, and replace the storage that was lost during the dry season.

During dry seasons where there is little or no precipitation to sustain streamflow, the water level of streams is often lower than the water level of the surrounding aquifer. In this case, ground water from the surrounding aquifer discharges into the stream, sustaining a low flow through the dry season. When small or intermediate-sized streams normally flow through the dry season, they probably are sustained by groundwater recharge.

Because the ultimate source of all water is precipitation—whether in the form of rain, frost, sleet, or snow—the character and quantity of water available for runoff into streams is controlled by climatic and physiographic factors. Significant among the climatic factors are:

- Precipitation: Form, intensity, duration, areal distribution, seasonal distribution, and frequency;
- Evaporation: Temperature, wind, surface area;
- Interception: Type of vegetation, density of vegetation;
- Transpiration: Type of vegetation, soil moisture, humidity, wind, duration and intensity of sunlight.

Among the physiographic factors are:

- Size, shape, gradients of the drainage basin;
- Soil moisture at time of precipitation, type of soils, land use and cover, permeability of soils, infiltration capacity of soils, groundwater levels;
- Stream channel geometry: cross section and longitudinal profile of stream, channel storage.

In choosing a surface water supply, it is usually the low-flow character of the spring or stream that is most important. If even limited information about climatic and physiographic factors is available, it is often possible to make valid, preliminary judgments about the low-flow reliability of a supply. For example, an area of steep slopes, impermeable soils, and small channel cross-sections receiving a few high-point intensity storms seasonally will probably be subject to flash-flooding and have no sustained dry-season flow. Conversely, an area of moderate slope, well-distributed rainfall, permeable soils, and broad stream channels can be expected to have a much more favorable low-flow characteristic. If the latter area is heavily covered with vegetation, the seasonal fluctuation of ground water may be affected.

Lakes are depressions containing water that were formed by natural and man-made activities. In determining whether or not a specific lake can be used as a water source, primary consideration must be given to the amount of water available from storage in the lake, the amount of water recharged to the lake seasonally or annually, and the quantity of water that is intended to be withdrawn from the lake annually and during peak demand periods. It is obvious that if annual recharge is less than annual discharge, the lake will eventually dry. For large lakes with great volumes of storage and large surface areas to intercept rainfall, withdrawals by small water-supply systems will have no significant impact. Smaller lakes, and particularly man-made catchments, must be carefully evaluated with regard to both their storage capacity and the total amount, rate, and variations in rate or recharge. Recharge can be in the form of direct precipitation, surface runoff into the lake, in-flowing streams, or ground water.

Another important factor in evaluating the yield of a lake or pond is the local rate of evaporation. Evaporation varies in proportion to the difference between the moisture content of the air at the surface of the body of water and the moisture content of the air above the body of water. Evaporation is affected by water and air temperature, wind, atmospheric pressure, configuration of the surface area, and water quality. Since all of these vary, the most reliable method of assessing evaporation in an unknown area is by field investigation using evaporation pans.

Rainfall, collected in cisterns, has been a source of water for human use for centuries. In the simplest form of rainfall catchment, runoff from a roof or other catchment area is channeled into a storage basin. The storage basin must be large enough to meet the demand for water through the dry season. Similarly, there must be sufficient annual rainfall to provide the runoff required to fill the storage basin.

Springs can be a very good source of water for a community supply. Generally, water from springs can be used without treatment if the source is adequately protected with a spring box. Not all water from springs is free from contamination. A sanitary survey of the spring site will help determine whether contamination is likely.

Sanitary Surveys of Surface Sources

A village interested in development of a community water supply may have several sources of surface water available to it. When a choice has to be made between sources, the quality of the water at the source and the quantity it produces must be considered. To determine water quality, a sanitary survey should be conducted.

As discussed in Chapter Three, a sanitary survey is a field evaluation of local health and environmental conditions. The goal of a sanitary survey is to detect all sources of existing and potential bacterial and chemical contamination and to determine the suitability of the source for a community water supply. Information should be gathered through observation of local conditions, through sampling and testing of water, and through interviews and conversations with local leaders, health officials, and residents. The following factors should be considered when doing the survey: (a) physical characteristics of the location which indicate potential contamination; (b) bacteriological quality of the water; and (c) physical and chemical qualities of the water.

A water source should be as free from bacteriological contamination as possible. The greatest and most widespread source of such contamination is human and animal feces and urine, or fecal contamination. A sanitary survey determines the degree to which water sources may be subject to harmful levels of fecal contamination. To find out if water actually contains fecal bacteria, it is necessary to take a water sample and have it analyzed.

By simple measures such as removing obvious sources of contamination from a catchment area, fecal contamination may be controlled and even eliminated. If contamination is not reduced by these means, then the water source should be considered unacceptable.

The chemical and physical quality of water is also important. The problem is that only *some* chemical and physical properties can be determined through a sanitary survey. Generally, complex laboratory testing is needed. In many rural areas, there is no laboratory for

Surface water is often collected in containers and carried home for use.

water testing, and a sanitary survey is the only way to determine the suitability of a water source. An important element, discussed in Chapter Three, of a national safe water program is the establishment and operation of testing laboratories that can serve even the rural areas.

In conducting the sanitary survey, bear in mind that 100 percent acceptable conditions will rarely be found. Human, animal, and farm waste will be a problem in many areas. Water sources with some threat of contamination may have to be used as an alternative to no water at all. However, a safe groundwater source may be available and the community should look in this direction whenever a sanitary survey reveals (and laboratory analysis, if available, confirms) that surface sources are of questionable quality.

Rivers and Lakes

A study of the characteristics of the watershed must be done to determine whether there are potential sources of contamination of surface water. The watershed is the area within which rainfall flows over the surface of the ground into rivers and lakes. An acceptable watershed should be as free from human and animal wastes as possible. An area with latrines, septic tanks or animals is not appropriate for a watershed feeding into a drinking water supply. Such an area is a source of fecal contamination which may make water unsafe to drink. A study of the watershed should also determine that streams entering ponds to be used as water sources are not so contaminated as to make the supply unfit for drinking. A contaminated stream flowing in the watershed could lead into the water supply and make the water unfit for drinking.

Ideally, the watershed should not be used for farming. In densely populated rural areas, this ideal is very difficult to attain so attention must be given to ground water or plans made to treat the surface water. On some farms, pesticides and fertilizers are used to increase crop production. Rainfall carries these elements from the fields into the water source and contaminates it. Also, if there are farms, erosion is likely to occur. The soil that enters the pond or lake will settle to the bottom and cause it to fill up rapidly. This reduces the amount of water available to the users and limits the life of the pond. A better site should be chosen, or trees and grass should be planted in the watershed to prevent soil from entering the water supply. Where an intake is located below an inhabited area, the water quality should not be trusted. If there are possible sources of contamination upstream, then water treatment will be necessary.

Direct Rainfall Catchment Systems

A sanitary survey can indicate potential sources of contamination in direct rainfall catchment systems, usually roof catchments. The first step in the sanitary survey is to determine the roofing material already in place. Tile and corrugated metal make the best collectors for drinking water. Water from thatched, tarred or lead roofs is likely to be very contaminated and very dirty. Catchment systems should not be installed where houses have roofs made from these materials, although this rule is frequently violated in developing nations. If possible, the roofing should be upgraded. Find out if a suitable cistern is available. The cistern should be clean, leak-proof and covered to protect the water quality.

Springs

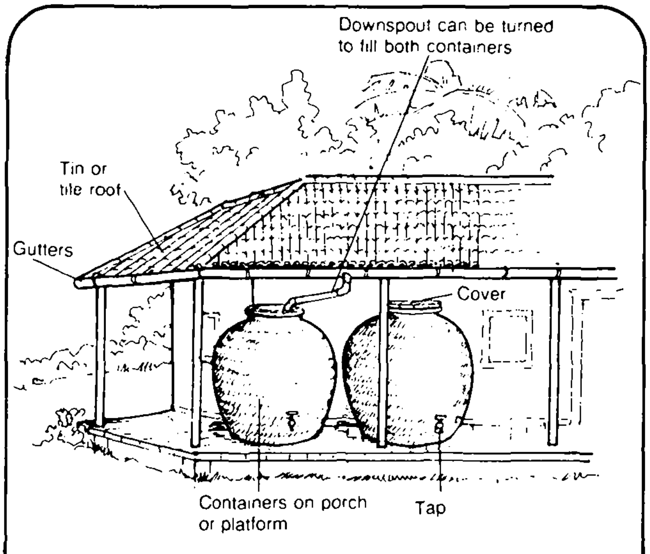
The first step in a sanitary survey of a spring site is to determine the physical conditions above the point where the water flows from the ground. If there are large openings or fissures in the bedrock above the spring, contamination of the spring from surface runoff may occur. Surface runoff enters the ground through the fissures and contaminates the spring water underground.

Find the true source of the spring. Many times, a small stream disappears into the ground through a fissure and emerges again at a lower elevation. What appears to be a spring actually may be surface water that has flowed underground for a short distance. The water is generally contaminated and may flow only during the wet season.

Determine if there are sources of potential fecal contamination. Livestock areas, privies, septic tanks and other sewage disposal sites are sources of contamination. If they are located above the source or closer than 100m to it, contamination may occur and disease-causing bacteria can enter the water.

The second step in the sanitary survey is to study the area at the spring site. The type of soil may indicate that contamination is likely. Filtration to remove germs may be poor if permeable soil deeper than 3m is within 15m of the spring. Water passes quickly through coarse soils and pathogens are not filtered out. If this condition exists, or if there is any suspicion of contamination, a water analysis must be done.

A spring flowing from limestone may also be subject to contamination. Earth movements create fissures and cracks in limestone allowing surface run-off to enter the ground rapidly with little or no filtration of impurities. If a spring flows from a limestone bed, check the water after a heavy rain. If it appears turbid, suspect surface contamination and either analyze the water or choose a better site.



Direct Rainfall Catchment Systems

Sanitary Surveys of Groundwater Sources

Water can be found almost anywhere under the earth's surface. However, ground water must maintain good quality and be capable of sustained flow over long periods to be an acceptable source. To locate adequate supplies of ground water in developing countries, experience and common sense must be combined with basic scientific knowledge and techniques. The interpretation of geologic data and the use of exploratory tools may require training of local people or the assistance of groundwater hydrologists from government and private organizations or universities. However, in most cases, groundwater volume, quality, and location can be determined with simple methods, if the evaluation is thorough.

Obtaining Ground Water Information

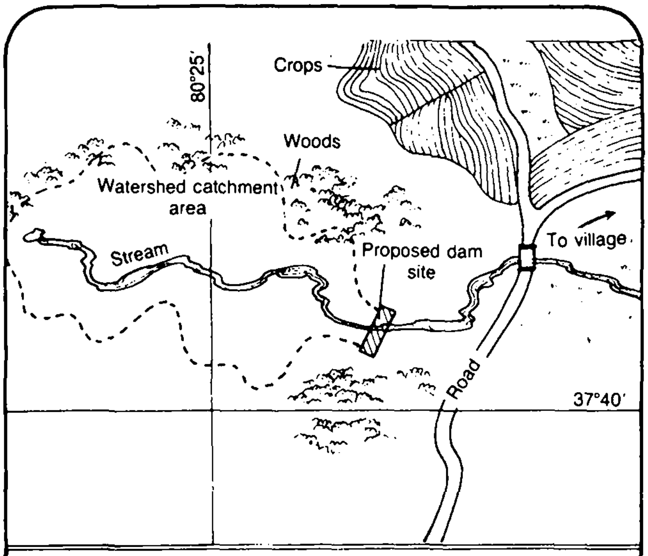
A survey of existing wells in the area is a good starting point in determining whether or not a groundwater supply is possible. Histories of existing wells will show how the water table has fluctuated in past years, and people can often recall the extent to which the water table dropped during extreme drought. A comparison of the amount of water being drawn from the wells with the recovery rate of the water table indicates the water-bearing potential of the aquifer.

A study of geological data, where available, can be helpful. Topographic maps can be used to mark precise locations of potential water well sites in the field and to construct land profiles and geological cross sections. By means of contours, the maps indicate the altitude of potential water well sites in relation to the altitude of nearby surface water bodies. Topographic maps also provide a wealth of information on surface features which have a considerable bearing on the occurrence of ground water.

Geologic maps show where rock formations outcrop on the land surface, and indicate their strike (the direction in which they lie) and their dip (the angle at which they are inclined to the horizontal). Other useful information shown includes the location of faults and contour lines, indicating depth to bedrock in the area. Faults are lines of fracture where rock formations are dislocated. The location and areal extent of aquifers can be determined from the type and location of rock outcrops and the location of faults. The width of the outcrop and the angle of dip indicate the approximate thickness of an aquifer and the depths to which it can be found. The combination of strike and dip indicates the direction of a potential well site that will penetrate the maximum thickness of the aquifer. The surface outcrops can be possible areas of recharge to an aquifer and may indicate the direction of ground water. The bedrock contours indicate the maximum depth to which a well should be drilled in search of water. Geologic cross-sections provide some of the main clues to groundwater conditions in an area. They indicate the character, thickness, and succession of underlying formations and, therefore, the depths and thicknesses of existing aquifers.

If maps and cross-sections of the area of interest are not available, aerial photographs can provide much information about the geologic and hydrologic setting of the area. This information includes: the probable thickness of water-table aquifers and sediment deposition; soil types; soil moisture; topography; hydrography (lakes, creeks, springs, both fossil and present); areas of groundwater discharge; type and density of vegetation; fracture traces; land use; man-made features such as dams and reservoirs; and farmsteads that may have water wells.

Well logs may not be available in developing nations. If they are, they should be used. A well log describes the location, elevations, diameter, and



Location Map for a Water System

depth of the well; depth, thickness, and description of rock formations penetrated; water level variations as successive strata are penetrated; yields from water-bearing formations penetrated and corresponding drawdown of the well upon completion.

Field Investigations

The nature and extent of the needed investigations in the field can be determined from the data accumulated during the preliminary investigation. If geologic maps are not available, it may be necessary to construct them from field observations. The scale of such maps depends on the scale of existing topographic maps, the size of the area of investigation, and the objective of the groundwater exploration.

Ground water is likely to occur in larger quantities under valleys than under hills. Valley fills containing weathered rock waste washed down from mountainsides are often found to be very productive aquifers. The material may have been deposited by streams or sheet floods, with some of the finer material getting into lakes to form stratified lake beds. Some of these deposits may have been transported by wind and redeposited as sand dunes. All these and other factors influence the rate at which the valley fill will yield water. Coastal terraces, formed by the sinking and rising of coastal areas relative to sea level in the geologic past, and coastal and river plains are other land forms that indicate the presence of good aquifers.

Any evidence of surface water, such as streams, springs, seeps, swamps, or lakes, is a good indication of the presence of some ground water, though not necessarily ground water of usable quality. The sand and gravel deposits found in river beds may often extend laterally into the river banks, which may be penetrated by shallow, highly productive wells.

The average flow of small streams often provides an indication of groundwater conditions. If a stream maintains a more or less uniform flow with no flash flooding and does not dry up in the dry season, the surrounding area may absorb water well. Where the earth absorbs water slowly, the runoff is usually heavy during rainfall, and because very little water is stored, low precipitation periods are marked by low flow or dry stream beds. Streamflow characteristics should be interpreted with caution, however, since other factors besides surface geology come into play. These factors include frequency, duration and intensity of precipitation, land use, vegetation, and topography.

Vegetation provides good clues to shallow groundwater occurrence. Areas of thick overgrowth generally contain streams and other surface waters and would be likely sites for shallow ground water.

Selecting the Water Source

The process of choosing a water source can be very complicated since it depends on many factors which vary widely from locality to locality. Among the considerations in selecting a water source are the following:

- Cultural acceptance
- Dependability
- Quantity and quality
- Cost
- Proximity to users
- Power requirements
- Availability of appropriate technology
- Operation and maintenance requirements
- Human resource and training requirements

While there are no absolute rules to be used in weighing these factors, there is one general principle that can be followed. If it is assumed that keeping costs low is a primary consideration, ground water from wells and water from protected springs are preferable to surface water sources such as rivers and lakes. The reasons are: (1) Practically all surface water is subject to biological contamination and the treatment of such water is expensive; ground water often requires little or no treatment; (2) Less expensive gravity-flow distribution systems are easier to install from groundwater sources; surface sources are more likely to involve costly pumping. In general, in the poorer areas of the Third World, ground water, shallow wells, and handpumps are the prefered technology.

Surface water, whether used for laundry (above) or in a secluded location (below), is more subject to contamination than ground water.

Retrieving the Water

When a suitable water source has been identified, it normally must be developed before the water is convenient for use. "Development" means that some man-made device must be installed to retrieve the water from its natural state. For ground water, this device is normally a well. For surface water, other intake structures are used. The following section describes the methods that are in common use for retrieving water.

Rainfall Catchments

Basically, there are two types of rainwater catchments: roof catchments and ground catchments.

Roof catchments should only be used where roofing materials are suitable, not on thatched, painted, or lead roofs. The water running from them is likely to be very contaminated and water is likely to seep into thatched roofs and be lost. Generally, sheet metal is preferable because of its light weight and strength. Tiles are also good because they can be made locally.

However, they are much heavier than sheet metal and need a strong roof structure to support them without sagging.

Ground catchments are areas prepared in a special way to collect rainfall for a water supply. The amount of water that can be collected depends on the amount of rainfall, the area of the catchment, and the runoff characteristics of the surface. Ground catchments, if prepared properly, will provide more water than roof catchments since more surface area is used for collection. For this reason, they are more economical for a small community. If rainwater is the primary water source, a roof catchment on each roof in a community is expensive and may be impractical.

The ground catchment surface is very important in collecting rainwater efficiently. Catchment surfaces must be impervious to avoid water losses from infiltration and seepage. On pervious surfaces, much of the rain will be lost for community use. Part of it will wet the ground and part will be stored in small ground depressions; other water losses will occur through infiltration into the ground, evaporation into the air, and transpiration through plants.

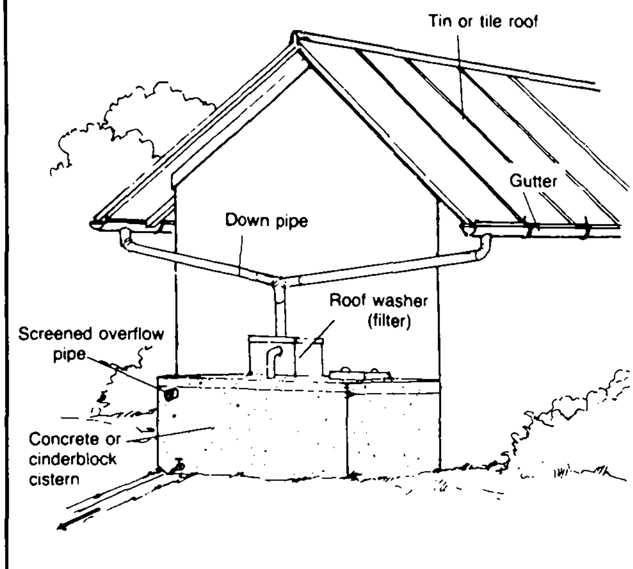
One type of ground catchment is a surface that has been smoothed and cleaned of vegetation. Compacted clay soils make good catchment surfaces because the clay is relatively impervious and will need little or no treatment to seal soil pores. In areas where there is no impervious soil, various materials can be used to cover pervious ground surfaces to prevent water losses. Cement, asphalt or even polythene sheeting can be laid over the surface of the ground to prevent seepage and infiltration. The major problem is that the materials used to cover the ground surface are very expensive and may not be available in many rural areas. The need for storage in a cistern and for treatment adds to the total cost. It is very important to prevent the intrusion of people and animals into the ground catchment area since they can cause fecal contamination. Attention should also be given to the surrounding vegetation to prevent dry vegetative material from falling into the catchment area and prevent attracting large numbers of birds to live or nest too close to the catchment area.

Surface Water Intakes

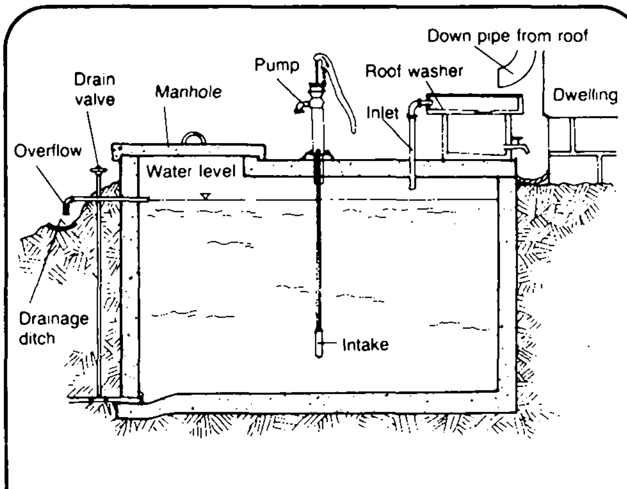
The installation of structures called "intakes" makes surface water accessible to a community. Three types of intakes are used for rivers and streams: infiltration intakes, gravity flow intakes, and direct pumping intakes.

One type of intake is designed so that water from a stream or river passes through the ground and into storage. These are called infiltration intakes because the water collected is filtered as it passes through the ground. Two types of infiltration intakes are wells dug in river banks and infiltration galleries.

If a well is dug in a river bank, water is pumped from the well to the users. During pumping, the water enters the well and the groundwater table is lowered.



Rainfall Catchment with Cistern



Underground Storage for Roof Catchment

When the groundwater table falls below river level, river water enters the aquifer. As pumping continues, this water flows through the ground, is filtered, and eventually enters the well.

If the infiltration method is to be used to supply water to a large population, infiltration galleries may need to be constructed. Infiltration galleries collect water from an area along a river bank through collection pipes parallel to the river. These pipes move the water into a storage well where it is held for pumping to a distribution system.

In mountainous or hilly regions, water from streams and rivers can be collected through intakes placed directly in streams. In higher elevations, a gravity flow system can easily be installed to deliver water if there is enough flow and grade for the water to reach the users. If the intake is located above any inhabited area, the water may not require treatment. People and animals are the major sources of fecal contamination. If neither are present at the place where the water is collected, or upstream from the collection point, fecal contamination is unlikely.

Water can be pumped straight from a stream or river to treatment and storage using direct pumping. There are many types of temporary intakes but permanent structures are better.

In order to design an intake for a pond, lake, or reservior, it is necessary to (1) select the location for the intake, (2) decide on the diameter and length of pipe required, (3) choose between flexible and rigid plastic pipe, (4) design an inlet strainer, (5) design floats and fixed intake supports, and (6) choose the appropriate installation.

In reservoirs formed by dams, several types of intakes can be used. Both floating and fixed intakes will function effectively, but floating intakes are easier to install and should prove more practical. A permanent intake can be constructed in the reservoir when a dam is being built. This type of intake consists of a concrete box with an inlet pipe built next to the embankment.

Development of Springs

A natural surface discharge of ground water is called a spring or seep. Springs have many desirable features as water supply sources. Because they are gravity fed, no power source is needed to develop them, and operation and maintenance requirements are low. Furthermore, springs can be developed, generally at low cost, in such a manner as to protect them from contamination, usually with local materials and manpower. True spring water, that is, water actually seeping from ground water and not a stream which has gone underground for a short distance, usually requires little or no treatment.

While springs are easily located, their location may not always be advantageous to development. There is no choice of where to develop a spring; it has to be near the discharge point. Springs are also subject to variations in flow. These may be short term (daily) and/or long term (seasonal) due to changes in precipitation. Further, extended changes in climatic conditions such as droughts can cause changes in the flow from springs. The natural flow cannot be regulated or used only on demand as a well can. Thus, there is usually a great deal of water that is not used. The development of springs can restrict or deny use of the water by former downstream users. This frequently is the case where flows are small. Also, because springs are open to the environment, they are susceptible to direct contamination, and care must be taken to ensure their protection. The best places for locating springs are on the slopes of hillsides and river valleys. Green vegetation at a certain point in a dry area may also indicate a spring. Springs can sometimes be found by following a stream to its source. In general though, local inhabitants are the best guides to springs in an area.

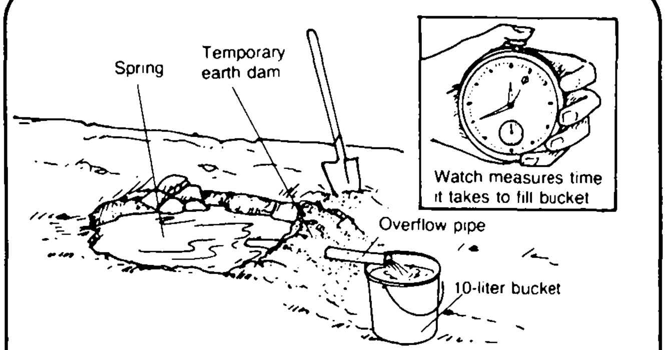
Ground water may be tapped by wells using locally constructed simple hand pumps.

There are two general requirements necessary in the development of a spring as a source of domestic water: (1) selection of a spring with adequate capacity to provide the required quantity and quality of water throughout the year; (2) protection of the sanitary quality of the spring.

Proper development of a spring as a water supply requires construction of an encasement or spring box. The features of a spring encasement involve: (1) an open-bottom watertight basin or well intercepting the source which extends to bedrock or another impervious layer, or a system of collection pipes and a storage tank; (2) a cover that prevents surface drainage or debris from entering the storage tank; (3) provision for cleaning out and emptying the storage tank; (4) provision for overflow; and (5) connection to the distribution system or auxiliary supply.

Springs usually become contaminated when barnyards, sewers, septic tanks, cesspools or other sources of pollution are located on higher adjacent land. In limestone formations, however, contaminated material commonly enters the water-bearing zone through sink holes and may be carried along with ground water for long distances. If material from such sources of contamination finds access to permeable soil, the water may retain its contamination for long periods of time and for long distances.

The following precautionary measures will help to ensure a consistently high quality spring water: (1) diversion of surface drainage from the site; (2) construction of a fence to prevent entry of livestock; (3) provision for access to the tank for maintenance (prevent removal of the cover by a suitable locking device); (4) monitoring of the quality of the spring water with periodic checks for contamination.



Measuring Spring Flow


Water supplies from protected springs are often pure and inexpensive to develop.

Water Wells

Wells are the primary means for tapping groundwater reservoirs. A well is simply a hole which pierces an aquifer so that water may be pumped or lifted out. The amount of water which can be extracted from an aquifer depends on its porosity and permeability. Porosity determines the amount of water which can be stored in an aquifer. Permeability determines how quickly and easily water can flow through the aquifer. Both these factors are important for determining the suitability of a well.

There are many different types of wells, and they are classified in many ways. Some classifications include large or small bore, mechanically or manually drilled, open or closed, deep or shallow. It is also common to describe wells in terms of the basic method of their construction as determined by the equipment and technique used. The chief methods are: Hand Dug, Driven, Jetted, Bored or Augered, Cable-Tool, Hydraulic Percussion, and Rotary Drilled.

Hand Dug Wells

Hand dug wells are circular holes made with hand tools. Excavated material can be lifted to the surface by bucket and rope.

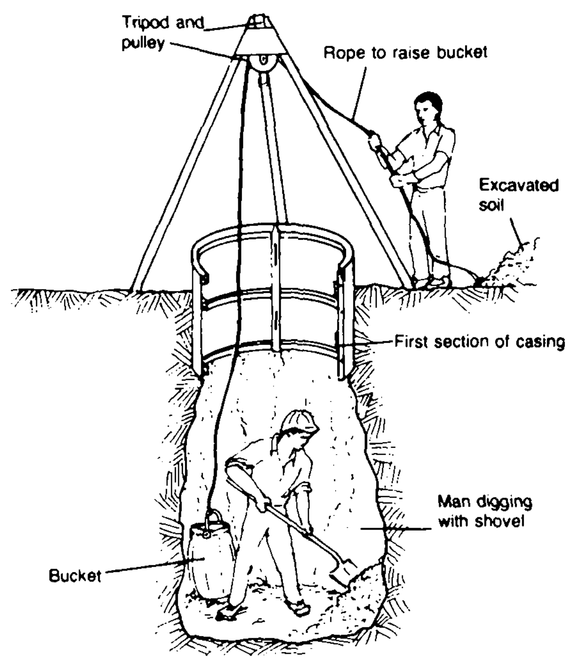
The hand dug well consists of three main components: the shaft, the intake area and the well head. The shaft is the main structure extending into the ground from ground level to the aquifer. A permanent lining for the shaft is generally necessary in all hand dug wells. This lining protects against cave-ins during construction and supports the walls after completion. The lining prevents polluted surface water from entering the well and ensures the quality of the water source.

The intake is the section of the well that extends into the aquifer below the water table. Water from the aquifer enters the well through the intake and is stored in the well for use. As water passes through the intake, sediment is filtered out.

The well head is a structure built around the well above the ground and serves two very important functions. First, it is a foundation for the installation of a pump, windlass, windmill or other means for extracting the water. Secondly, the well head prevents contaminating objects from entering the well and keeps people or animals from falling into it. The well head is built up around the well using the well shaft as its foundation. The well head should include a drainage apron. The drainage apron is a concrete slab which surrounds the well and channels surface water away.

Dug wells have rarely been excavated to over 100m and even those over 20m in depth are few. The usual average depth of a hand dug well is 10m or less. Hand digging wells is most successful in soils which are firm enough that cave-ins do not occur, yet not so consolidated that digging is made difficult and penetration slowed. Soils which do cave in can be penetrated by lining the hole or by sinking concrete rings as soil is removed. Hard rock makes digging more difficult and slower and often can only be accomplished by blasting with explosives which is rarely a feasible alternative.

Hand digging is an appropriate method of well construction in low-income villages because the residents can take an active part in the construction. This contribution of labor is important because the digging of a well requires more work than money. In a village where money cannot be contributed, labor can be donated to develop a well. With the exceptions of cement and reinforcing rods, the necessary materials are usually locally available, making it one of the cheapest methods of well construction in a rural community. The equipment which is needed is light and simple and suitable for use in remote areas.

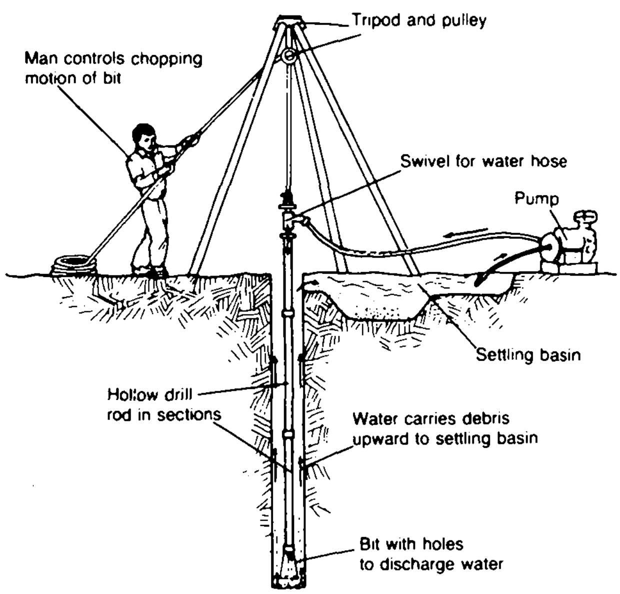


Hand-Dug Well

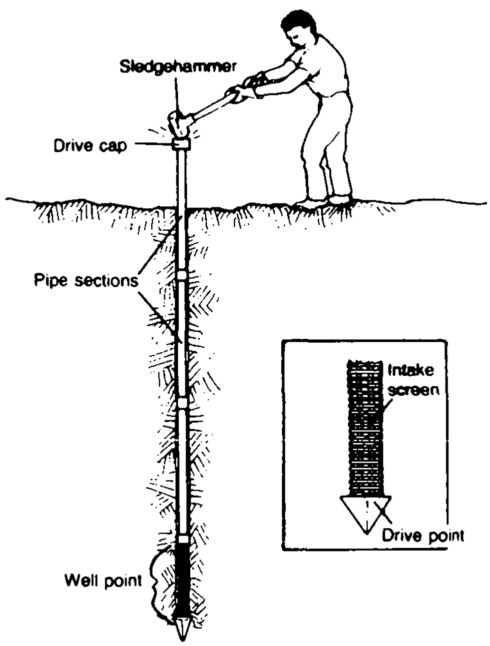
Driven Wells

Driven wells are constructed by driving a drive point connected to sections of metal pipe into the ground. The drive point is a perforated pipe or a well screen with a strong steel point to break through pebbles or thin layers of hard material. The drive point is driven deep enough to penetrate an aquifer, where it acts as a well screen, allowing water to enter the pipe while filtering out solids. The pipe to which the drive point is connected is made of metal to withstand the force of driving the pipe into the ground. The metal pipe serves as a casing for the completed well.

Driven wells are usually 30 to 50mm in diameter. The small diameter pipe used for these wells is light, portable, and easily installed by hand. Driven wells are rarely deeper than 15m. These wells may be used in compact soils, though they are not successful in hard soils or heavy clay.



Jetted Well



Driven Well

Jetted Wells

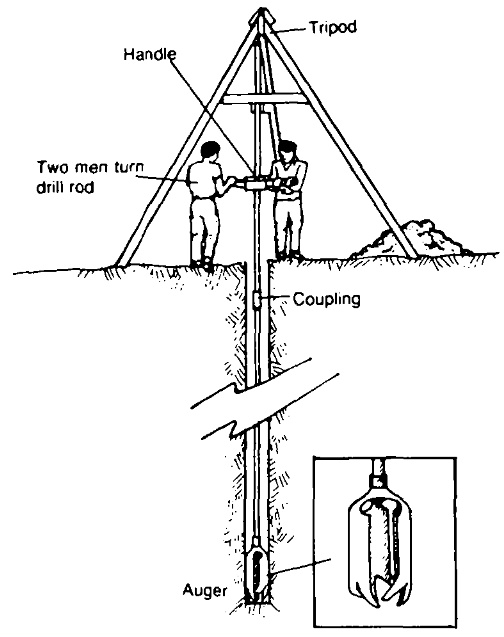
In the jetted method of well construction, a hole is drilled into the earth by pumping a stream of water through a pipe and drill bit at a high velocity. This stream loosens the material it strikes and washes the fine materials upward out of the hole. This method of well construction is most successful in sandy soils when the water table is close to the ground surface, though it may be used to penetrate some sandstone and schist formations.

Two methods of constructing jetted wells may be used: the jet percussion method which is used to install a well casing, or the wash-down method which is used to sink a well casing or a self-jetting well screen.

Bored or Augered Wells

Wells may be bored or augered by manual or mechanical methods. Hand augering is one of the oldest and most basic forms of manual well drilling. This method uses an auger attached to a length of drill rod which is turned with a handle at the surface. As the auger is turned, loosened soil accumulates in or on the auger. When the auger has filled, it is drawn out of the hole and emptied. Drilling progresses quickly for the first 6 to 8m. As the hole deepens, more and more drill rod sections must be coupled and uncoupled whenever the auger is emptied.

Hand augering wells is successful in all soils except rock. The method will usually reach a maximum depth of about 25m. The diameter of hand augered wells ranges from 50 to 300mm.



Bored Well

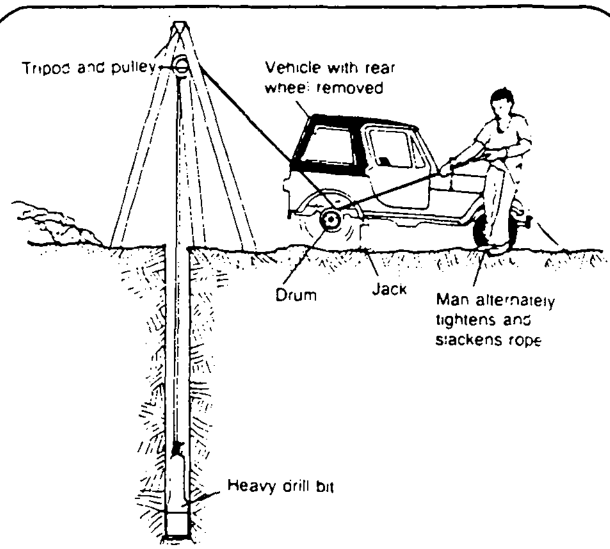
Cable-Tool Wells

Cable-tool drilling is a percussion method in which drilling is accomplished by lifting and dropping a heavy chisel-faced drill bit and drill stem. The impact of the bit breaks up the rock and loosens the material in the hole. The loosened material, known as drill cuttings, is removed from the hole by a bailer. In hard rock the hole is usually drilled without a casing, but in soft unconsolidated materials casing is used to keep the hole from caving.

Hydraulic Percussion Wells

Hydraulic percussion methods of drilling include those methods which use the up-and-down motion of drilling tools and a drilling fluid to sink holes. The "hollow rod" technique is used with large drill rigs, which apply the up-and-down motion to the tool string. Manual methods can be used to lift and drop lesser lengths of small diameter pipe. The mechnical and manual methods both use lengths of hollow drill rod, a check valve and a bit. The tool string is lifted and dropped a short distance into the hole which is full of drilling fluid (mostly water). On each downward stroke, drill cuttings suspended in the drilling fluid enter the pipe through the check valve. Cuttings cannot flow out the check valve, and are eventually forced out the top of the drill pipe. The drilling fluid is discharged into a settling tank and recirculated into the hole. Casing is usually driven as drilling proceeds.

The hydraulic percussion method is well suited for use in clay and sand formations that are relatively free of rocks or boulders. Wells of 30 to 150mm diameter and up to 80m deep can be installed in two or three days under ideal conditions. The method uses a minimum of equipment and can be relatively inexpensive, depending on whether the vertical motion is supplied mechanically or manually. The drilling operation requires a minimum crew of three, and may require as many as six skilled workers.



Cable Tool Well

Rotary Drilled Wells

Rotary drilled wells are advanced by rotating a drill string with a bit attached to the end of it. As the bit is rotated, it loosens rock chips and cuttings. At the same time a circulating fluid (water, mud or air) is forced down the inside of the drill pipe and out through holes in the bit. The fluid carries cuttings up the space between the drill pipe and the hole wall. Cuttings are removed from the drilling fluid at the ground surface and the fluid is recirculated. If air is being used, the cuttings are normally deposited just outside the hole and are removed manually.

Conventional rotary drilling machines drill holes from 250 to 300mm in diameter and 400m deep, and some can drill over 1,000m. Most rotary drilling machines are capable of drilling through the hardest formations. Rotary drilling is the fastest of all drilling methods. A rotary drilling rig can easily complete a well in one-quarter of the time required for manual drilling methods. Hard rock is most quickly penetrated when air is used to remove cuttings, but hydraulic rotary is equally fast when water-bearing formations are penetrated.

Rotary drilling rigs and the accompanying tools and materials are very expensive to purchase, operate and maintain. The annual cost of maintenance is usually equal to about 20 percent of the drilling machine's initial cost.

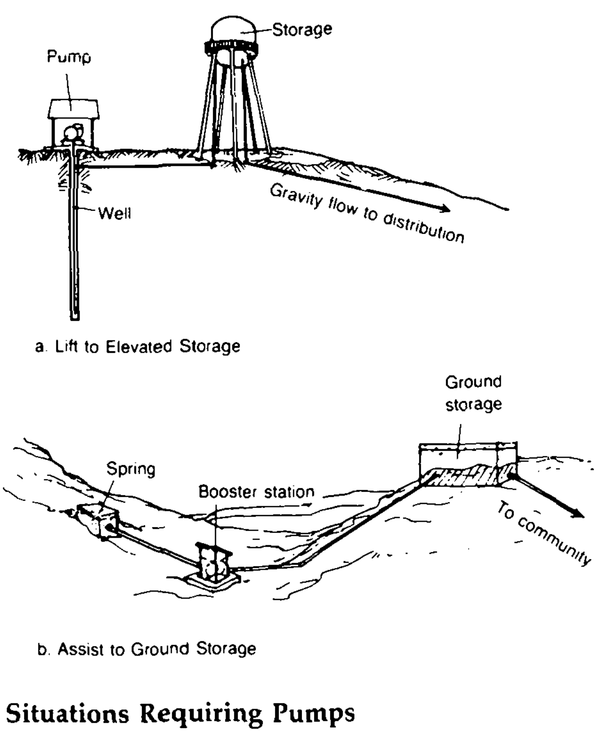
Production of Water

Intake structures and wells are only part of a solution to the problem of making sure there is water in sufficient quantity at the point of use. The water may be required for use at elevations higher than those at which it is found and, often, at some appreciable distance from the source. In this case, some means must be constructed for lifting the water and forcing it through pipes at suitable velocities to the points and elevations of use. This means is usually a pump. Some external source of power must be provided to drive a pump and cause it to lift and force water from one point to another.

Power Sources

There are many sources of energy which can be used to move water. These include man and animal, gravity, wind, sun, and fossil fuels. These are converted to useful power through hand pumps, wind mills, hydro projects, electricity production and fossil fuel engines. While all of these methods currently are used for producing water, the specific method chosen depends on the quantity of water required, the type of water supply, and the availability and affordability of a specific energy source. In fact, availability or affordability are usually the controlling factors in selecting a power source in rural villages. If relatively large quantities of water are required, the options are also limited

Water carriers may be forced to cross rugged terrain to reach water sources.



Situations Requiring Pumps

since man, animal or wind power are not sufficient to produce water in large quantities.

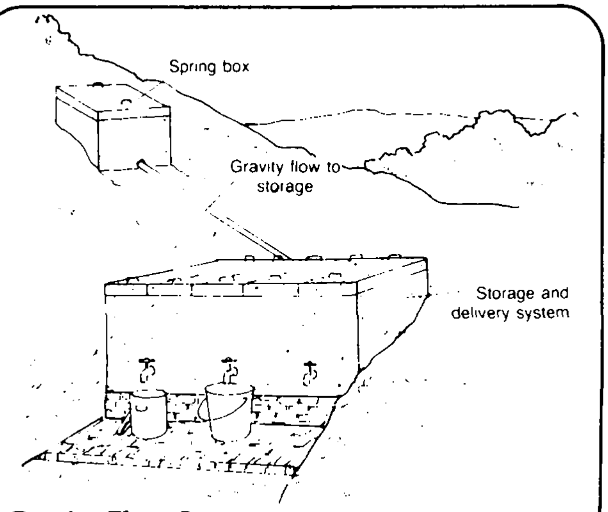
Water located at a higher elevation can be piped to a lower one by gravity flow. This type of system requires no other source of power, is very economical, and is simple to operate and maintain. Water that comes from a gravity flow system at the outset can also be pumped with a hydraulic ram to higher elevations. Since gravity flow systems are economical, they should be used whenever possible. Comparisons of gravity flow systems with other sources of power should take into account the cost of operation and maintenance as well as capital costs.

Wind energy is a very attractive energy source for the production of water. Wind is free and a windmill is simple to operate and maintain. It does have drawbacks, however, including moderate production of water. Wind must be blowing at 8 to 12 miles per hour to start pumping; there should be a constant source of wind year round; and a suitable site is needed. Many of these conditions can be met along large bodies of water, in mountain passes, on the crest of hills, on open plains, and, seasonally, in many parts of the world.

Before a site is selected, background wind information is necessary. If not already available, whether through other windmill performance or by measurement, new measurements should be taken over a year's time. The site should be such that the windmill can be placed at least 4.5m above any wind obstructions within 120m. Although the higher the wind speed the greater the water production, the practical maximum usable wind speeds are 25 to 30km per hour. This is because windmills are designed to "furl" or swing out of the wind at higher wind speeds to protect the mill from damage.

Electricity gives the most flexibility in providing power for water production. Electric motors are available from a fraction of a horsepower to many horsepower (HP) to meet a variety of pumping needs. Most pump systems are adaptable to electric power. Electric motors are relatively economical to operate, are simple to maintain, and are long-lived. They are the most efficient of the motor-driven pumps for producing water. If electricity has to be generated just for powering a motor, however, the cost can be much higher and the operation and maintenance of the power-generating equipment is costly and complicated. As a general rule, if a fossil fuel engine must be used to generate electricity, then it is probably more efficient and less complicated to use the engine to drive the pump directly. If the electricity is to be used for other purposes, however, a generator can usually be sized to power pumps also with very little additional cost.

Conversion of sunlight to electricity through photovoltaic cells is an alternative to using a fossil fuel engine to generate electricity. While the technology is well known and is currently being used to power pumps, the capital costs are quite high and it will be at least several years before it will be economical for most applications. It is an attractive alternative though, in that operation and maintenance are minimized and fuel is not required. If water is pumped to storage only when the sun shines, then the need for batteries is eliminated, thus substantially reducing initial costs and simplifying the operation and maintenance.



Gravity Flow System

A windmill pump is capable of servicing a small community.

Although fossil fuel powered motors are costly to operate and maintain, and fuel may be difficult to obtain, there often is no other choice if water is to be produced in sufficient quantities to be beneficial. When fossil fuel engines must be used, it is preferable to use diesel rather than gas. The initial cost is generally more, but the cost of fuel is less as are the costs of maintenance and repair. The diesel engine does not require spark plugs or points and operates at a low rotating speed, thus prolonging its life. Natural or bottled gas engines are low in operating cost and have a longer life because they are very clean burning. However, these fuels are not widely available.

Pumps

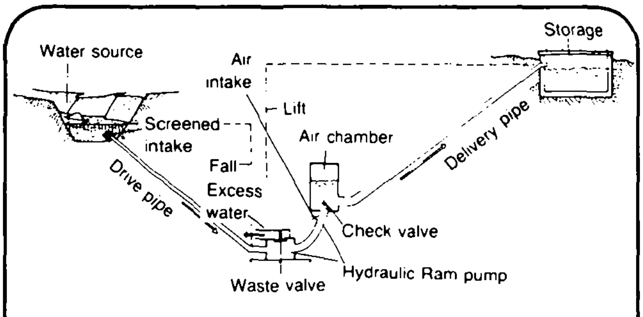
The preferred method of delivering water from the source to the point of use is by gravity flow because no external power source or mechanized apparatus is required. However, when a water source is at a lower elevation than the point of storage or use, or the rate of flow must be increased, some other method of pumping must be used.

Pumps can be placed into two categories based on their power source. Category One pumps can be powered by animals, humans, wind or water. These pumps usually produce low volumes of water at or near the source. They include bucket, impulse, and positive displacement pumps. Category Two pumps are usually powered by electric motors or internal combustion engines. These pumps include single stage suction, jet, submersible and line shaft turbines. They produce medium to high quantities of water compared to Category One pumps. The positive displacement pump mentioned in Category One can also be power driven and will produce relatively high quantities of water.

A brief description of the pumps and the relative merits follows:

- Bucket. This system may be considered where relatively large diameter wells (dug) are available, the wells are relatively shallow, and small quantities of water are needed or available. In shallow wells, it is common to throw a bucket tied to a rope directly into the well. In deeper wells, leverage is required or an animal is used to raise the water. This is undesirable from a public health viewpoint as contamination can and usually is introduced into the well by careless placement of the rope and/or bucket. For this reason it should not be considered unless other alternatives are not available. Continuous-belt bucket pumps can be made much more sanitary than a rope and bucket system but are much more expensive to install. Essentially this method involves attaching small buckets to a continuous loop.

- Impulse (Hydraulic Ram). A hydraulic ram has very few moving parts and therefore is very economical to operate and maintain. Hydraulic rams may be used singly or in tandem depending on the amount of water available and required. The water is raised to a higher elevation by the force of falling water. This creates a drive force within the ram by compressing air which, in turn, pushes a small amount of the falling water to a higher elevation. In order to work, most rams require a flow of at least 12 liters per minute and a fall of 50cm.

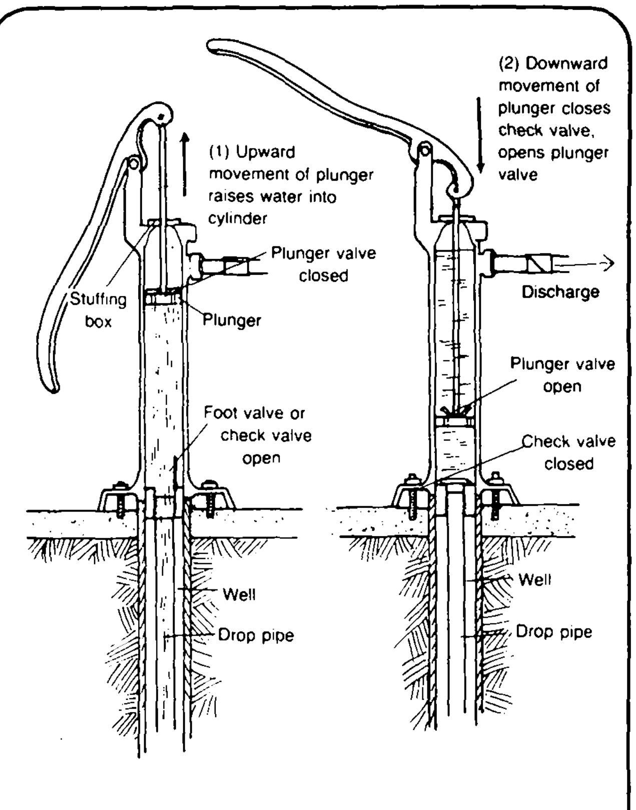


Impulse Pump (Hydraulic Ram)

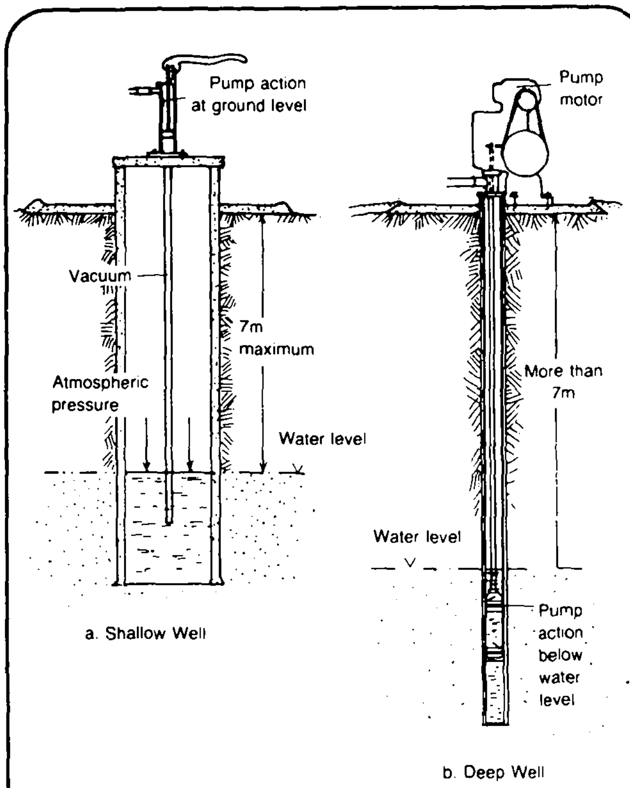
Animals are often used to carry water or to power pumps.

• Positive Displacement. This pump consists of a cylinder containing a piston. It is called a positive displacement pump because it displaces an amount of water equal to the distance the piston travels. Efficient double acting pumps are available which pump on the upward and downward or forward-backward stroke of the piston. The cylinder may be located above or in the water. When above water, suction is required to lift the water to the piston. (This type of pump usually requires priming and is less desirable than a pump with the cylinder in the water both from a contamination viewpoint and because a source of priming water is needed.) The cylinder can be driven by a variety of power sources including a hand windmill or motor.

Positive displacement pumps are the pump of choice if only hand or wind energy is available or if motors are available and deep pumping and low flow are requirements.



Positive Displacement Pump



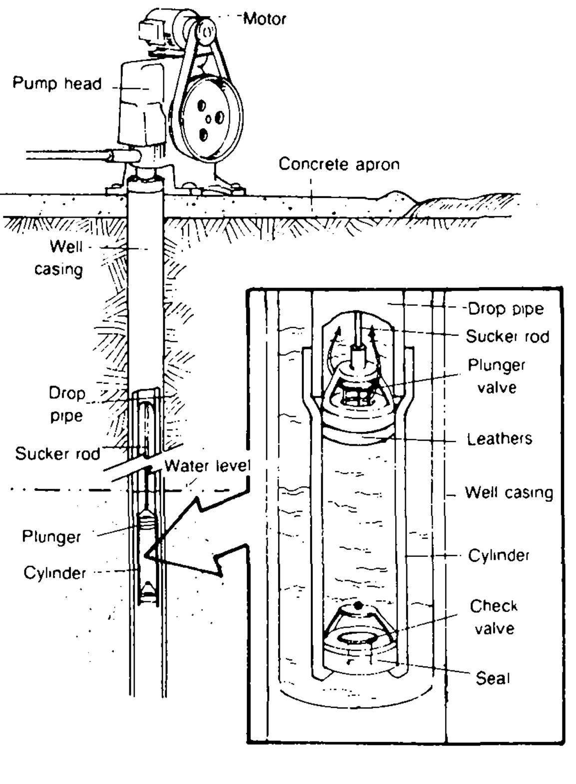
Shallow and Deep Well Pumps

• Motor Driven. These may be divided into shallow well pumps and deep well pumps. Shallow well pumps must be located within at least 7m vertically of the water surface when at sea level and closer at higher elevations. This is because they rely on a vacuum in the suction side of the pump to get water to the pumping mechanism. (The actual suction capability varies with the pump being considered.) For every 300m of elevation above sea level, the pump must be 25cm closer to the water. Shallow well pumps include surface mounted positive displacement (piston type) pumps and centrifugal pumps which, in turn, include shallow well jets, turbines and straight centrifugal pumps.

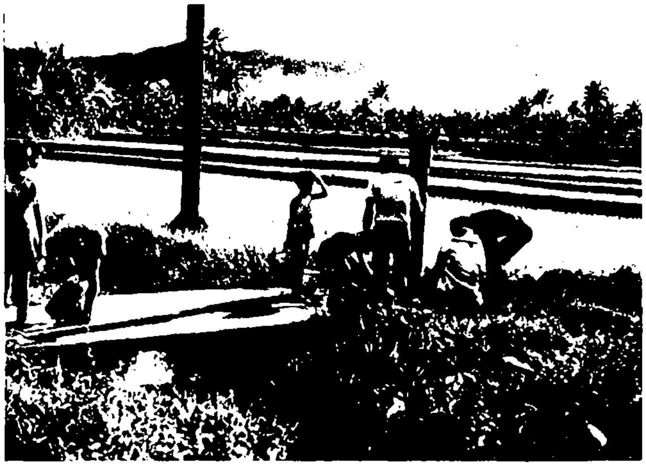
Deep well pumps can pump water from over 7m deep either because the pump itself is in the water (such as a submerged piston pump, a submersible pump or a line shaft turbine) or because the pump uses jet action to lift the water to within the suction limits of the pump. While piston pumps can theoretically pump from very great depths, there are practical limitations because of the weight of the sucker rod. This, combined with other limitations, indicates that 300m is the greatest depth from which piston pumps are effective.

Line shaft turbines, like the positive displacement pumps, have the advantage of the motor being at the surface. However, a drive shaft connects the motor to the pump. The deeper the well, the more bearings are required along the drive shaft and the greater the chance of bearing failure. In addition, the shaft needs to be relatively straight, which requires a very straight well hole. Since it is extremely difficult to keep deep wells straight, the pumping depth is often limited. For this reason, practical pumping depths in small diameter wells (12 to 24mm) should be limited to 12 to 35m deep. Larger wells, 30mm and larger in diameter, can be pumped at greater depths. However, bearings are still a problem as is the possibility of breaking a shaft.

Submersible pumps have the advantage of allowing placement in wells that are less straight. They can usually be set at greater depths. Since the motor is below the pump, the whole unit must be pulled for repairs. However, since there are no moving parts connecting a motor at the surface to the pump, installation is much simpler. Operation and maintenance problems are reduced due to fewer moving parts. These pumps can produce water from great depths, but the greater the depth, the larger the motor and the electric cable to the motor.



Motor Driven Positive Displacement Pump (Submerged Piston)



These children are collecting water from a community pump.

Treatment of surface water is often necessary to make it safe for domestic use.

Treating the Water

Water intended for domestic use, including drinking, must be free of organisms and chemical concentrations that are hazardous to human health or that cause the water to taste, smell, or look bad. Water treatment is the process of making impure water potable, i.e., safe to drink and use. Since treatment processes are sometimes expensive, it is best to develop a water source that is naturally potable. However, many water sources, especially surface waters, are not naturally potable and some water treatment is often necessary.

In any water treatment situation, the priority treatment process is disinfection since the absence of pathogenic organisms in a water supply is essential to good health. Clarification of water supplies is often necessary for efficient disinfection. Conditioning is important to develop an aesthetically pleasing water supply.

Individual Household Treatments

Individual household water treatments are simple methods of killing some pathogenic organisms in small quantities of drinking water. They are appropriate for groups without the resources or finances to construct and operate larger treatment systems. Local materials can be adapted to the design of these methods and the necessary construction and operation skills are minimal. Four types of individual household treatments are storage, filtration, boiling and chemical disinfection. They can be used alone or in combination with each other, depending upon the quality of the water supply.

Storage

The simplest method of water treatment through storage is holding water in a container for at least two days before using it. This short term storage of household water supplies will kill some disease-causing organisms and it will settle mild turbidity. It will not kill *all* pathogens and is not effective for heavy turbidity. Storage containers can be of metal, glass, plastic, or glazed ceramic materials. The use of earthen pots should be avoided if possible because of the risk of bacterial growth in the porous clay walls. Household containers are normally from 10 to 30 liters in volume.

Storage containers must be covered to keep dirt and other contamination from entering the water supply to keep algae from growing, and to prevent evaporation. A screen at the inlet will filter grit. A spigot for drawing water can be added to reduce the risk of contamination. The storage container must be cleaned often to prevent bacteria from growing in the settled sludge. Ideally, stored water should be boiled or chemically disinfected to make it completely safe to drink.

Filtration

Turbid water supplies can be clarified by filtration, which is the process of passing water through a porous material to remove suspended particles. Several types of filters are used for household water supplies. Most types are relatively ineffective against bacteria and fine turbidity, but will strain out coarse materials. The filtering medium can become blocked or contaminated itself after prolonged contact with turbid water. It must be cleaned frequently to avoid adding bacteria to the water supply. Filtered water should be boiled or otherwise disinfected before drinking.

Porcelain or ceramic filters are available commercially in some areas, but they are usually expensive. They consist of a filter candle which filters water from one storage vessel to another, or from one compartment to another within a single storage unit. They may also be attached directly to the taps of a water delivery system. Ceramic filters are relatively common in prosperous areas. They are effective for mild turbidity, but must be cleaned whenever sediments

Methods of Water Treatment for Small Rural Communities

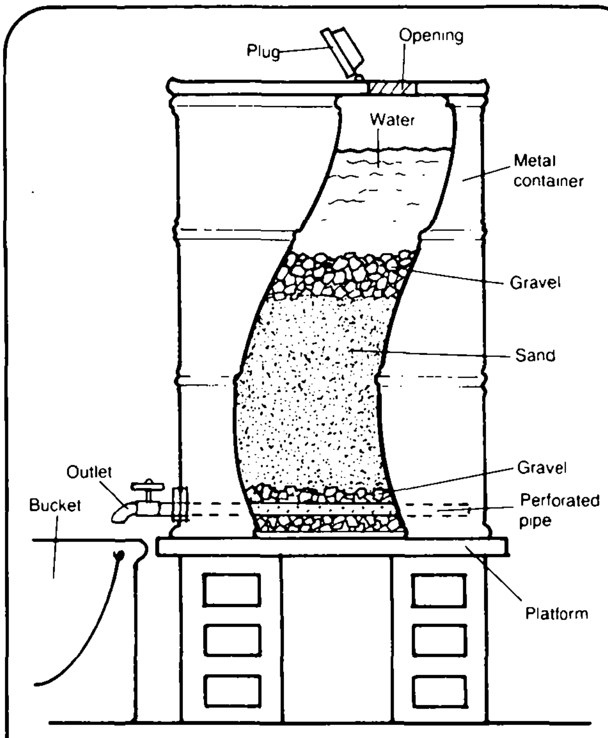
Method	Type of Treatment	Construction Cost	O & M Cost	Reliability	Construction Skill Required	O & M Skill Required
Storage	Clarification of mild turbidity	Low	Low	Small volumes of water only; used with filter and/or disinfection	Low	Low
Household filter	Clarification of turbid water; removes some pathogens	Low	Low	Up to 2700 liters/ day; used with disinfection	Low	Low
Boiling	Complete disinfection	Low	High	Small volumes	Low	Low
Chemical disinfection by hand	Disinfection of clear water; kills most pathogens	Low	High	Difficult to determine; taste test only	Low	Medium
Plain sedimentation basin	Clarification of very turbid water	Medium	Low	Use with filtration and disinfection	Low	High
Slow sand filter	Clarification and disinfection	High	Low	Kills most pathogens with proper maintenance	High	Medium
Simple disinfection unit	Disinfection of clear water	Low	High	Frequent chlorine checks are necessary	Medium	High

build up on the candle and reduce the filtering action. The candle is cleaned by scraping it with a brush and by occasionally soaking it in a mild chlorine solution.

Charcoal, ricehulls and other local materials are sometimes used as filtering mediums for small water supplies. Charcoal removes bad tastes from some water supplies. These materials must be changed often to prevent recontamination.

A sand filter is an inexpensive and simple filter to construct and maintain. It is made of a large barrel partially filled with a layer of clean sand on top of small stones. Turbid water poured into the top of the barrel flows through the sand, which traps the sediment. The resulting clear water comes out of a perforated pipe at the bottom of the barrel. A layer of gravel can be placed on top of the sand layer to prevent erosion of the sand where the turbid water is poured in. A continous flow through a 200-liter barrel filter can process approximately 2700 liters of water per day. The sand layers must be changed every two to three weeks to prevent bacteria from growing in the sediment trapped in the sand layers and recontaminating the water.

Household sand filters are often used with rainfall catchments or other sources where water may contain small debris. They can filter large quantities of water quickly but do not kill pathogenic organisms. They must be carefully maintained because dirty filters can breed and spread bacteria. A household sand filter is only a clarification process that prepares water for boiling or chemical disinfection.



Sand Filter

Boiling

Boiling is the most effective way of disinfecting small supplies of water. All pathogenic organisms are destroyed in water brought to a rolling boil. Cooking pots or large steel drums over fireplaces are common vessels for boiling water supplies for groups of less than twenty people. The water must be covered, cooled and stored in the same container it is boiled in to prevent recontamination. Constructing a boiling unit is simple and inexpensive, but fuel required to boil the water (such as firewood, charcoal, kerosene or bottled gas) may be difficult to get and can be expensive. Boiling is impractical for large quantities of water or large groups of people, or for those who cannot afford or have no access to fuel. In China, most drinking water is boiled while the morning meal is being cooked. While the water is boiling, it is poured into large thermos jugs from which is is drunk as tea or hot water throughout the day. This procedure has been quite cost effective in controlling waterborne disease and has played a significant part in the dramatic drop in the death rate achieved in recent years.

Chemical Disinfection

Contaminated water can be disinfected with chemicals. Iodine, bromine, and chlorine can eliminate most disease-causing organisms in water, but they do not kill all pathogens and they are not effective against organisms embedded in solid particles. Chemical disinfection is only appropriate for clear water supplies. Turbid water must be settled or filtered first.

Chlorine is the most widely used chemical disinfectant and is marketed in many forms. Directions for use are supplied on the purchased package and should be carefully followed. A small amount of chlorine powder or liquid can be added to a water supply and allowed thirty minutes to react to the contamination present. Liquid laundry bleach is often the easiest form of chlorine stock to apply in this manner, but it losses its disinfecting ability when stored for a long time.

Chlorine added to a water supply reacts with soil particles and inorganic materials as well as disease-causing organisms. The amount of chlorine needed to disinfect a water supply is called the "chlorine demand," and it changes according to the condition of the water to be treated. Extra chlorine must be added to turbid water, for example, to overcome the inorganic materials present and kill the bacteria as well. The amount of chlorine left over in a water supply after killing any bacteria present is called "chlorine residual." It provides some continuing protection of the water supply against subsequent contamination. The level of chlorine residual in a chlorinated supply must be measured regularly to be certain the treatment remains effective.

Manual chemical disinfection is not always reliable. The quality of raw water often changes, and it is difficult to determine how much chemical is needed for proper disinfection. An insufficient amount will not disinfect the supply at all, and an overtreated supply can have such a bad taste that the treated water is rejected by the users. A simple rule of thumb is to add a chlorine solution such as laundry bleach to a container of water just until a chlorine taste is noticed.

Simple Community Treatments

There are simple community water treatment methods appropriate for groups larger than a single household. They require larger volumes of water and more construction, operation and maintenance skills than simple household methods. Three types of simple community treatment are plain sedimentation, slow sand filtration, and chemical disinfection. Depending upon the quality of the water supply, they may be used separately or in combination.

Plain Sedimentation

Plain sedimentation is a method of clarifying very turbid water. It is often a preparation for filtration. Plain sedimentation is holding water or moving it slowly through a large basin until most of the suspended particles have settled to the bottom.

A sedimentation basin is usually rectangular and made of concrete, but it may also be made of steel, stone, or local materials. It must be completely leakproof and it should be covered to prevent algae growth or recontamination of the water. Water enters a typical sedimentation basin through an inlet near the top of one end of the basin, is slowed by a baffle or stilling wall near the inlet, and leaves the basin through a trough at the top of the tank on the far end. Valves or gates can be added to control the speed of the water. Floors of sedimentation basins are often sloped to make removal of settled sludge easier. The size of a sedimentation basin depends on the average daily water needs of the community it is serving. The basin can be designed to provide a constant flow or it can be filled and emptied as needed. Building a sedimentation basin requires trained designers and skilled construction workers.

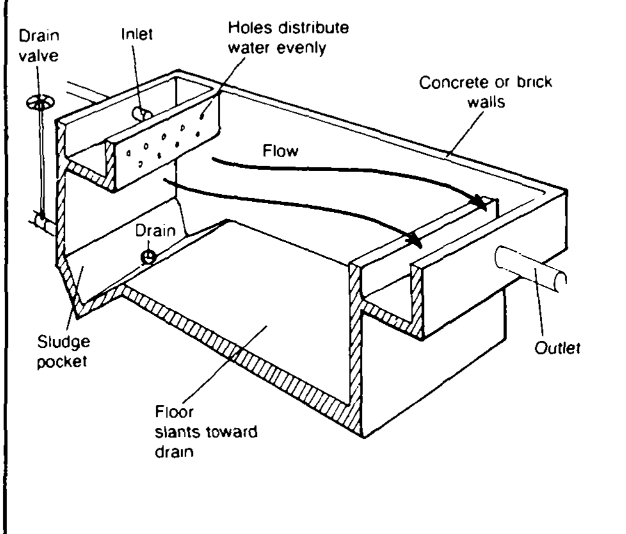
Water is usually held in a sedimentation basin for at least two days. Very turbid water may need a chemical additive to induce settling. Water passing out of a sedimentation basin is clear but probably needs to be disinfected before it is safe to drink.

Slow Sand Filter

A slow sand filter removes pathogens and clarifies large water supplies with low turbidity. It consists of a steel drum or a large concrete tank partially filled with layers of small stones and very fine sand. The filter tank is flooded with water which slowly seeps through the sand. After several days, a thin slime called a schmutzedecke forms on top of the sand. The schmutzedecke contains forms of microscopic life that filter out and kill most of the pathogenic organisms in the water passing through it. The clean water flows out of the bottom of the slow sand filter through a drainage system of baked clay bricks or concrete pipes. The filtered water is usually stored in an outlet tank. Valves control the rate of water flow so that a constant depth of water remains on top of the sand to preserve the schmutzedecke. If the schmutzedecke dries out, the filter bed breeds bacteria, making the filtered water more contaminated than the raw water.

Design of a slow sand filter system requires some skill. The inlet and outlet arrangements, flow rates, tank sizes, sand sizes, and sand volumes must be carefully calculated. Construction of the filter tank does not require highly skilled labor, but construction costs are high and a large site is needed. Operation and maintenance skills and costs are low. The filter is cleaned every several weeks when the filter rate slows by draining it and carefully scraping several centimeters of sand off the top of the sand bed. Raw water is allowed to flow through the sand again until the schmutzedecke has reformed. This usually takes a couple of days. The dirty sand can be cleaned and reused.

The slow sand filter can reduce the bacterial count of the raw water by 85 percent. It can reduce turbidity significantly, although sedimentation is necessary for very turbid water. Water not completely disinfected by the slow sand filter can be chlorinated afterwards. Because of its capacity to improve the physical and bacteriological characteristics of a water source, the slow sand filter is an excellent means of treatment for rural communities with limited resources.



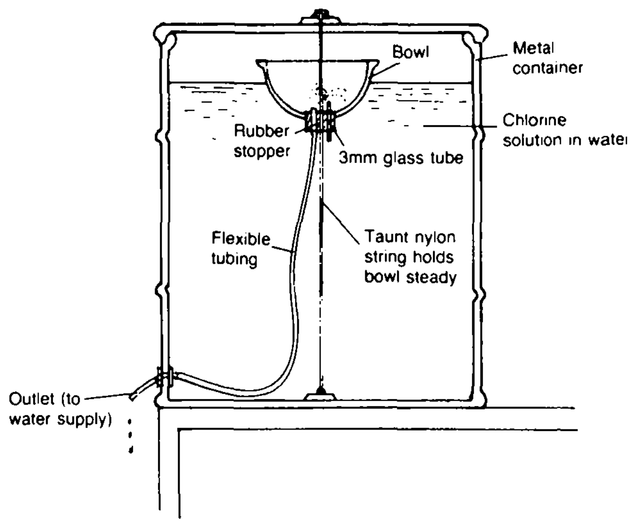
Plain Sedimentation Basin

Chemical Disinfection

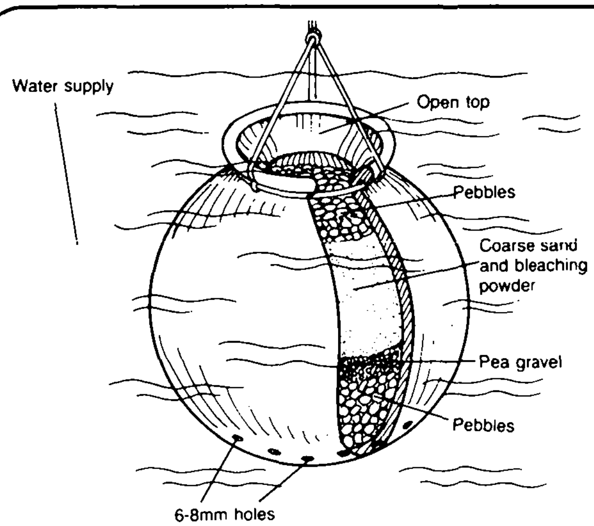
Storage, sedimentation and filtration reduce the bacterial content of large quantities of water, but rarely disinfect a supply entirely. More complete treatment of a clear water supply can be achieved with chemical disinfectants, if regular operation and maintenance are possible. A chemical disinfectant dispenser can be used to add a small amount of chemical to a well or storage tank at a constant rate. Chlorine is the most widely used chemical disinfectant because it is relatively inexpensive and available in many areas.

Simple chlorinators, which dispense chlorine at a constant rate into a water supply, can be bought or made with local materials. Design and adjustment of chlorinators can be complex. Regular testing and maintenance are necessary to ensure their effectiveness.

There are two types of simple chlorinators. A *diffuser* is used in non-flowing water supplies like wells, cisterns and tanks. It consists of a pot or another container filled with coarse sand and chlorine powder submerged in a water supply. The chlorine seeps into the water supply through holes in the container. Diffuser chlorinators have slow rates of disinfection and are most effective in wells or tanks not producing or holding more than 100 liters/day. For larger wells, more pots are required.



Drip-Feeder Chlorinator



Simple Diffuser Chlorinator

A *drip-feeder* is a large tank which feeds a chlorine solution at a constant rate into a reservoir of slowly flowing water. It consists of the tank (usually about 200 liters and made of concrete or an empty steel drum), a cover, a floating valve (often a bowl or a wooden float), an outlet, and a flexible tube leading from the valve to the outlet.

The tank is filled with chlorine solution, and the valve floats on top of the solution. A hole in the bottom of the valve is blocked with a stopper which has two holes in it. One hole has a flexible tube passing through it which runs from the bowl to the outlet of the tank. The other hole has a smaller tube passing through it which rises in the bowl to just below the level of the chlorine solution in the tank. This placement causes the chlorine solution to flow up through the small tube, collect in the bowl and drip down the other tube to the outlet and into the water supply. The flow into the bowl can be altered by raising or lowering the small tube. Regular attention to the level of the solution and occasional replacement of the parts are necessary for drip-feeders.

Advanced Community Treatment

Advanced treatment processes for community water supplies are those that require highly skilled design, construction and operation and are usually very expensive. They are rarely appropriate to rural water supply systems, but several are briefly described here.

Conditioning is the elimination of minerals and substances that give water a bad color, taste or odor. It makes water aesthetically acceptable, and makes hard water soft and thus more useful for laundry. Conditioning water supplies is less important than disinfection, but pleasant water encourages people to use a safe source.

Aeration is the conditioning process of exposing water to oxygen in the air. It changes iron and manganese in water to solid particles so they can be removed. Aeration will also remove some of the gases and organic matter that cause bad tastes and odors. Many methods of aeration can be used on small water supplies. The advice of an expert is recommended.

Desalination is the process of removing salt from a water supply. It is usually a highly technical and very expensive process. Solar distillation is the simplest method of desalination, but is rarely appropriate for small water supplies. Choosing a low-salt water source is recommended.

Clarification. Coagulation and flocculation is a chemical process that speeds sedimentation of water. An alum solution added to turbid water causes small particles to collect into larger particles which settle quickly. Coagulation and flocculation is often used in sophisticated treatment systems.

A *rapid sand filter* is a tank containing coarse sand used for clarification of turbid water. Water is forced quickly through the sand bed. A schmutzedecke does not have time to develop in a rapid sand filter so no disinfection takes place. A pump is necessary to backwash the sand. Construction and operation costs can be high and maintenance is required often.

Disinfection. Motorized chlorinator units feed a chlorine solution into a water supply under pressure. The chlorine is in gaseous, liquid or powder form, and several different types of motorized units are available. They require a power source and sophisticated design and maintenance.

Treatment Plants. A small, prefabricated package treatment plant may be an economically viable alternative for some small communities. Treatment plants are highly technical systems which combine several different processes to clarify, disinfect and condition large volumes of water. They require a reliable source of energy, skilled design, construction, operation and maintenance personnel, and constant supplies of chemicals. They are expensive to design, buy, operate and maintain. They are rarely appropriate for small rural water supply systems, although they can sometimes be used at small town hospitals, schools, or other locations where it would be economically feasible to have trained operating personnel.

Emergency Water Treatment

Methods of emergency water treatment are those which can be established on short notice. Disasters which cause a disruption of water supplies demand a fast appraisal of local conditions and available water resources. Emergency water treatment is needed when a source becomes contaminated, when a treatment facility has been destroyed or when a change in water source is necessary.

Disinfection is the priority treatment process to prevent outbreaks of waterborne diseases. Boiling water or adding chlorine or iodine tablets to supplies are suitable methods for disinfecting small quantities of drinking water. For large groups an automatic chlorination unit of some kind is most efficient and effective. Diffusers or drip-feeders are designs most easily improvised from available materials. More sophisticated motorized chlorination units may be used if a reliable power source is available.

Planning for Treatment

The addition of any form of water treatment to a water system causes an increase in (a) the cost of developing the system (b) the amount of maintenance required and (c) the risk of breakdown.

If it is determined that water treatment is necessary, the following factors must be considered when choosing the treatment system to use.

- Amount of funds available to carry through the project. Most rural communities have limited funds and cannot afford expensive projects. The choice of using a treated or a non-treated source and the choice of a treatment technique depends upon the funds available to the community.

- Costs of construction. The construction of a water treatment facility is expensive and construction costs must be estimated before choosing the process. Compare the construction costs of the processes that will provide the needed treatment. Also, compare the costs of the treatment system and a pipeline to the community from a source needing no treatment. If the difference in cost is not great, the development of the pipeline may be the better alternative.

- The trained personnel available or the possibilities for establishing necessary training programs. Trained personnel are needed to operate and maintain water treatment systems. The success of water treatment depends on the dedication, skill and supervision of trained personnel and the equipment and supplies available to them. If trained personnel are not available or are inadequately trained, the water treatment system will not function properly and water quality will be poor.

- Costs of operation and maintenance. The cost of chemicals (e.g. chlorine) for treatment, fuel to run pumps, and salaries for personnel may be beyond the means of the community. Chemicals and spare parts must be readily available to avoid the closing down of the treatment system.

The general policy should be one that restricts the use of water treatment in rural areas to only those cases where it is absolutely necessary. By selecting a source of water which needs no treatment, a community can save money. In cases where water treatment is absolutely necessary, the most efficient and least expensive method must be chosen.

Storing and Distributing the Water

An improved water system should include some type of storage, so that water may be conserved for periods of peak use, and some system of distribution so that the water need not be collected at the source, which is usually a time-consuming procedure. Systems of storage and distribution in developing nations range from simple cisterns to individual household water taps.

Cisterns

The simplest and most direct distribution system for a water supply is the collection of rainwater from roof or ground catchment areas with provision for storage in cisterns or tanks at ground level and in close proximity to the users. Roof catchment requires no fuel or power and has served for centuries as a direct supply for families. Storage requirements for such a simple system depend on the frequency and amount of the rainfall, the nature and area of the catchment surface, and the water requirements of those being served.

Although simple in principle, rainwater collection systems, when properly constructed with underground cisterns for individual homes in a community, are not always economically attractive. Cisterns should be constructed of masonry, brick, or concrete, and must be of sufficient size to provide an adequate supply during low rainfall periods. To make maximum use of available roof areas, gutters leading to the cistern should be installed. The cistern must be properly designed with provision for screening to exclude leaves and other debris that may be collected from the roof. Although roof catchment water is of reasonably good quality and preferable to untreated surface water sources, boiling or disinfection by other means is recommended before use as drinking water. A sand filter may be installed ahead of the cistern to improve water quality. This adds to the cost of construction and requires a level of maintenance that often is not provided on a regular basis.

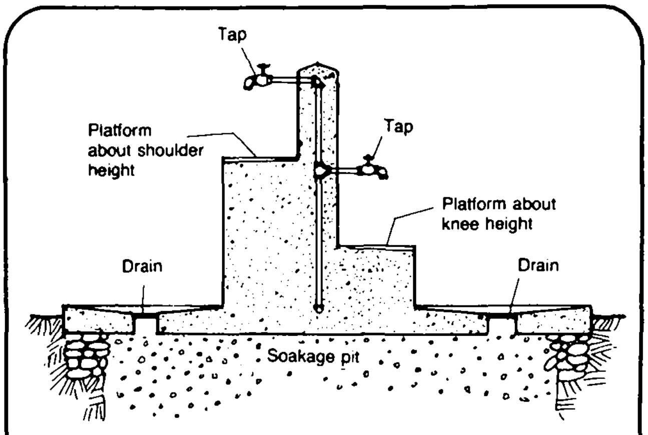
The cistern must have an access manhole with a tight cover to exclude insects, animals, dust, and other contaminants. Despite the precautions taken to ensure proper construction of a cistern, it will require periodic cleaning and disinfection. Water is usually withdrawn from the cistern by a hand pump although, for large installations, motor driven pumps may be used.

Construction of a large community storage tank is one means of water storage.

Smaller tanks can be used to supply livestock.

Standposts

An intermediate level system that is widely used consists of supplying water from a gravity or pumped supply to a distribution system of public standposts located throughout the village or community. Standposts should be built in sufficient numbers to minimize the time used to fill containers. Obviously, the greater the number of standposts, the more the capital outlay for the system. In some instances, private standposts at individual homes can be provided with additional costs borne by the household receiving the special service. Provision of such service should be encouraged, since this is the initial step in providing individual house connections if interior plumbing is installed. If the pressure in the distribution system is adequate, there is an immediate benefit to those with a private standpost. It provides a facility to fill an elevated or roof-supported storage tank and allows irrigation of a garden.



Design of Standpost with Multiple Taps


Public standposts supplied through a community water plant can be an adequate water system.

When standposts are used as water distribution points, careful attention must be given to the design of the loading platform structure. Among the factors to be considered are the height of the platform or loading surface, drainage from the platform, adequate support for the riser pipe, and the type of faucet. Public standposts are subject to heavy uses and abuses, and should be constructed of durable materials that will last for long periods of time without deterioration.

The distance from the faucet to the loading platform on which containers rest while being filled should be sufficient to accommodate the vertical length of the containers, and the spout should project far enough so that it will not be necessary to tip the jug or vessel being filled. The height of the platform should be used to minimize the amount of lifting. Drainage from the facility is of particular importance to avoid standing water and nuisance conditions. The riser pipe should be encased within the structure to prevent bending or dismantling the pipe. Faucets must be of good quality, strong and durable. Self-closing faucets are desirable to avoid waste resulting from carelessness in allowing water to run without containers in place.

Even with good location and design of standpost facilities, a routine inspection program and frequent repairs will be required to maintain them in good operating condition. Every effort should be made to provide an attractive facility to encourage its use and discourage people from returning to the use of what may be a more convenient but unsafe source.

Although the water supplied at the faucet may be of good quality, significant pollution can occur between the points of collection and use. This is more of a problem where water is stored in large containers within a home instead of being used directly from the collection container which is usually rinsed at the time of collection. Those concerned with the design of distribution systems should recognize that the provision of a safe supply at the standpost can be negated by secondary contamination resulting from poor personal hygiene practices by the users.

Privately-owned systems with proper government control provide an option for supply and distribution. Such systems may be found at an individually-owned trading store, a school, or a religious institution. Also, a private individual or company may supply water, either by sale of water directly from the tap or by delivery to individual homes by truck. Public subsidy of privately-owned supplies may be desirable to allow some public control that will assure continuity in maintaining the supply and in providing public access.

Selection and Design of Distribution Systems

From a technical standpoint, the distribution system should be designed by a competent engineer who will gather the information needed. This information includes a topographic survey of the area to be served, the nature and location of the source of supply, the water quality characteristics, the water quantity demands, the possible need to provide for fire protection, the minimum pressure to be maintained in the system, and the availability of materials and personnel, both for the construction phase and the continuing operation and maintenance of the system. Although the criteria for the technical design are of great importance, economic, social, and political considerations are major influences on the selection of appropriate technology. Unless the system is locally suitable, it will receive neither public support nor use.

Although sophisticated methods of cost-benefit analysis are available for decision-making for fully integrated systems, such methods are not applicable to most situations in developing countries. There are simply too many variables that cannot be quantified and whose relative importance from one country to another, or even within different regions in the same country, covers a wide range. Rigorous economic analysis may indicate that overall cost-effectiveness favors a system whose initial cost is high but, because of anticipated lower costs for maintenance and operation, is more cost-effective than one with lower initial costs. Limitations on available funds may justify a least-capital-cost solution, further enhanced by the need to use locally available materials even though use of higher quality materials would reduce long-term maintenance costs. Although it is not possible to generalize for all situations in developing nations throughout the world, systems with the lowest per capita initial cost are often chosen even though long hauling distances and journey time may be involved. Chapter Nine discusses the economics of water supply in greater detail.

Wells with hand pumps are the simplest and cheapest means of providing a good supply. If the pumps are of good quality and there is organization to maintain them, these systems are also the most reliable since hand pumps are simple in construction and easy to repair.

Piped supplies, whether by gravity from springs or upland sources or from sources where pumps are required, can be designed to minimize hauling distances if standposts are used. Piped supplies with standposts have advantages over hand pumped wells. They not only make it possible to provide a greater number of distribution points more conveniently located and reduce manual labor required for pumping, but they also allow greater quality control at the source. The cost of a piped supply is usually greater than that for a well and hand pump system and generally requires more inspection and maintenance. Despite the benefits of a piped supply, the additional costs may not be justified or economically feasible in a rural setting or small village.

Before making a decision to develop a piped supply, the social and economic benefits as well as the health benefits should be carefully evaluated. Health benefits may not be realized to the extent anticipated unless concomitant attention is given to personal hygiene education.

The transmission and distribution of water through a piped supply to individual homes requires several interdependent units which must be properly designed, constructed, operated, and maintained to provide the service intended. As noted earlier a source at sufficient elevation to allow gravity flow at the pressure needed to supply the consumer is highly reliable. The water would be transported through pressure conduits to a service reservoir and then to a pressure pipe. A combination of gravity flow to a treatment plant and pumping to the distribution system may be required, depending on topography.

Direct pumping into water mains is common but has the disadvantage that an interruption in power disrupts the supply. In a direct pumped system, wide variations in pressure can occur depending on demand, unless the pumping arrangement is such that additional pumps are activated as demand increases. The pumping arrangements necessary to meet variations in demand can be provided but require careful design and operation. A preferred system is pumping with provision for storage of water in elevated tanks. Constant speed pumps can be used. During periods of low demand, the excess water being pumped is used to fill the reservoir. The stored water provides a supply during peak hourly demands and is available for fire fighting purposes. Elevated storage also assures that a predetermined pressure level can be maintained in the system.

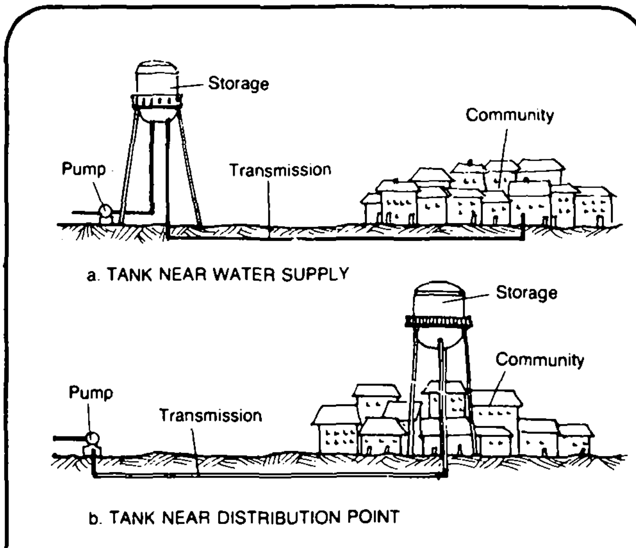
Other advantages to elevated storage are: (1) the use of smaller diameter pipes from source to reservoir than would be required if pumpage were directly to the village distribution system; and (2) with proper valving, supply can be maintained during periods when maintenance and repairs of the transmission conduit from source to reservoir are required.

From the consumer's point of view, a continuing supply of water, even during power outages, and a supply at reasonably uniform pressure, as provided by a service reservoir, instills confidence in the reliability of the system. This is important because consumer confidence in the system frequently influences the ease of collection of charges. If a simple, dependable well and hand pump system is replaced by a piped supply without a service reservoir, interruption in the piped supply caused by pump failure, power outage, or a break or excess leakage in the piping system may destroy consumer confidence and make the consumer reluctant to pay for the support of the system. The more complex and expensive systems require a higher level of operation and maintenance which means that operating personnel with the skills to make repairs quickly and effectively are needed. It is also important to have an adequate inventory of replacement parts for pumps, pipes, valves, and other devices.

Storage Requirements

The volume of storage that must be provided depends on the pattern of water withdrawal in the community. There are wide variations in withdrawal patterns in different parts of the world. A factor of particular importance is the peak daily demand rate. In addition to meeting the peak daily demand, provision should be made to store enough water for normal breakdown or maintenance interruptions.

The location of the service reservoir influences pressure distribution and available supply. If topography is suitable, the reservoir should be located on high ground, close to the center of the demand area. If the site is flat, an elevated storage tank will be required. This should be close to the central distribution area to minimize friction losses by avoiding long service mains and larger diameter pipes. An attractive reservoir in the center of town is often a source of pride to the population, and with a small amount of park area and landscaping can serve as a focal point for community social and political gatherings.

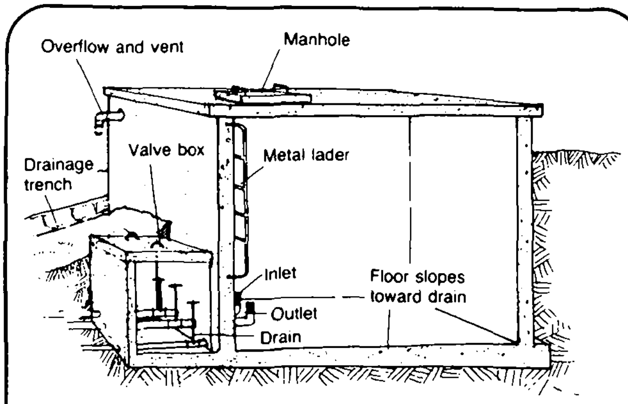


Elevated Storage for Large Populations

The choice between ground storage and elevated tank storage to equalize flow rates and pressures depends on local topographical conditions. Storage in ground level reservoirs is usually advantageous because of lower initial costs and ease of maintenance. If high ground is available within reasonable distance of the community, a ground level reservoir can provide a gravity supply at adequate pressure to the distribution system. The pipeline from the reservoir must be designed with sufficient capacity not only to supply present needs, but also to meet future demands in areas where growth is expected, and to supply future community facilities such as hospitals or schools. Location of such future facilities may be restricted if the pumping equipment, reservoir, and pipelines are not properly designed.

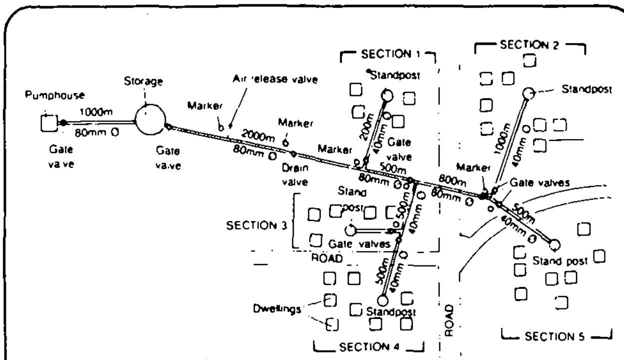
The pressure in the distribution system depends on the water level maintained in the reservoir. During periods of heavy demand, the hydraulic grade line—the level to which water would rise at any point in the system—becomes steeper because of increased head loss from greater friction in the distribution system pipes. When the tank is located in the center of the distribution area, water is pumped into the reservoir during periods of low demand, while at the same time a supply is provided to the consumers. During periods of high demand, water is supplied to consumers from both the source and from the reservoir, although there is some decrease in pressure in parts of the system.

Ground level reservoirs are usually constructed of masonry, mass concrete, reinforced concrete, or steel. Reservoirs may have earth embankments as walls if soil conditions are such that there is no excessive leakage. If leakage is a problem, the reservoirs can be lined with concrete, rubble masonry with cement joints, or plastic sheets. Such reservoirs are not usually covered, and evaporation losses may be excessive. Water from open reservoirs should be treated before it is distributed because of contamination from the catchment area and from humans or animals.

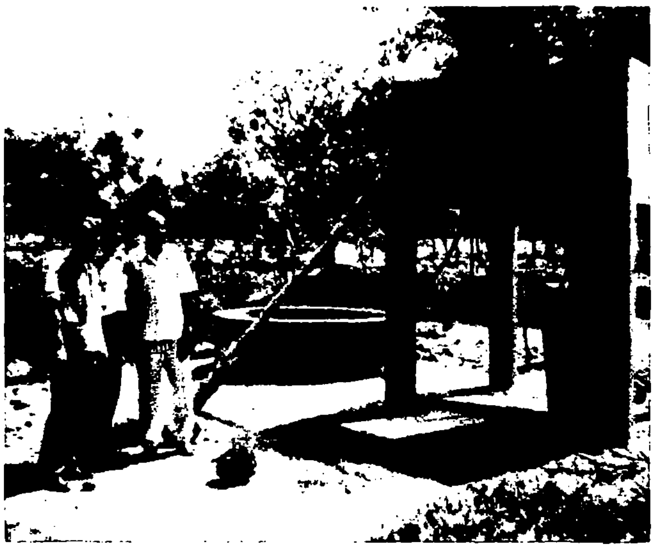


Ground Level Storage Tank

Elevated tanks may be constructed of reinforced concrete, steel, or wood. Steel is most widely used, but requires more maintenance to protect it from corrosion. Wood tanks for smaller communities are relatively easy to construct where suitable materials are available. Careful construction is required to prevent leaks and resulting deterioration and unsightly appearance. Wood tanks also present problems since they more readily support bacterial growth than do concrete or steel tanks. Although the basic consideration in the design of storage facilities is cost, pleasing architecture should not be overlooked. An elevated tank can be aesthetically attractive and gain public esteem at little additional cost to the community.



Design Map of Transmission Main and Distribution System


Small scale elevated storage tanks can be constructed inexpensively.

Distribution System Layout

The configuration of the distribution system is dictated by the layout of existing community housing and the direction of development. Systems are described as branching, grid, and looped or belt systems, but in many cases the system may be a combination of types of layout.

The grid or grid-loop system layout is preferred. The pipes are interconnected which provides for circulation throughout the distribution system, reducing stagnation at dead ends such as can occur in a branching system configuration. With proper location of valves, it is possible to isolate a small portion of the grid system for repairs and still provide water to consumers at other points without interruption. Incorporating a loop in the system improves water pressure and delivery to commercial, industrial, or heavily populated districts.

Branching systems are simple to design and construct and are less costly than other types because they require less pipe, fewer valves, and smaller diameter pipe for most sections of the area. In small villages, the branching system may be the preferred choice despite the disadvantages of stagnation at dead ends. This disadvantage can be alleviated by periodic flushing at hydrants located at dead ends.

Pipe Materials

The principal factors to be considered in the selection of pipe are: local availability; durability, which includes strength and resistance to internal and external corrosion; initial cost, and ease and cost of installation and maintenance; types of joints to minimize leakage; and ease of tapping and making repairs.

The relative importance of these features varies, depending on local conditions, with the result that different materials will be selected at different locations. Materials in common use are cast iron, steel, asbestos cement, concrete, plastic, copper, brass, galvanized iron and steel, and wood. Bamboo is also used, particularly in gravity systems in rural areas. Although a bamboo system is relatively easy to construct, and where available is inexpensive, it is not suitable for pressure systems and has a relatively short useful life.

Regardless of the type of pipe used, it is important that the pipe be handled and laid with care to avoid damage during construction and subsequent failure resulting from improper support of the pipe when in place. Cast iron pipe has a long history of successful use and is produced in various diameters. Although quite resistant to corrosion, the carrying capacity may be decreased as a result of tuberculation, which is the formation of pits and growth of nodules on the interior of the pipe. This type of pipe is usually lined with cement mortar, plastic or other linings. The pipe can also be protected from external corrosion caused by contact with certain soil types. With proper lining and coating, cast iron pipe has an extremely long service life. The usual length of cast iron pipe is about 4m.

Steel pipe is lighter and more easily handled for assembly purposes than cast iron pipe. It is, however, more subject to corrosion unless properly lined and coated. Steel pipe is available in a wide range of sizes, from 1.25cm diameter up to 180cm. Larger diameters can be provided by riveting or welding steel plates on the job. Large diameter pipes are subject to collapse unless the pipeline is provided with adequate vacuum relief devices.

Asbestos cement (A-C) pipe is made of asbestos fibers, sand, and cement. It is strong, light in weight, easy to install and can be readily tapped. The pipe is not subject to corrosion by water supplies although it can be corroded by sewage. Couplings for A-C pipe are relatively inexpensive and have rubber rings to provide a watertight seal. A-C pipe is available in sizes from 100mm and larger, in 4m lengths. Asbestos fibers have been linked to cancer so it is best to use another type of pipe.

Plain concrete pipe is relatively inexpensive and useful for pipelines under low pressure. It is not subject to tuberculation. For low pressure installations, a caulked mortar bell and spigot joint can be used. Precast concrete pipe with lock-joints is used for high pressure installations to provide a watertight system.

Plastic pipe is widely used and has many desirable features. It is available in sizes from 1.25cm and up. The types of plastic pipe in common use are polyvinylchloride (PVC), polyethylene (PE), polybutylene (PB), and ABS (acrylonitrile, butodiene, and styrene). Plastic pipe does not corrode, is light in weight, and easily installed. PVC and PE pipe are the types principally in use for potable water supplies. Polyethylene (PE) tubing is available in 30m rolls in small sizes, is very flexible and easily handled. Copper, brass, and block and galvanized iron and steel are widely used with satisfactory performance, particularly in the smaller diameters, as service piping from the distribution system to standposts or to individual homes or other buildings.

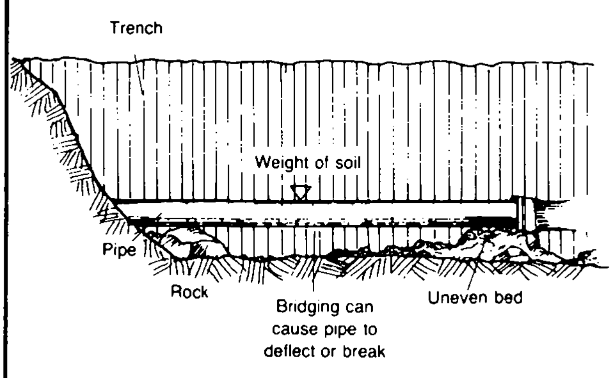
Regardless of the type used, all pipe should be handled with care, inspected for defects, and the inside of the pipe cleaned of dirt or any other materials which may have gotten into the pipe during transport and/or construction. The pipe should be properly supported and, when laid in a trench, provided with adequate bedding to avoid undue stress on it resulting from the backfill (cover) placed over the pipe or from uneven settling of the backfill.

The grade at which pipes are laid should be uniformly up or down, avoiding a ripple-type of grade and avoiding high points as much as possible. At places where high points are unavoidable, air relief valves should be located. These could consist of T-fittings, with a vertical leg of the T much larger in diameter than the diameter of the pipeline. The T should be plugged at the top. The plug can be tapped with a line going to the ground surface where a faucet can be located to allow for periodic manual release of air.

The sudden shut-off of a pump or closing of a valve can induce water hammer in a pressure pipe with resulting pressures far in excess of normal operating pressure. The condition had been known to cause buried pipes to blow out of the ground. Consequently, it is very important to "anchor" pressure pipes at all vertical and horizontal bends. The best way to do this is with restrained joints, but concrete thrust blocks can also be used. The advantage of the former is that they depend only on the weight of the pipe itself and the water it contains to keep the joints from blowing apart. Thus, the ground can be excavated near the pipe and the pipe will still be protected. The disadvantage of the latter is that, if the soil adjacent to the concrete thrust block is excavated, the pipe is no longer protected.

Before the pipe is covered, it should be tested for leakage by slowly filling it with water. The pipe line should be practically watertight for small diameter systems. Any joints that show excessive leakage should be repaired or replaced. Backfill material should not contain large stones or other objects which could hit the pipe and damage it.

Before a new line is put into service, it should be flushed thoroughly at a sufficient velocity to remove any particles of dirt which may have entered the pipe during the laying process. Following the flushing operation, the pipe line should be disinfected by filling it with a chlorine solution with a concentration of 50mg/l of available chlorine. The strength of the chlorine should be tested several times during a 24-hour period to ensure that the chlorine level is maintained. The chlorine solution should be flushed out at standposts and individual services to ensure their disinfection. The entire stretch of line being disinfected should be thoroughly flushed out with the potable source water. The line can then be used by consumers.



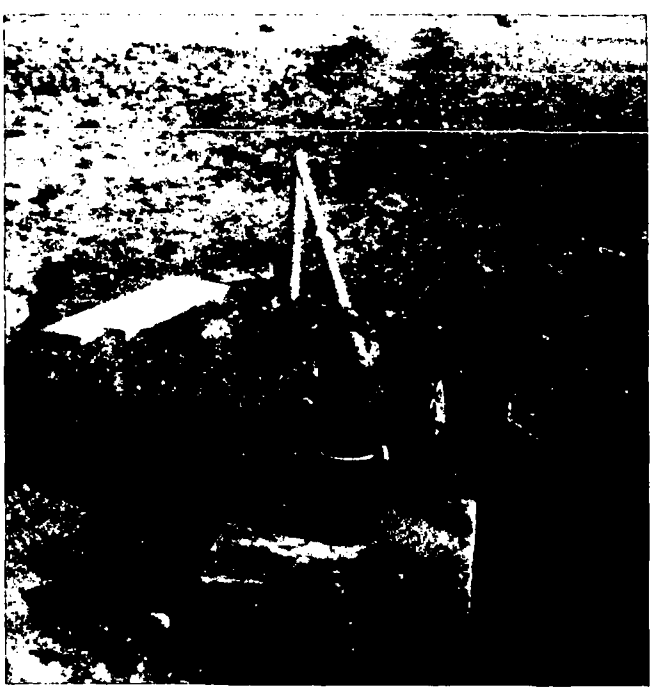
Incorrect Pipe Installation

Operation and Maintenance

Operation and maintenance considerations must be stressed at each stage of the water system development process. It should be kept in mind that at the village level in developing nations, a trained engineer will not be on hand to deal with the malfunctions that inevitably occur. Often, system users themselves will have to perform routine maintenance tasks. Developing the human resources to maintain systems is discussed in Chapter Eight. Here it should simply be noted that trained personnel and other resources are likely to be scarce. Therefore, whenever design decisions are being made, the question should be asked: "How easy will this be to operate and maintain?" Ask the question when:

- a water source is identified;
- a retrieval system is being designed;
- a treatment technology is being selected;
- a distribution system is being designed;
- a pump is being chosen;
- lengths of pipe are being selected.

A system which is technically well-designed is of no use if it falls into disrepair and is ignored by the intended users. System planners should establish a maintenance program to keep this from occurring. This includes infrastructure development, personnel selection, training, supply of spare parts, and community support.



Improper maintenance of pumps (note water leakage) will eventually cause serious problems.

Operation and Maintenance of Facilities

Correct operation and maintenance procedures should be established when the project is begun. These procedures will help maintain quality by assuring that the well or intake structure is protected against contamination. Thorough and regular inspection of pumps and monitoring of conditions which affect the system's yield will help keep the quantity of water provided constant. Materials required for maintenance, such as chlorine and tools, should be kept in stock. These procedures are most successful when one or more individuals are trained and assigned the responsibility of carrying them out, there is systematic supervision and when the community provides adequate funds for them.

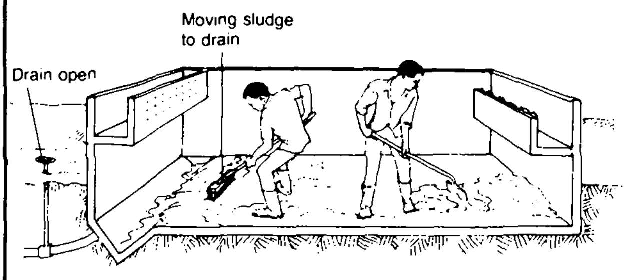
Careful design and consideration of the situation for which a system is planned should reduce mechanical difficulties, but mechanical problems or failures should be expected and planned for. Spare parts, materials and tools should be kept on hand so that trained personnel, if available, may make the necessary repairs as soon as possible. If this is not feasible, a system for procuring the required materials or expertise should be established. In some villages, there may be someone already responsible for operation of an existing facility—the electric light plant, a corn processing mill, a bicycle repair shop. Advantage should be taken of these skills in operating and maintaining the water supply system.

In the same way, there may be an organization with a shop located at the regional level to oversee the operation and maintenance of farm or highway equipment. This organization might be willing to add another section to backstop the operation and maintenance of rural water supply systems in the area. These possibilities should be investigated by the national or regional safe water agency and the local water committee before it is decided to set up separate water supply operation and maintenance support facilities at the local and regional levels.

Need for Routine Maintenance

The basic requirement for a maintenance program is the availability of detailed maps and records showing the location and sizes of all wells, intakes, treatment and storage systems and structures, and all pipes, valves, pumps, standposts, hydrants, house connections, and any other information which will facilitate routine inspection and maintenance. Reliance should never be placed on memory. All records of service and repairs of equipment should be maintained in a central set of record books and, together with the location map, should be kept up to date.

A major deficiency in the management of rural water supply systems is the lack of a systematic routine maintenance program. The person in charge of the system, with help from the water and sanitation agency, must clearly define in writing responsibility for maintenance and see that the detailed maintenance



Cleaning Out Sedimentation Basin

schedules are followed. Managers also have the responsibility to ensure that maintenance personnel have proper tools, replacement pipe and spare parts, and access to shop facilities for maintenance and repair. Managers should know to whom they can go at the local, regional or national level for assistance when confronted with problems they cannot correct alone.

Water quality must be clearly understood and should be uppermost the minds of those responsible for the operation and maintenance of the water system. Periodic testing to determine bacteriological quality in the system should be a routine procedure wherever possible. Unfortunately, in many areas throughout the world, bacteriological control on a routine basis is not possible because of the lack of laboratory facilities within reasonable proximity of the village. The cooperation of a nearby hospital should be solicited to test the water periodically if it is at all possible to get samples to the hospital facility. Other alternatives are the use of potable water-testing kits and/or mobile laboratories.

It is incumbent on the operator to take special precautions to thoroughly disinfect the system whenever a pipeline failure is repaired or an extension made. The operator must also be constantly on guard to prevent cross-connections between the community's supply and one which is not under the jurisdiction of the community. Such cross-connections can occur, for example, when an individual uses a private well of unknown quality as an alternate supply and through a connection to the community supply introduces the potential for contamination.

Maintaining positive pressure in the system should be stressed in instructions to operators. Pumping from the system (e.g., for rooftop storage or for fire fighting) should not be allowed to drop the pressure below atmospheric pressure. Valves and hydrants, if provided, should be inspected on a regular schedule at least every three months. Hydrant repairs should be made at once to stop water wastage from leaks. Mains should be flushed regularly to prevent accumulation of excessive deposits, particularly in over-sized lines with low velocity of flow, and at dead ends.

Pipeline maintenance includes repair of main breaks, joint leaks, broken service lines, and leaks in valves and other fittings. There should be no delay in repairing any detected leak. Every leak should be looked on as an emergency situation. A policy of preventive maintenance of equipment should be instituted and supervised for all systems. Such a policy reduces the requirements for standby units.

Maintenance as a Test of Progress

This chapter began with the thought that, in the International Decade for Water, developing nations would try to improve water systems in as many communities as possible. It would be unfortunate if improvements were seen largely in terms of new system construction with little attention paid to how well systems are maintained, as has often been the case in the past. International donor patterns have probably been a factor in this; development funds have been available from external sources whereas maintenance funds usually must come from the developing country's limited budget or from the community. Whatever the reason, *lack of maintenance is the main reason rural water systems in developing nations break down.*

If scarce resources are not to be wasted, developing country governments and international donors must place greater stress on maintenance. In fact, the case can be made that maintenance and repair of existing systems should even receive a higher priority than new construction. In the first place, most developing nations already have a backlog of systems that need major repairs or routine maintenance. Secondly, if the intent is to serve more people, the number of water supply systems actually working, not the number of systems built, is the real measure of the quality of service. Thirdly, if the developing country government wants quick results in its water supply program, the best way to get them is through repairing systems, some 20 percent of which may be out of order at any given time.

Finally, repair and maintenance of systems should receive particular stress because it represents a more difficult task than new construction. In the long run, successful operation and maintenance requires community participation of some kind. The community enthusiasm that leads to participation may be easily kindled for the short period required for new construction; it is much more difficult to maintain devotion to successful operation and maintenance year after year.

Thus the real test of progress by developing nations in improving water supply systems lies not only in the number of new systems but also in the number of effective maintenance programs that are carefully set up and supervised. A country that shows solid results in the latter area is truly building for the future.

SOURCES
CHAPTER FOUR

Sources used in the preparation of this chapter include materials produced especially for use by the AID Knowledge Synthesis Project; *Small Water Supplies*, by Sandy Cairncross and Richard Feachem, London: The Ross Institute, 1978; *Village Water Supply: A World Bank Paper*, Washington: World Bank, 1976; *Water, Health and Development: An Interdisciplinary Evaluation*, by Richard Feachem, et al., London: Tri-Med Boods LID, 1978; *Water Supply for Rural Areas and Small Communities*, by E.G. Wagner and J.N. Lanoix, Geneva: World Health Organization, 1959.

RELATED TECHNICAL NOTES
CHAPTER FOUR

RWS.G	Overview of Rural Water Supply
Methods	
RWS.1.M	Methods of Developing Sources of Surface Water
Planning	
RWS.1.P.1	Planning How to Use Sources of Surface Water
RWS.1.P.2	Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources
RWS.1.P.3	Selecting a Source of Surface Water
RWS.1.P.4	Choosing Where to Place Intakes
RWS.1.P.5	Evaluating Rainfall Catchments
Design	
RWS.1.D.1	Designing Structures for Springs
RWS.1.D.2	Designing Intakes for Ponds, Lakes and Reservoirs
RWS.1.D.3	Designing Intakes for Streams and Rivers
RWS.1.D.4	Designing Roof Catchments
RWS.1.D.5	Designing Small Dams

Operation and Maintenance

RWS.3.O.1	Operating and Maintaining Household Treatment Systems
RWS.3.O.2	Operating and Maintaining a Sedimentation Basin
RWS.3.O.3	Operating and Maintaining a Slow Sand Filter
RWS.3.O.4	Operating and Maintaining a Chemical Disinfection Unit

Methods

RWS.4.M	Methods of Delivering Water

Planning

RWS.4.P.1	Choosing Between Gravity Flow and Pumps
RWS.4.P.2	Choosing Between Community Distribution Systems and Household Water Connections
RWS.4.P.3	Selecting Pipe Materials
RWS.4.P.4	Selecting a Power Source for Pumps
RWS.4.P.5	Selecting Pumps
RWS.4.P.6	Manufacturing Hand Pumps Locally

Design

RWS.4.D.1	Designing a System of Gravity Flow
RWS.4.D.2	Determining Pumping Requirements
RWS.4.D.3	Designing a Transmission Main
RWS.4.D.4	Designing Community Distribution Systems
RWS.4.D.5	Designing a Hydraulic Ram Pump

Construction

RWS.4.C.1	Installing Pipes
RWS.4.C.2	Installing Mechanical Pumps
RWS.4.C.3	Installing Hand Pumps
RWS.4.C.4	Constructing Community Distribution Systems
RWS.4.C.5	Constructing a Distribution System with Household Connections

Operation and Maintenance

RWS.4.O.1	Detecting and Correcting Leaking Pipes
RWS.4.O.2	Operating and Maintaining Mechanical Pumps
RWS.4.O.3	Operating and Maintaining Hand Pumps
RWS.R.O.5	Operating and Maintaining Household Water Connections

Methods

RWS.5.M	Methods of Storing Water

Planning

RWS.5.P.1	Determining the Need for Water Storage

Design

RWS.5.D.1	Designing a Household Cistern
RWS.5.D.2	Designing a Ground Level Storage Tank
RWS.5.D.3	Designing an Elevated Storage Tank

Construction

RWS.5.C.1	Constructing a Household Cistern
RWS.5.C.2	Constructing a Ground Level Storage Tank
RWS.5.C.3	Constructing an Elevated Storage Tank

Operation and Maintenance

RWS.5.O.1	Maintaining Water Storage Tanks

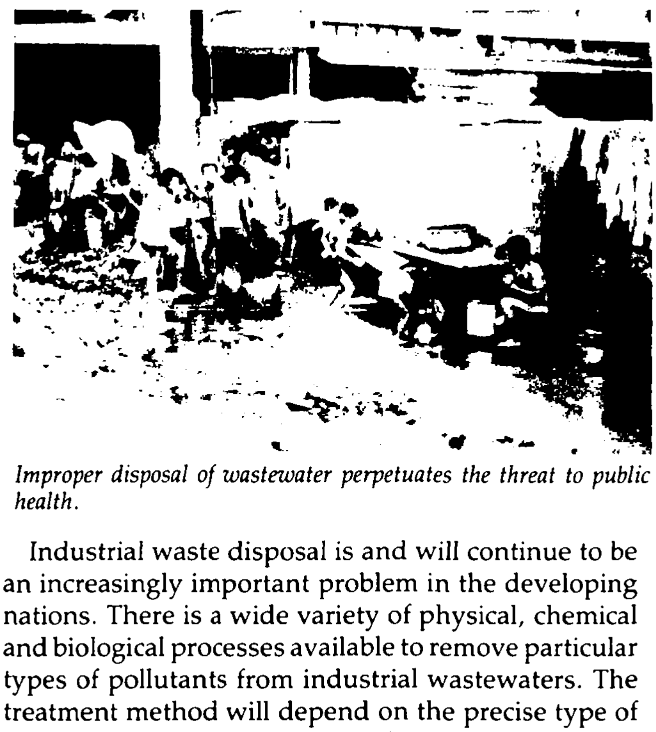
CHAPTER FIVE
WASTE DISPOSAL SYSTEMS

SUMMARY

Waste disposal includes non-water carried human excreta disposal, domestic wastewater disposal, solid waste disposal, and industrial waste disposal. The most common non-water carried human excreta disposal methods are bury and cover, overhang toilets, bucket deposit and collection, pit or vault privies, bored hole latrines, water-sealed privies, aqua privies, compost toilets, chemical toilets, burn-out or incineration toilets, and oil-flushed toilets. These are listed in order of least to most complex.

Domestic wastewater disposal methods suitable for use in rural communities in developing nations include septic tanks, cesspools, evapo-transpiration beds, elevated mounds, package aerobic units, sand filters, trickling filters, and stablization ponds. If certain conditions can be met, the water-sealed privy is probably the best non-water carried excreta disposal method. The choice of a wastewater disposal method depends on the amount of wastewater to be disposed of, the resources available, and the type of soil present.

Urban or town solid waste disposal on an organized, community-wide basis can be an expensive, labor-intensive undertaking. In many rural villages, scavenging and re-use of waste materials makes solid waste disposal a relatively minor problem. If a solid waste disposal system is needed, it should probably be one such as composting that allows for re-use of waste material or a sanitary landfill which allows the land to be used later for another productive purpose.



Improper disposal of wastewater perpetuates the threat to public health.

Industrial waste disposal is and will continue to be an increasingly important problem in the developing nations. There is a wide variety of physical, chemical and biological processes available to remove particular types of pollutants from industrial wastewaters. The treatment method will depend on the precise type of industry and the pollutants which need to be removed from its wastewater.

CHAPTER FIVE
WASTE DISPOSAL SYSTEMS

Waste disposal covers (1) non-water-carried human excreta disposal and domestic wastewater disposal from bathing and food handling in the home, (2) solid wastes, and (3) industrial wastes. Methods of human excreta disposal include non-water carried arrangements such as pit or vault privies; on-site disposal such as septic tank systems that do not use collecting sewers; and water-flushed systems that carry wastes to sewers. The latter two procedures can readily handle domestic wastewater which is often called gray water or sullage. Within the three broad categories of human excreta disposal methods, there are a number of variants which are discussed here in order of the simplest means to the more complex. Solid waste choices are treated in a similar manner. Finally, industrial wastes are considered briefly because, even though they are not a major problem in rural villages, they may affect the quality of rural water supplies. As industrial processes grow and move into the countryside, those responsible for the health of the people need to think and plan ahead for the coming industrial pollution problems which will be generated.

While the resources needed for each waste disposal method are indicated and the requirements for operation and maintenance are given, details of design, dimensions and construction are not included. These may be found in the appropriate Technical Notes listed at the end of the chapter. This chapter is intended only to provide an overview of waste disposal methods. The compendium of methods is quite long but, in some instances, many of the alternatives can be readily set aside because of cultural preferences, required technical skills, or the availability of water. There will then remain only two or three methods from which a choice is actually made.

Excreta Disposal Without Water Transport: Alternate Methods

The following methods, in order of least to most complex, are the most common ones for disposing of human excreta without water transport: (1) Bury and cover; (2) Overhang toilets; (3) Bucket deposit and collection; (4) Pit or vault privies; (5) Bored hole latrines; (6) Water-sealed privies; (7) Aqua privies; (8) Compost toilets; (9) Chemical toilets; (10) Burn-out or incineration toilets; (11) Oil-flushed toilets.

Bury and Cover

This method is as simple as it is primitive. A person uses a paddle, shovel or any improvised digging tool to open a small hole, defecates and covers the feces, effectively isolating it.It is important to bury the feces four to six inches deep to lessen the chance that hookworm larvae that hatch in the feces work their way to the surface and infect barefoot workers. While bury and cover can be fairly safe in dry climates and dry seasons, it should not be used in high rainfall areas on land that is a watershed for a domestic water supply. Sandy, soft top soil makes digging easy. Clays and rocky earth make the method difficult and perhaps even impossible. Young children cannot use this method and it is unsuitable for small homesites or densely built-up villages. Bury and cover can and should be used by field workers and other outdoor laborers without access to alternate facilities.

Overhanging Toilets

A perch over a body of water is a type of toilet. The perch must clear the bank to be sure the excreta falls into the water. The point of discharge must be downstream of other water uses. This method is primitive but it is no worse than the dangerous practice of towns and cities discharging sewage without any treatment to streams, rivers, lakes, bays, and the oceans. Overhanging toilets can be highly dangerous to health if the perch is over a pond where fish can be infected with human liver flukes (Clonorchis or Opisthorchis) or a stream where crabs and crayfish can be infected with lung flukes (Paragonimus).

Care must be taken to ensure that washwater is not used for cooking or drinking.

Bucket Deposit and Collection

Waste disposal by defecating and urinating in a bucket is a common practice. The bucket can be placed below a seat against the outer wall of a house. There must be someone to remove the bucket, empty it, clean it and put it back in place. Many societies simply reject having people do such tasks. Careful handling is required throughout to avoid contact with infectious human excreta. The excreta has fertilizing and soil conditioning value after it has been stored or composted.

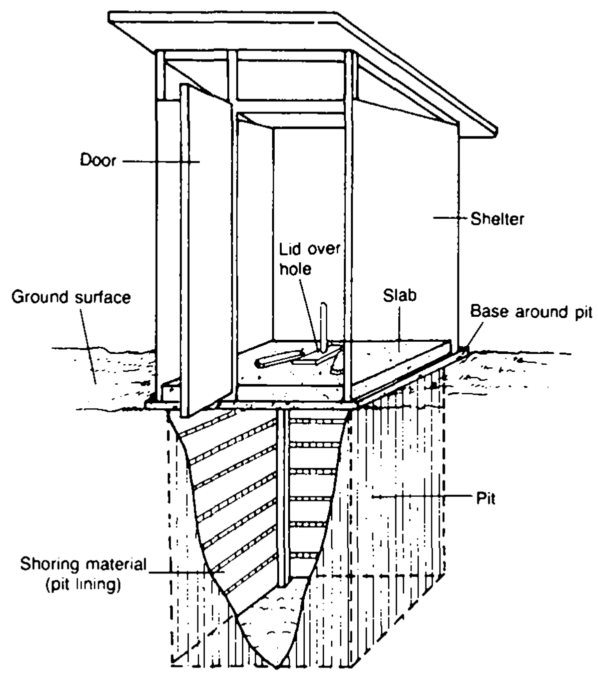
Pit and Vault Privies

These are excavated chambers in the earth with a minimum capacity of $1m^3$. If the excavation is lined with concrete, brick, or plaster-sealed masonry, it is a vault privy. Otherwise, it is a pit privy. The key structural feature to either type of privy is the slab or floor which covers the pit, supports the users, and determines the dimensions of the pit and the privy superstructure. Where privies are promoted and installed in organized campaigns, concrete slabs are usually made at a central shop. Although wooden or bamboo slabs may be used, the advantages of concrete slabs are strength, durability, re-use over subsequent pits, and ease of cleaning. The slab should have slightly raised step plates for positioning while squatting and a cover for the drop hole that can be set aside when the privy is being used, or a more elaborate seating device with a riser, seat and cover can be installed.

The bacteria and chemicals from human excreta move from the pit through the soil. Pathogenic organisms move very little as they do not survive in a totally alien environment. Chemicals in solution, such as chlorides and nitrates, can move with subsurface water flow for 200m or more. Pits should be located at least 15m from well and spring water sources. The pit should be downslope from the water sources as the infiltration water will follow the surface slope.

Customarily pits are square and usually are shown that way in illustrations. However, a circular pit of 85 to 90cm in diameter can be hand dug and is more resistant to caving as the walls have the strength of an arch. Where soils are loose, sandy and cave easily, liners of wood, bamboo or masonry must be used. Lining will increase the cost of a unit by 40 to 60 percent. The more readily available lining material, wood and bamboo, will rot in two or three years, which is about five years short of the expected useful life of a pit. The life of a pit or vault depends on the amount of use it gets and the speed of decomposition of the excreta. In hot regions, decomposition is rapid which extends the life of a pit or vault. The bottom of the pit or vault should not reach into the water table if it can be avoided.

The privy superstructure should be of local materials and use local methods of building. Elaborate designs and structures such as brick and concrete block are impractical because they cannot be moved when the pit is full and the slab must be moved to cover a new pit and because the costs become exhorbitant. They may be incompatible with the modest homes of rural people. Incredible though it may seem, there have been projects in which the privy installations cost more than the families' homes.



Pit Privy

Where a seat is used, a lid provides a cover for the pit below. The cover for a squatter slab can be a board fitted to cover the opening with a vertical handle 50cm in length. The matter of a cover can be left to the family's choice but its availability and use is important if fly-breeding and foul odors are to be avoided. The greatest health benefit of a privy pit or vault is that human excreta, particularly feces, is isolated, off the ground surface, away from water sources, and much less accessible to insects and domestic animals.

There may be fly breeding and odors associated with privies. The best preventive measure is keeping the lid in place and daily cleaning of the slab, seat and cover since urine on them is a major source of odor. Odors from pit contents can be totally controlled by the addition of lime or agricultural limestone but such materials may not be easily available to rural people in most of the world. The ashes from wood or straw cooking stoves, if added to the pit regularly, will also help control odors. Fly control depends on the cleanliness of the privy and the use of the cover to ensure darkness in the pit or vault since flies move toward the light. An effective means of fly control is a tube, 6 to 10cm in diameter and 1m long, inserted obliquely from outside the edge of the mound and the privy superstructure just into the pit. If flies are bred in the pit, they will move up the tube toward the light. If the exit end is open, they will fly away carrying germs and be able to go on breeding. If the exit end of the tube is capped as it should be with plastic screening, the flies will live out their lives in frustration. Metallic screen can be used but it will usually corrode in less than a year. The tube also provides some ventilation of the pit, reducing odors.

A vault to hold human excreta dropped directly into it requires an impervious chamber. The most likely material is concrete, although brick, concrete block or masonry can be used. Whatever the material, vaults are costly. They may be suitable where homes are close together, yard space is very limited, and there is no prospect of water-carried waste disposal. Vault construction is demanding of skills, material and cost. As the vault is a storage chamber where some decomposition reduces the volume of the contents, sooner or later it will have to be emptied. This should be considered when the vault site is chosen and it is constructed. The contents of the vault must be disposed of or treated for use as fertilizer. Sanitary trenching and composting are acceptable methods of disposal. In comparison, at the end of the useful life of a common pit privy, all of the above-surface parts can be placed over a newly dug pit and the old one covered with the newly excavated earth. Vault privies are not used widely. They may be a good alternative in areas with loose sand and badly caving soils.

Bored Hole Latrines

Such latrines were used in some campaigns in the South Pacific, particularly on the Philippine Islands fifty years ago. They persist in the literature. A specially built boring machine manually turned by a crew of four is required. The machine bores a hole 30cm in diameter which extends to the upper groundwater strata so that the excreta will move into the ground water and extend the life of the bored hole. The volume of the hole is only $0.2m^3$ since 5m is the maximum depth. Filling is rapid and the family cannot replicate the hole at a new location unless they have access to a boring machine and the necessary labor. The slab size required for a bored hole latrine is about one-half of that for a hand dug pit. The reduced expense of a slab is offset by the cost of the boring rig and the labor to operate and maintain it. The small volume of the hole and the penetration of excreta into the upper groundwater strata are serious disadvantages of bored hole latrines. Their use should be avoided.

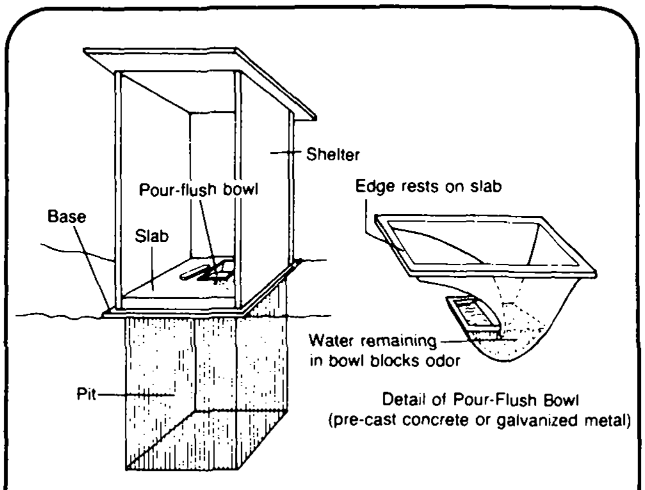
Water-Sealed Privies and Aqua Privies

Some privies are designed so the excreta drops into water. This can be done either by using a trap seal similar in shape to a water closet trap or by extending a drop tube into a water-filled receiving chamber. A water-sealed privy uses a trap while an aqua privy uses an extended tube. These units are considerably more elaborate than pit privies and carry the vault type one step further. The purpose of water seals is to prevent the escape of odors from the chamber in which excreta accumulates.

Even a rudimentary water-sealed privy is an improvement over no system at all.

T' e water-sealed privy has a U-shaped trap below the opening through which feces and urine pass before they fall into the pit. These units are also called "pour-flush privies." The trap seals odors so they cannot escape from the vault into the privy enclosure. Urine and fecal material must be flushed clear of the trap after each use with about three liters of water. A supply of water must be in the privy at all times. In arid areas and during prolonged dry seasons, there may not be enough water to spare for flushing. The water does not have to be clean as it is going to a chamber or pit containing human excreta so sullage or gray water can be used.

Water-seal traps must be made in a central shop. They must be durable, strong, and have a very smooth impervious inner surface. Concrete and vitrified clay are satisfactory materials for water-seal traps. Unglazed clay does not work well as feces sticks to it and urine is absorbed into it. Forms are needed to make traps and people must have or learn the skills required. The Ministry of Health of Thailand developed an excellent procedure for making concrete traps with exceptionally smooth inner surfaces.

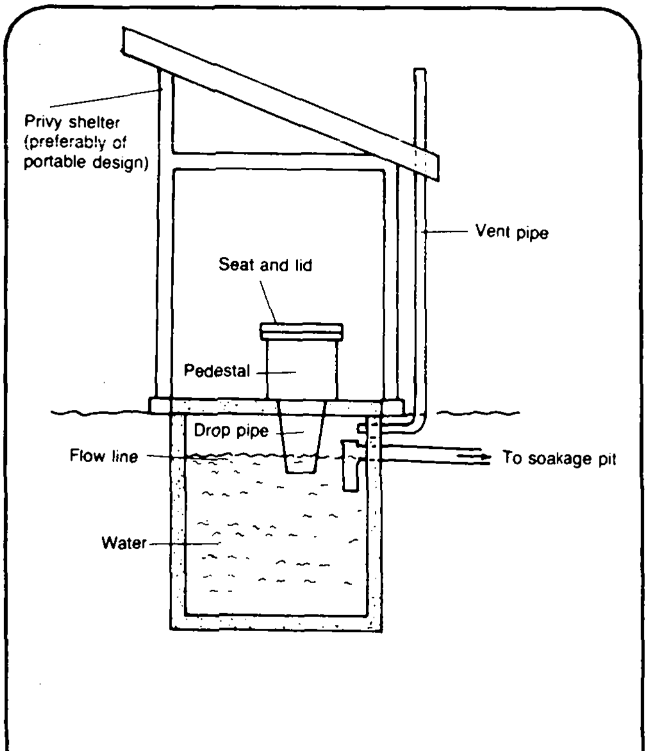


Privy with Pour-Flush Bowl

A slab type pit privy with the trap set in the slab directly over the pit can be designed. The seal not only keeps odors in the pit, it keeps insects and other animals from moving in and out. A venturesome rat might get in, but it will not get out.

A trap with an off-set seepage pit can also be used. The likelihood of stoppage in the connecting line from the trap to the pit is a great disadvantage of this design and it requires more fabricated material—the pipe. There is no advantage to an off-set pit.

Rather than a trap, aqua privies have a tube that extends into an impervious water-filled vault. Water is not needed for flushing but it is required for cleaning. The funnel-like opening and chute must be kept meticulously clean since they can quickly become filthy and malodorous. Cleaning after each use is necessary. The interior surface must be smooth, impervious and easily cleaned.



Completed Aqua Privy

Since the vault is filled with liquids at all times to keep the seal, there is displacement of liquids with each addition of waste and water. The displaced liquid is carried by a pipe to a seepage pit or a subsurface soil absorption line. An aqua privy is much like the tank portion and absorption line of a septic tank system except the excreta is being deposited directly to the "tank." The vault can be constructed in the same manner as for a vault privy. Aqua privies may be converted to modest-sized septic tank systems when water closets are installed in a house. These can also be incorporated into small bore sewers when sewerage becomes available. The cost of aqua privies is much greater than that of common pit privies. For the vast majority of rural village home use, aqua privies are too costly.

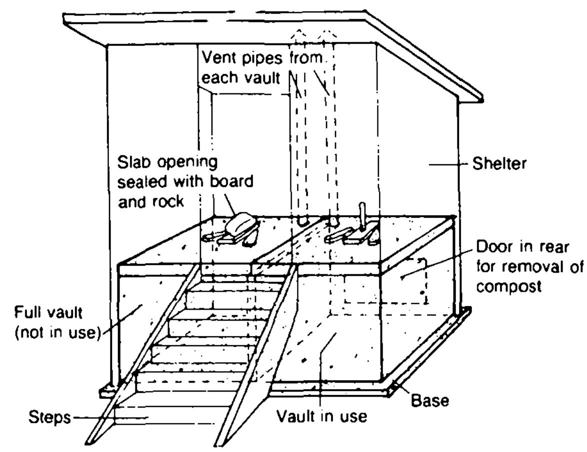
Water-sealed and aqua privies accumulate semi-solid sludge. Like septic tanks, they must be cleaned out from time to time. They therefore must be designed so that a part of their cover can be opened to get at and remove the sludge. There must also be a sanitary means of disposing of the sludge by trenching, composting, or adding to a stabilization pond.

Compost Toilets

Composting involves aerobic stabilization of organic material. In Scandinavian countries, Canada, some parts of the U.S., and France, there are a variety of compost toilets in use in vacation homes on lakes and in the mountains. Such home-made models may be feasible for some users. Compost toilets require no water, they do not freeze and, if properly designed and operated, they can be installed in homes and other buildings without excessive odor nuisance. Under properly controlled conditions, the composted excreta can be used to fertilize soil.

Aerobic composting is a relatively odorless process of treating organic wastes to make them odorless, unattractive to flies, reasonably dry and suitable for use as fertilizer for certain crops. The process takes place in materials with a moisture content of from 40 to 65 percent. The material must be exposed to air by periodic turning and mixing or by other means. Wet material can be applied over, or mixed with, dry or precomposted material to bring the moisture content to within the required limitations.

Compost units have been improvised from such objects as oil drums. In the Philippines, a modified compost toilet consists of a perforated oil drum in a well-ventilated, woven palm enclosure, under the floor of a simple bamboo house. By periodic stirring, the fresh excreta is mixed with partially composted material and becomes dry and almost odorless. If perforated drums are used, one can be rolled out of the enclosure and replaced by another. The partly filled drum can be rolled periodically or the material stirred to complete composting while the other is being filled.



Compost Toilet

Two essentials for compost toilets are air and ventilation. The air supply from outside passes under the composting mass and to some extent through it and over it. If the process becomes anaerobic, the odors are very strong and perhaps even dangerous as explosive methane is a large component of the gas mixture. Such units are not suitable for widespread campaigns for improved excreta disposal in rural villages.

Chemical, Pump-Out Toilets

Such toilets are familar to travellers on jet aircraft. What looks like a conventional water flush toilet is in fact a chemical mix which is recirculated through filter screens. The intense blue liquid contains dispersants, emulsifiers, deflocculaters, and deodorizers. Aircraft units recirculate the liquid as many as 80 times without it appearing to have had any contact with human excreta. That is the most sophisticated use of chemical toilets.

Simpler forms are portable units for workers harvesting crops, on construction jobs, and for public use at temporary entertainment events. Such variants are a plastic molded unit much like a privy, with a toilet seat and a tank below it. The tank contains the chemical mix and there is no recirculation. After sufficient use, the tank is pumped out and the mix replaced. The pumpage is trucked to a sewage disposal point. The need for specially prepared chemical mixes, pumpage and disposal rule out the use of such units in rural villages and towns.

Incineration or Burn-Out Toilets

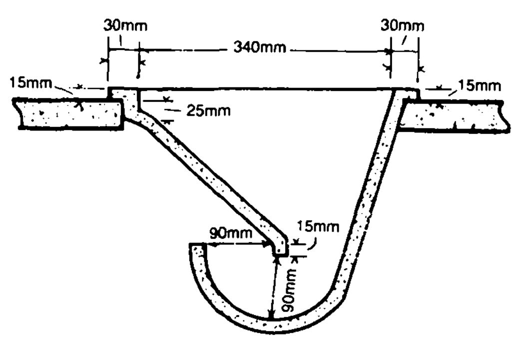
These require an input of fuel, gas, kerosene, or wood which are generally too limited and too costly to use to burn human feces. It is far better to collect the raw feces and spread them on fields of crops not to be eaten raw. There have been applications in rural areas in cold climates in which the receiving chamber serves as a fire-box with a chimney and openings for fuel and air.

Oil-Flushed Toilets

Toilets like this are very elaborate and have a place only where the energy facilities and mechanical capabilities of an urban industrialized community are readily available. The flushing liquid is pumped recirculated mineral oil. The flushed material goes to a holding tank where the feces settle. Settled sludge is pumped out periodically. The oil rises to the top of the tank. It is filtered chemically to remove odiferous substances and prepare it for re-use. Oil-flushed toilets have been used in areas with severe water shortages but they are not a good choice for rural areas of tropical and semi-tropical regions.

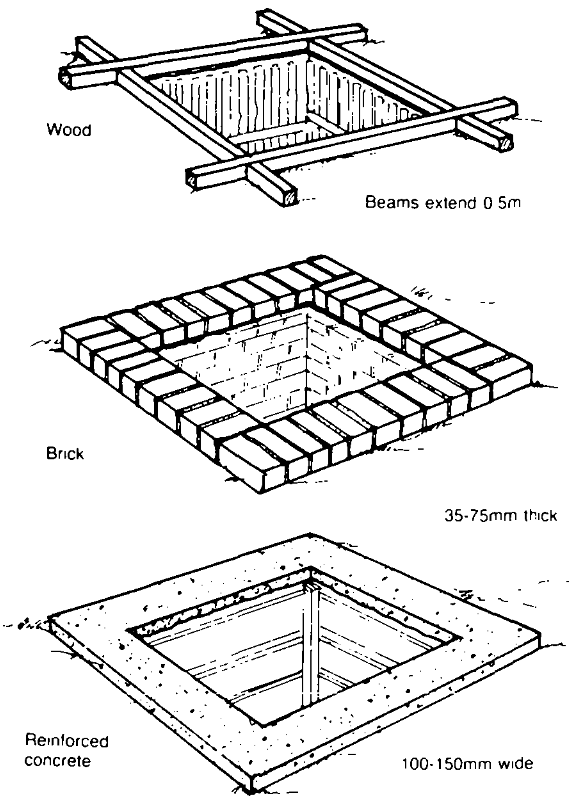
Excreta Disposal Without Water Transport: Ranked Choices

1. The *water-sealed privy* isolates human excreta from the ground surface and from water sources. The trap seal prevents access by insects and small domestic animals, including rats, and prevents the escape of odors. Water must be readily available and each user must flush the trap. The slab and trap must be cleaned often. Finally, traps must have impervious, smooth inner surfaces. If all of these requirements can be met, the water-sealed privy is the best choice.



Concrete Trap or Bowl for Water-Sealed Privy

2. The *pit privy* with concrete slab is a major step forward in controlling the disposal of human excreta over use of the open ground surface. A successful pit privy campaign requires preparing people for acceptance and use of the privies and following up with monthly visits by a sanitation or health aide to encourage use, cleaning and maintenance. When a family reaches the point of thinking of its privy as a part of its house, excreta hygiene has become a part of the family's living habits. Pit privies are the least costly alternative even with concrete slabs. If loose sand and hard rock make digging a pit extremely difficult, it may be necessary to resort to a bucket and collection system.



Typical Pit Bases

3. *Aqua privies* require an impervious water-tight receiving chamber and a seepage system to carry off the displaced liquids. The system provides complete isolation of the excreta, controls odors and prevents animal and insect access. Aqua privy chutes or extension tubes must be cleaned at least daily and in some instances after each use. The seepage system must have ample absorption so that the liquids do not come to the ground surface. Aqua privies can later be converted to septic tank systems or be connected to sewer systems. Such conversion requires running water in the house and a water closet. The construction of the vault and seepage system is costly in materials and labor. The extension tube or chute must be smooth and impervious to prevent filthy accumulations. Aqua privies are not a good method for area-wide projects intended to reach the majority of families in rural villages.

4. *Vault privies* are aqua privies without the extension tube into a liquid-filled chamber. The impervious vault is simply a holding pit that prevents seepage into the soil. Since it is fitted with a removable access opening, the vault can be cleaned out. A vault privy can be converted to an aqua privy, a water-sealed privy, a modest sized septic tank system, or incorporated into a small bore sewer system. If running water in a house is not in view in less than two or three years, the added cost of a vault privy is not justified.

5. *Bored hole latrines* have serious disadvantages which were described earlier in this chapter. The unit has a low capacity and the family cannot replicate it. Excavation requires a heavy, cumbersome boring rig. Motor-driven bores, costly and difficult to maintain pieces of equipment, have been used in such places as dam construction sites, and oil and mining camps. Also, bored hole latrines contaminate the upper groundwater stratum. Bored hole latrines have no lasting advantages over pit privies. Their only advantage is that the size of the covering slab can be kept down to 60cm by 60cm where a slab for a dug pit must be 100cm by 100cm. Assuming both slabs are the same

Pit construction can be done with local labor.

thickness, the slab for a bored hole requires only a little more than one-third of the concrete and reinforcing material which a pit slab must have.

6. *Overhang toilets* simply drop human excreta into a river, stream, lake, bay or sea. Obviously, they introduce excreta into the water. The amounts may be insignificant in light of the water's assimilative capacity, so the method may be acceptable and hygenically preferable to indiscriminate disposal on the ground. The one exception is in areas where schistosomiasis is prevalent. That is not a minor exception as it is estimated that there are 200 million or more cases of that debilitating disease in the world, and the number of cases is increasing. Before a community uses overhang toilets, determine if schistosomiasis, Clonorchis, Opisthorchis and Paragonimus are present.

7. *Bury and cover* is an improvised method of isolating human feces. It cannot be used in a family yard but it may be the only means for nomadic people. It is a useful method for field and crop workers, for woodsmen, and even for miners. Bury and cover takes feces off the ground surface and makes them less accessible to animals and insects. This method requires a great deal of community education to have it done deep enough and every time.

Non-Sewered On-Site Wastewater Disposal

Wastewater disposal requires the availability of water. Non-sewered wastewater disposal includes the treatment and disposal of waterborne excreta, sewage, and other liquid wastes on the site of or in close proximity to the structure served. Where piped water is provided, increases in water use and in the volume of wastewater to be disposed of follow. Potential health hazards will increase unless provision is made for proper wastewater disposal. The on-site treatment and disposal facility for the wastewater may consist of a conventional septic tank with an underground absorption system (sanitary field), a cesspool, an evapo-transpiration bed, an elevated mound or fill system, a package aerobic unit, a sand filter, a trickling filter, or a stabilization pond system. Physical-chemical and activated sludge processes are inappropriate for on-site wastewater disposal.

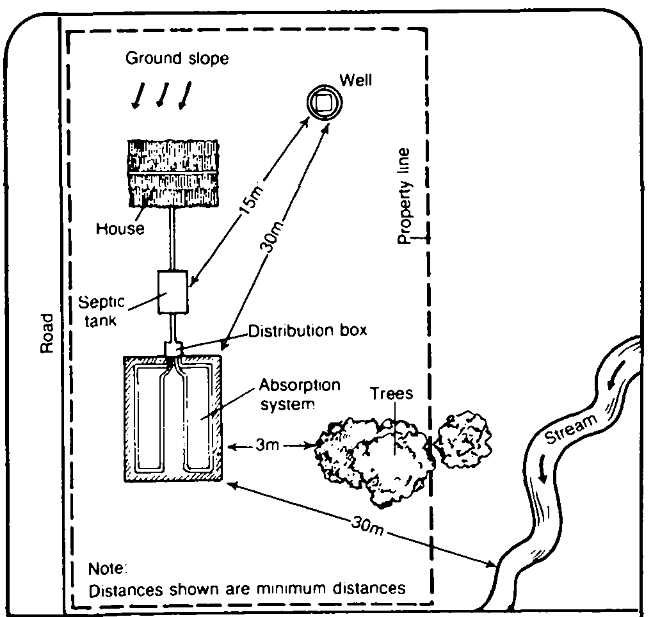
Wastewater Quantities

Water used for purposes such as latrine and water closet flushing, clothes and dish washing, cooking, bathing, and personal hygiene becomes wastewater. Table 9 provides the approximate water use for some fixtures and facilities to use in estimating wastewater flows. Table 10 shows estimated daily water consumption in rural areas of regions of the world. These are rough estimates only. Water use and wastewater flows for design purposes should be determined where possible by actual field measurements taken in the area to be served or in a similar area.

The wastewater coming only from flushing water closets and latrines is called "black water." All other wastewater is "gray water" or "sullage." It has been estimated that the gray water production in a developing country is 75 to 80 percent of total water use which may range from 15 to 40 liters per person per day, depending on whether water is available from a standpipe or from a house connection. Other sources report that about one-third of the total wastewater is black water.

Table 9. Water Use by Fixture

Type of Fixture	*Approximate water requirement in liters*
Water-seal or pour-flush latrine, per use	1-3
Flush toilet, tank type, per use	13-23
Washbasin, per use	5
Bathtub, per use	120
Shower, per use	95-115
Home with complete plumbing, use per person per day	150-300



Sample Location Map for a Septic Tank

Table 10. Daily Water Use in Rural Regions of the World

Region	*Water use in liters per capita per day*
Africa	15-35
Southeast Asia	30-70
Western Pacific	30-95
Eastern Mediterranean	40-85
Europe (Algeria, Morocco, Turkey)	20-65
Latin America and Caribbean	70-190
World Average	35-90

Subsurface Soil Absorption Systems

The provision of running water in or adjacent to a dwelling or other structure immediately introduces the need for sanitary disposal of the used water. Where municipal sewerage is available, connection to the public sewer is satisfactory. Where a public sewer or wastewater removal system is not available or anticipated, the method of collection, treatment, and disposal of wastewater must be on each site. With suitable soil, the disposal of wastewater can be simple, economical, and inoffensive. Careful maintenance is essential for continued satisfactory operation of subsurface soil absorption systems (sanitary fields).

Where the house has running water, a sink, lavatory, bathing facility and water closet, the wastewater must be disposed of in a sanitary manner. Three means are:

(1) Cesspool, or cesspool followed by a seepage pit, soakage pit or trench, or absorption field.

(2) Septic tank followed by an absorption field or bed.

(3) Septic tank followed by one or more seepage pits.

All three of these methods depend on the separation of solids for digestion and storage in a tank or pit, and the absorption of the liquid overflow into the soil. Only wastewater from household plumbing fixtures should go into the system. Rain water, including roof, footing, and floor drainage, must be excluded from a subsurface soil absorption system. This relatively clean water should be disposed of separately as it would overload the system and cause overflow of sewage onto the ground surface. Overloading a system means that the absorptive capacity of the soil is exceeded. This happens frequently.

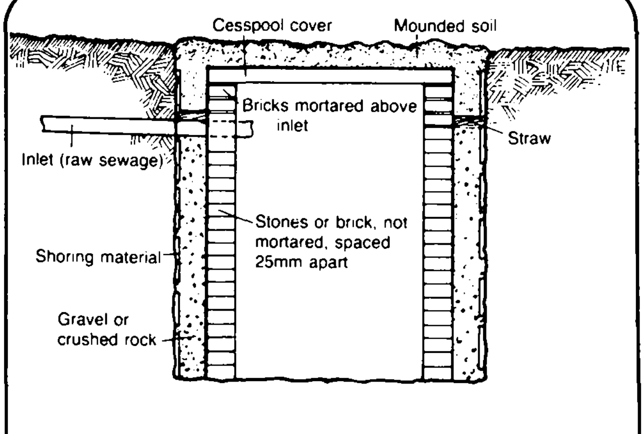
Cesspools

A cesspool is a pit with covered, open-joint or perforated walls that receives wastewater. Cesspools should not be used if the ground water is a source of water supply since they depend on wastewater seeping into the ground. Many health agencies prohibit the installation of cesspools where ground water is close to the surface or where creviced and channeled rock is at depths close to the cesspool bottom. Under these conditions, cesspool liquids can travel readily to wells or springs used for water supply.

Cesspools should be located downslope from sources of water supply. No horizontal distance may be safe in coarse gravel unless the water-bearing stratum is below the gravel and separated from it by a layer of thick clay or hardpan. Lesser distances may be permitted where ground water is not to be used presently or in the future. In all cases, the bottom of the cesspool should be at least 1m above the highest groundwater level.

Cesspools are used where excavation is easy and their side walls can be readily supported by brick or concrete block without mortar, and where upper ground water will not be withdrawn for human use. Circular cesspools are less likely to cave in. The need to build a strong cover is the only limit to the diameter of the hole but one and a half meters is usually the limit. There are ways to estimate the necessary depth in accordance with soil absorption capacity. Three meters is usually the depth limit for hand dug holes.

The cesspool hole functions as a settling unit, a storage unit and an uncontrolled digestion unit. The liquids seep through the open liner joints into the surrounding earth. If that is loamy, sandy soil, the cesspool will function for several years. In any event, it can be readily replaced.



Cesspool

Septic Tanks

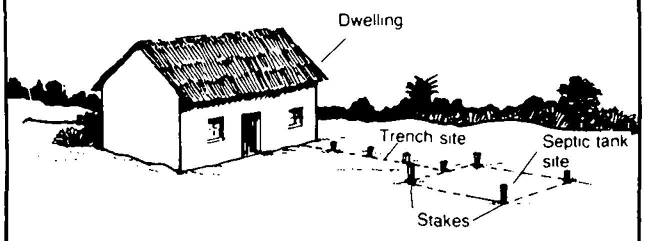
A septic tank performs the same functions as a cesspool with two differences. The tank is impervious and watertight so the displaced liquid must be discharged to be absorbed into the soil. Within the tank, the processes are the same as in a cesspool pit: settling of solids, storage of solids and uncontrolled digestion of solids.

In considering dimensions of a septic tank, storage is the determining factor. Where wastewater volumes are up to 100 liters per person per day, 400 to 500 liters for a family of four, the tank volume should equal four days of wastewater—1000 to 2000 liters. With this tank volume and, most importantly, with very favorable soil absorption, a septic tank system can work for many years. Unfortunately, these conditions are not met very frequently.

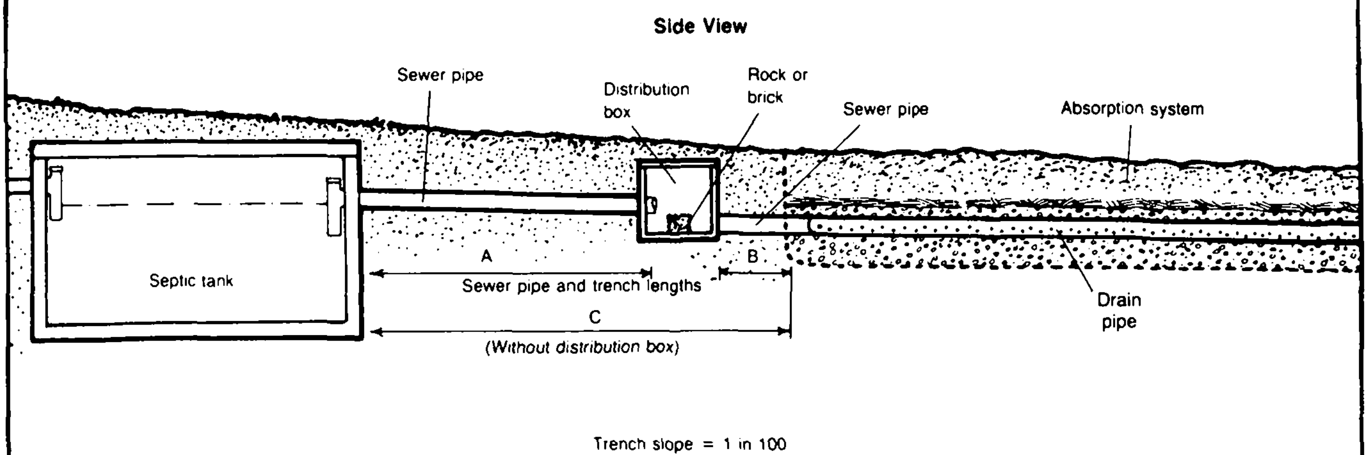
Septic tanks can be made of concrete and concrete block, brick, or stone masonry. Precast reinforced concrete, steel and fiberglass tanks are often available. Masonry or brick tanks require two 1cm cement plaster coats on the inside to provide a smooth watertight finish. Steel tanks should not be less than 12 to 14 gauge metal thickness and should be coated inside and outside with a heavy, continuous, protective material resistant to acid and corrosion. Tar, asphalt or epoxy paints will do.

The recommended liquid depth of a septic tank is 1.25m; the ratio of width to length is one to two or three. Depths as shallow as 75cm and as deep as 2m have been found satisfactory. Compartmented tanks are somewhat more efficient in keeping solids in the tank. Open-tee inlets and outlets are generally used in small tanks and baffled inlets and outlets are recommended for the larger tanks.

Conventional subsurface absorption systems (sanitary fields) consist of narrow trenches partially filled with crushed stone or washed gravel through which a perforated or open joint pipe is laid. The septic tank effluent is distributed through the pipe and gravel or crushed stone to the surrounding soil. Absorption systems are referred to by various terms including absorption trenches, absorption field, leaching or percolation field, tile field, drain field, or subsurface irrigation lines.



Septic Tank and Sewer Pipe Trench Sites



Sewer Pipe From Septic Tank to Absorption System

Soil characteristics determine the length of absorption lines needed. Soil is made up of decayed or broken down rock containing varying amount of organic material such as animal and plant wastes. Soil can be described as gravel, sand, silt, and clay, depending on which is predominant, or sandy loam, gravelly loam, silty loam, loam, clay loam, and clay, with and without large stones or boulders. Loam is a mixture of gravel, sand, silt, and clay containing decayed plant and animal matter or humus. On the average, topsoil will be about 10 to 15cm deep.

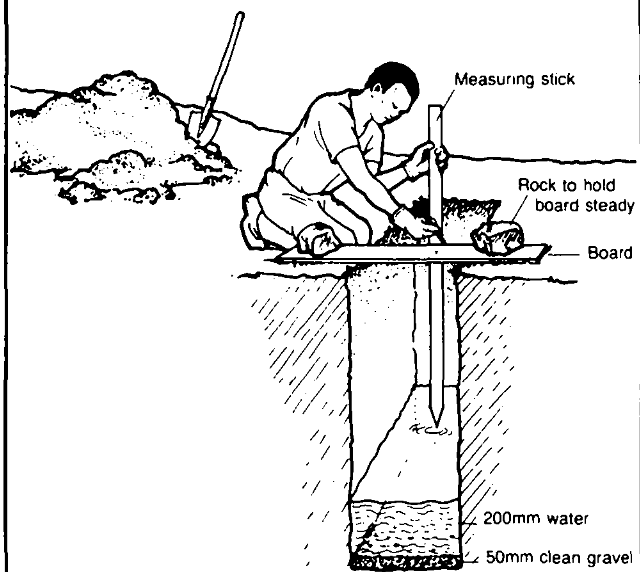
Clay loam and clay do not absorb well because they swell on water contact and prevent absorption. These types of soil are unsuitable for subsurface disposal of wastewater. Some of the clay chemicals in soil can be displaced by salts, acids, and bases through ion-exchange processes. This accounts for soil acidity and alkalinity, the friability of some clays, the binding of potassium and ammonium in soil, and the travel of nitrogen through soils. Where such characteristics are known, clay soils may be absorptive for a year or two.

The permeability of a soil, or the ability of the soil to absorb and allow water and air to pass through, is related to the chemical composition, texture and granular structure of the soil. The soil texture describes the proportion of clay, silt, and sand. The granular structure of the soil refers to the agglomeration or clumping of particles of clay, silt, and sand. The microbial population modifies soil properties. A lump of soil with good structure will break apart, with little pressure, along definite cleavage planes. If the color of the soil is yellow, brown, or red, air and water can pass through. If the soil is grayish or mottled brown and red, there is a fluctuating water table or lack of aeration. These are tight soils that are probably unsuitable for subsurface absorption of wastewater. A grayish soil, however, may be made suitable if drained. Magnesium and calcium tend to keep the soil loose, whereas sodium and potassium have the opposite effect. Sodium hydroxide, erroneously used in so-called septic-tank cleaners, causes a breakdown of soil structure with resultant smaller pore space and reduced soil permeability. It may liquify some solids in the tank, but it reduces absorption in the soil.

Aerobic oxidizing bacteria, that is, oxygen-loving bacteria, are found in the zone of aeration. This zone extends through the topsoil and into the upper zone of the subsoil, depending on the soil structure and texture, earthworm population, root penetrations, and other factors. The topsoil contains organic matter, minerals, air, water, supportive vegetative organisms such as bacteria, fungi, and molds as well as protozoa, nematodes, actinomycetes, algae, rotifers, earthworms, insects, and larger animals. A gram of topsoil can be expected to contain millions of bacteria and other organisms. In their feeding, these organisms change the complex organic matter in the tank effluent to simpler chemical forms. Earthworms play an important role together with other soil flora and fauna in keeping soil aerated.

Septic tank effluent, for example, which contains material in solution, in colloidal state, and in suspension, when discharged into or close to the topsoil, will be acted upon by these organisms and be reduced to "soil" as well as liquids and gases. This occurs if the sewage is not discharged at too rapid a rate or in too great a volume and concentration into the earth in the zone of aeration. A waterlogged soil destroys the aerobic organisms, producing anaerobic conditions that tend to preserve the organic matter in septic tank effluent. This delays its decomposition and increases mechanical clogging of the liquid-soil interface with organic matter including slimes and sulfides.

The ability of soil to absorb septic tank overflow is measured by percolation tests which have been used in the United States and Canada for over 50 years. This test consists of digging a hole, filling it up with water, and measuring seepage of the water into the soil. While it is a useful indicator of very impervious soils, such as clays, and soils which readily absorb water, such as sand, it may be misleading for soils which have marginal absorptive capacities. One reason the percolation test may not yield accurate information for such soils is that is does not exactly simulate what occurs in an absorption system where the soil is not under continuous liquid contact. Greater success is being realized by the examination of soil characteristics to predict soil suitability for septic tank discharge absorption. Soil scientists from agriculture practice are the best source of learning about these soil characteristics. They have been most valuable in helping people in health agencies to classify soils for septic tank soil absorption line use.

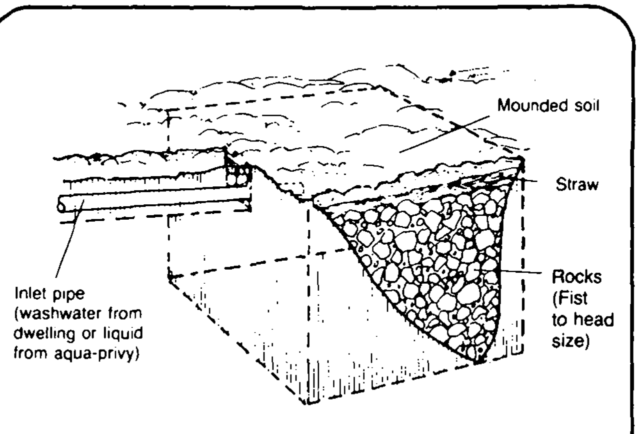


Conducting Soil Permeability Test

Septic tank leaching pit systems, also referred to as seepage pits, can be used for the disposal of settled sewage effluent. A leaching pit is a cesspool that receives only settled wastewater since the septic tank separates the solids when all goes well. A leaching pit can also be used for separated gray water with few solids, and for aqua privy or septic privy liquid overflows. Manuals on septic tank systems provide information on sizing using percolation test results or soil characteristics.

If leaching pits are used, the soil must be suitable and the water supply must be from a public system connection or a protected private well. Wells or springs must be 50 to 70m from the seepage pit and at a higher elevation. The bottom of the pit should be at least 0.75 to 1m above the highest groundwater level and any channeled or creviced rock. If this cannot be assured, subsurface absorption fields should be used. In special instances, where suitable soil is found at greater depths, pits can be dug to the absorptive stratum. There must not be any use of ground water at these depths.

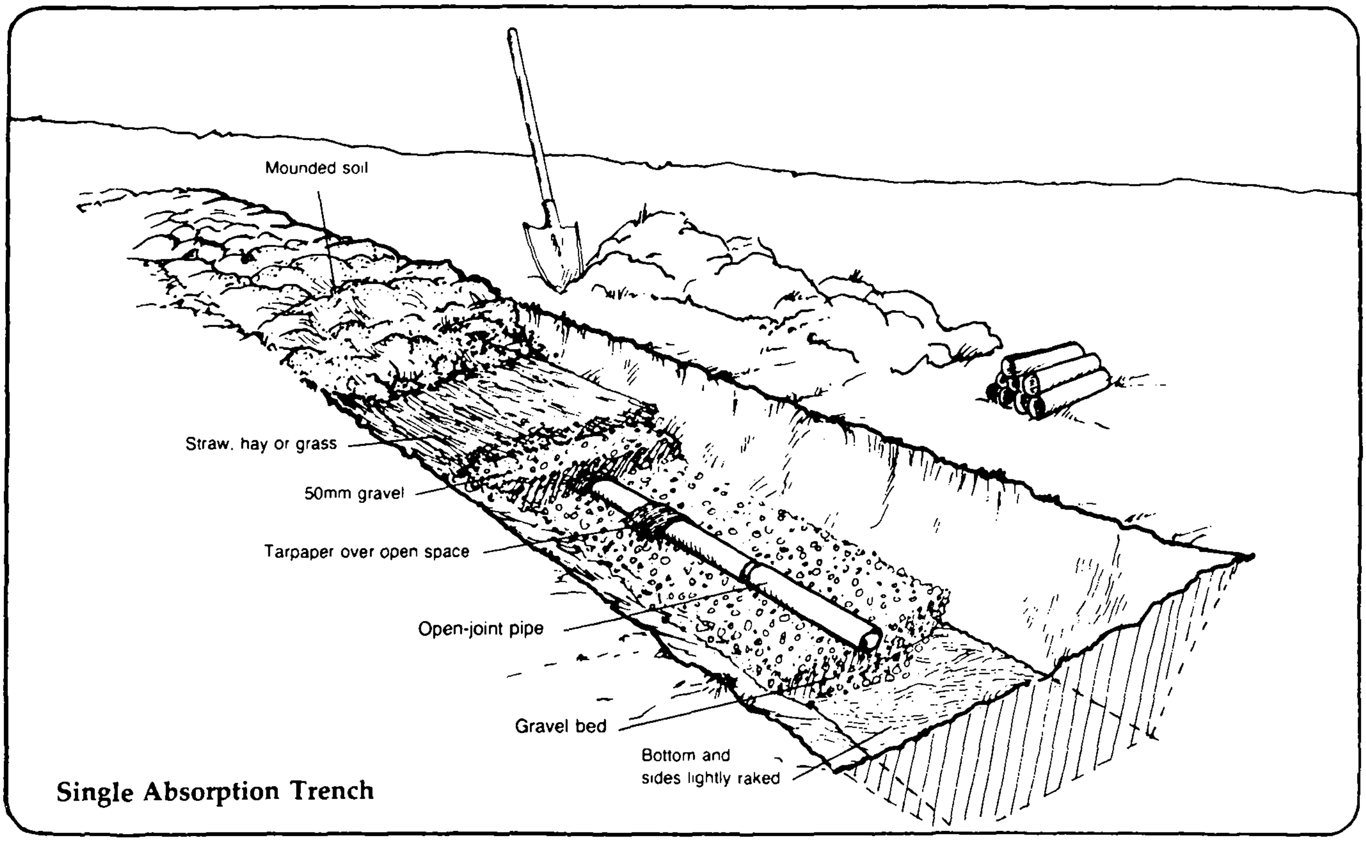
A leaching pit may be round, oval, square, or rectangular. The wall below the inlet is dry-wall construction. That is, it is laid with open joints, without mortar. Field stones, cinder or stone concrete block precast perforated wall sections, or special cesspool blocks are used for the wall construction. Concrete blocks are usually placed with the cell holes horizontal. Crushed stone or coarse gravel should be filled in between the outside of the leaching pit wall and the earth hole.



Leaching Pit

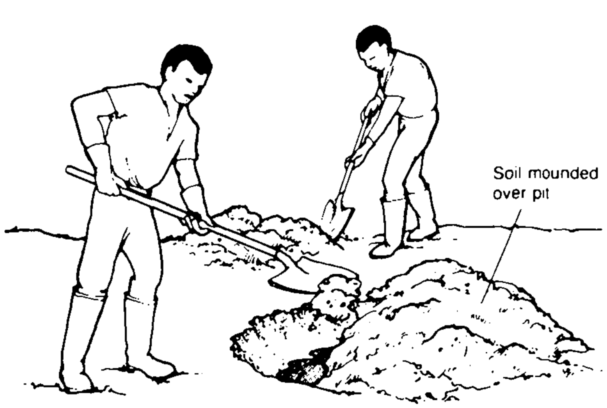
Advantages and Disadvantages of Septic Tank Subsurface Absorption Systems

A septic tank system requires an ample supply of piped water, suitable soil, space for the absorption system, and an adequate depth of suitable soil over



Single Absorption Trench

clay, hardpan, bedrock, and ground water. A safe separation distance must be possible between the absorption system and any well water supply, spring, or surface water. The septic tank must be cleaned out every three to ten years. Usually, the contents of the septic tank are pumped out using a sewage pump and hoses and are emptied into a container with all equipment mounted on a truck. Or, the tank can be cleaned out by hand. The septage must be disposed of carefully and safely. One method is to dig a trench or pit at least 60m from any water supply or dwelling, empty the septage into it, and cover the pit with dirt after the liquid has soaked in. Septage can also be safely disposed of by composting or feeding it into stabilization ponds. Water use and leaking fixtures should be controlled to prevent overloading the septic tank and a consequent sewage overflow to the surface of the absoption system.



Septage Disposal Ditch

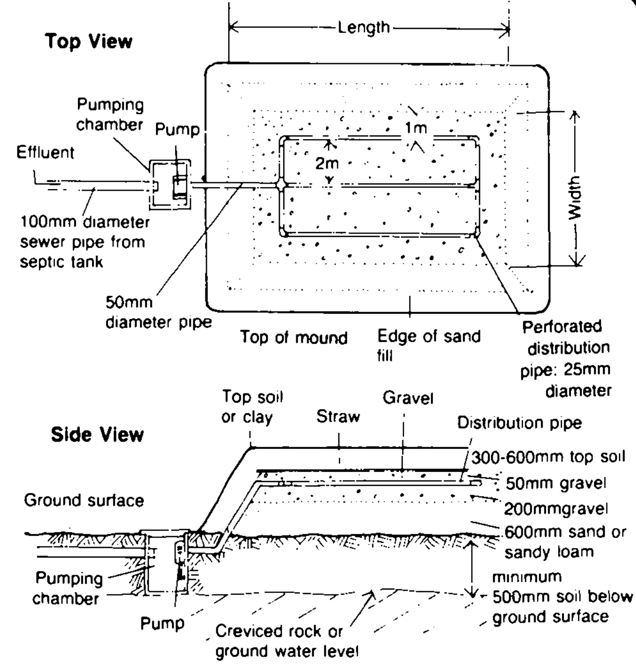
A properly designed, constructed, operated and maintained system can provide many years of trouble-free service. Sewage will be disposed of in a sanitary manner, modern plumbing fixtures which are easily maintained and cleaned can be provided within the dwelling unit or school or commercial building, household chores are simplified, and the system itself will require little maintenance. The annual cost of a home septic tank system is usually less than municipal sewerage but slightly more than an aqua privy and considerably more than a pit latrine.

Success of a septic tank system depends on the capacity of the absorption system, trench or pit to absorb the water. The greatest convenience of a septic tank is that it makes full household use of running water possible so that flush toilets, lavatories, bath tubs, showers and sinks can be installed. Unfortunately, only a small percentage of the people in most developing nations can afford such facilities in their homes.

Alternative Means for Disposing of Septic Tank Discharges

When soil conditions are so unfavorable that an absorption trench or pit is certain to fail, another way to dispose of septic tank discharges must be found. The best alternative is to develop or wait for a public sewer connection. For individual homes where disposal of wastewater is at the point of desperation, all too frequently where trenches and pits have failed, there are two choices. Their use in the developing nations will be restricted to wealthy people since both methods require a pump, electricity, and pump controls.

The *mound system* is nothing more than an absorption area above the original, impervious ground surface. The system can be used in areas with high ground water. For families of four with a water closet, lavatory, bath or shower and sink, the mound should be about 50cm high, 10m long and 7m wide. Within the mound are absorption lines. The septic tank discharges to a small sump pit that will hold 100 to 150 liters. A float control starts an electric motor driven pump whenever the sump pit is full which will be three or four times per day. The pump fills the lines in the mound. In very favorable topography, flow may be by gravity so that a pump is not needed. Liquids from the lines leave the mound by thermal evaporation and transpiration through the grass and plants growing on the mound. The first sign of overload is seepage to the original ground surface along the edges of the mound.



Mound System

The *"low-pressure" system* gets its name from the pump characteristic which moves the septic tank effluent from the sump pit at very low flow rates and very low pressure. Small, 2.5 to 3cm, diameter plastic pipe which is perforated to release the liquids is laid in the top 6 to 8cm of the soil. This system will work if the top layer of soil is porous with all the characteristics of high quality agricultural topsoil. Overload will be evident as the pumped liquids come to the ground surface. Aside from the electricity, pump and pump control needs, the "low pressure" system requires small diameter plastic pipe. The restrictions are severe for tropical and semi-tropical use.

There are other means of disposing of septic tank effluent and wastewater. These include sand filters for effluents and various combinations of aerobic stabilization processes. These are not applicable to individual home requirements, although there is equipment available for pumping air into secondary compartments of individual septic tanks. Otherwise, these methods are best for community collection and treatment of wastewaters. The most likely community system is one or more stabilization ponds. This is the only type of community system discussed here.

Stabilization Ponds

Human excreta contains all the nutrients needed to sustain animal life and support plant growth. Whether excreta is disposed of on the ground, in a pit, or into water, a vigorous biological regime uses it as food. Bacteria start the processes and protozoa and other higher life forms continue them. Fungi, insect larva, adult insects and worms follow in a chain of transformations and predation. In water, algae, crustacea and fish are active participants in the process of one eating the other.

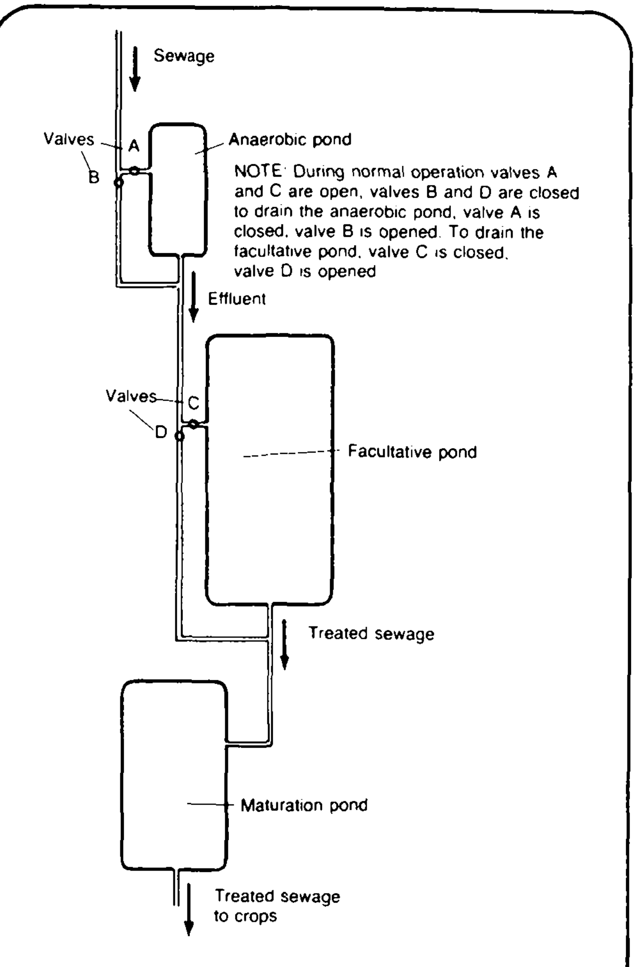
Types of Stabilization Ponds

The presence of dissolved oxygen from the air and photosynthesis determines whether the process in a stabilization pond is odorless or odoriferous. In the presence of oxygen, the process is aerobic. It ends with oxidized products such as carbonates, sulfates, phosphates and water. In the absence of oxygen, the products are disagreeable in odor and appearance. This is anaerobic decomposition which ends with partially decomposed products such as hydrogen sulfide, mercaptans and skatole, all malodorous. Methane is an odorless gas with good fuel value produced during anaerobic decomposition. Digestion of wastes, solid and liquid, which is designed to recover methane are bio-gas processes. These are described in the section on solid wastes.

The presence of oxygen determines if decomposition is aerobic or anaerobic. Many anaerobic organisms are sensitive to the presence of oxygen and cannot survive in aerobic environments. In waters that are anaerobic, many desirable aquatic organisms such as fish cannot survive. In anaerobic waters, the fish may be dead but the waters are not. They teem with anaerobic organisms. In all natural aquatic systems, as well as stabilization ponds, both anaerobic and aerobic decomposition are going on. Anaerobic conditions occur on the bottom, where oxygen supplies are limited, while aerobic decomposition occurs in the upper part of the pond where oxygen is supplied by photosynthesis and by absorption from the atmosphere. Stabilization ponds can be designed and managed to operate in various modes.

Stabilization ponds are identified by the predominant biological action within them. These are *anaerobic*; *facultative*, a combination of anaerobic and aerobic; and *maturation*, which is essentially aerobic. A fully *aerobic* pond is for growing and harvesting algae. A *fish or vascular plant* pond is aerobic and managed to produce food. These latter two types are productive purpose ponds.

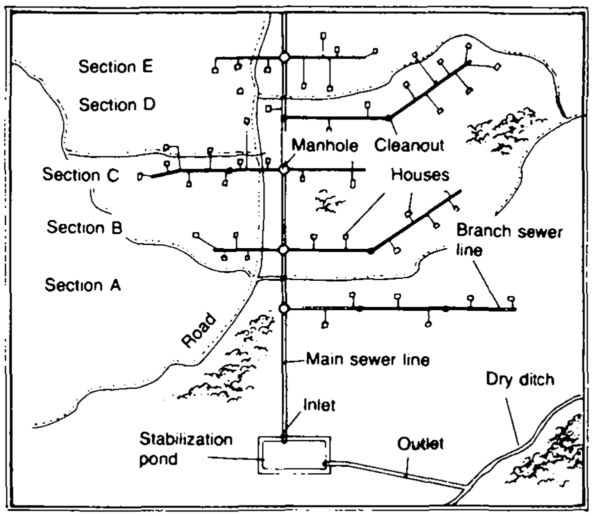
Waste stabilization ponds are the simplest of all waste treatment techniques. There are about 2000 stabilization ponds in the United States being used for the treatment of municipal wastes and possibly an equal number for the treatment of industrial or agricultural wastes. Stabilization ponds have been and are being used in over forty countries under a variety of climatic conditions.



Stabilization Pond Layout

Anaerobic ponds are often built in tandem with facultative ponds so that anaerobic decomposition of organic wastes is followed by further treatment in facultative ponds. Anaerobic ponds are about 1.5-2.5m or more in depth. Retention time in these ponds is from five to 20 days. These ponds can produce foul odors unless a natural cover, such as fats and oils from slaughter houses, is formed on top of the pond.

Facultative ponds are shallow bodies of water 1-2m deep spread over a large area. Wastewaters are retained for seven to 30 days to render them stable and inoffensive for discharge into receiving waters or on land. Organic matter contained in the waste is stabilized and converted in the pond partly into more stable matter in the form of algae cells and partly into inorganic products which leave the pond in the effluent. In facultative ponds, aerobic conditions are maintained near the surface as algae activity releases oxygen. An anaerobic environment exists near the bottom where organic matter has settled. Most of the waste stabilization ponds used are of the facultative type.



Master Sewer Map with Site of Stabilization Pond

Aerobic stabilization ponds are only about 1-1.5m deep and usually are used for algae culturing and harvesting rather than ordinary waste treatment. These are also called photosynthesis ponds, particularly when they are very shallow. Retention time is from 10 to 40 days.

Maturation ponds provide five to 10 days additional detention time, following full treatment in a facultative pond, to ensure the "die-away" of fecal organisms.

Fish/vascular plant ponds are a form of maturation pond for the production of fish and the growth of vascular plants. These must be aerobic for the survival of fish.

A typical pattern is an anerobic pond followed by a facultative pond or, in cases where the waste is especially troublesome, a small anaerobic pond followed by a series of facultative ponds. Success depends on the quantity of wastewater, its strength and the pond size.

Wastewater Strength

Wastewater strength, or its concentration of biologically oxidizable organic nutrients, is stated as the biochemical oxygen demand, BOD. A sampling of the wastewater is placed in well-oxygenated water in a bottle which is then incubated for five days at 20°C. The oxygen used by the microorganisms already in the waste during the five days is determined by measuring the dissolved oxygen before and after incubation. The difference between these two dissolved oxygen (DO) measurements is the demand for oxygen exerted by the microorganisms in the water. The BOD of a wastewater, or a stream, lake, bay or sea sample, or a treatment process sample, can be determined. The test gives a measure of the oxidizable organic material. It does not measure materials which are not a food for microorganisms, nor does it give information on inorganic compounds or synthetic organic compounds which the microorganisms cannot use as food. BOD values are expressed in mg/1, or milligrams of oxygen used in a liter of water, usually over a five-day period. The daily domestic wastes from a home, excreta included, has a BOD from 175 to 250mg/1iter. Smaller volumes of wastewater generally have higher BOD values. BOD tests of wastewater entering a pond compared to tests of the effluent from a pond show the success of the pond in treating the sewage.

Stabilization Pond Requirements

Stabilization ponds are well adapted to tropical and semi-tropical areas where water-carried sewage flows to a common point by gravity. The sewage system may be a simple one serving only a few homes. Or, it may be more extensive, connecting many more homes to a network of sewers. The basic requirements are in the areas of land availability, human resources, climate, siting, and facility design.

A stabilization pond requires a substantial amount of surface area for proper operation. In warmer climates, less area is needed than in more moderate climates. For a pond serving 1500 people, approximately one hectare of area for a pond 2m deep is needed. At four people per family, that would be about 400 homes. In rural villages and small towns, the cost of acquiring the land and its availability are not likely to be a major problem. The site must be downslope and preferably downwind of the village and must not cause groundwater contamination.

A stabilization pond may require more operation and maintenance than sanitation facilities for individual dwellings. The person who maintains the sewers that carry wastewater to the pond can also maintain the pond. In most small communities, maintenance requires only the part-time services of a semi-skilled person. Operation and maintenance includes repairing pond walls, cutting or removing weeds near the bank to reduce mosquito breeding, inspecting and repairing fence and warning signs, inspecting and repairing flow control gates and observing the pond for signs of overloading. Periodic draining of the pond followed by sludge drying and removal is necessary to get rid of sludge accumulations. This sludge is usually safe to use as fertilizer on crops that are not used directly as food.

Climate conditions significantly influence the size of a waste stabilization pond. Rainfall and evaporation may affect the depth of the pond since rapid evaporation can expose deposited sludge and cause odors. Cloud cover for periods of a month or more may require as much as a 25 percent increase in the surface area of the pond. If there is little or no wind, add 10 to 20 percent to the surface area. The maximum mixing effect of the wind can be obtained if the pond's surface has an unobstructed wind path of 100 to 200m. The single most important climatic factor affecting size is water temperature since warmth speeds up biological actions.

If gravity flow is to be used, the pond site must be at a lower elevation than the dwellings it will serve. Distance from the dwellings is a consideration. Facultative ponds should be 200 to 500m from residential areas. The distance required will depend on local customs, climate, loading applied to the pond, adequacy of design, and the standard of maintenance provided.

It is often beneficial to build more than a single pond. Two ponds facilitate servicing, sludge drying, and cleaning since one pond can be drained while the other remains in service. In addition, where BOD reduction is a major consideration, the practice is to use either a combination of anaerobic and facultative waste stabilization ponds or facultative ponds independently. When it is important to reduce the number of pathogenic organisms, ponds connected in series produce the best results. A series-connected system might include anaerobic, facultative, and maturation ponds or only a facultative and maturation pond.

The layout and mode of operation depend on the objectives and the degree of flexibility required. Series design is generally used where the organic load is great and it is desirable to reduce the coliform count. Parallel systems are used where considerable flexibility of operation is a high priority. The World Health Organization has published a comprehensive manual, *Waste Stabilization Ponds* by Ernest F. Gloyna, that provides details on design. Sanitary engineers experienced with stabilization ponds should be consulted when ponds are being designed.

In summary, the following factors regarding stabilization ponds should be considered:

- Communities which have or plan to have sewers with household connections and require wastewater treatment should consider stabilization ponds as their best choice.

- Provision for maintenance must be made. A local person should be trained for the work.

- The design and construction should benefit from the experience of ponds already in use in the area. Publications of the World Health Organization provide useful guidance.

- Stabilization ponds produce an effluent greatly reduced in BOD. That effluent can be discharged into natural waters. It can also be used for irrigation, preferably not on food crops that are eaten raw.

Village residents meet to discuss sanitation-related health problems.

Trees from excavated site may be recovered for use as home heating fuel or as building supplies.

Rural Solid Waste Management

Among public services undertaken by a community, solid waste management will rank as a costly one. The benefits will be the reduction of public health problems, improved cleanliness and appearance of homes, public areas, markets, streets and roads, and the elimination of clandestine dumps. The development of an improved environment through a community effort will contribute to increasing the level of home and personal hygiene. It will also help to set a standard of cleanliness, bettering the quality of life.

This discussion focuses on handling of solid wastes in rural villages of 1000 or fewer people. There is very little quantitative information on solid wastes in these settings, nor is there much information on the composition of solid wastes from such villages. The modes of food production, distribution, and use differ from larger urban areas in the same countries. Much must be based on conjecture from the economies of rural villages and wide variations are certain to be encountered.

Community solid waste management requires specific funding. Financing cannot be left to chance either initially or for the future. Collection is the major cost item—perhaps 70 to 80 percent of the cost—as it requires containers, some type of vehicle, and a large amount of labor. Collection is a transportation operation in which the return trip from the disposal site is an empty one with no payload. In a labor-intensive economy, two or three workers per 1000 people served may be needed.

Goals and Objectives of Solid Waste Management

The primary health objectives of solid waste management are to reduce fly breeding in putrescible material, and rat feeding and harborage in the wastes. Where human feces are handled by bucket collection and cartage, inclusion of this as part of a solid waste plan will reduce worm infections among children and may help in the control of schistosomiasis in adolescents and adults. To achieve any great reduction in commmunicable disease related to human feces and insect and animal vectors, the solid waste effort must be part of an environmental sanitation plan which includes safe and ample water, sanitary handling of human and animal excreta, food sanitation, and, depending on the diseases occurring, control of insect and animal vectors. In light of the continued rapid population growth in the Third World, attention also needs to be focused on the plant foods nitrogen (N), phosporus (P), and potassium (K) and the trace elements which are present in solid wastes. These plant foods increasingly will have to be returned to agricultural soils if food supply sufficient to protect the health of the greater populations which lie ahead is to be produced and sustained through the next century.

One objective of solid waste management is to have a clean and tidy place in which to live. Cleanliness creates an environment that supports good health habits, that brings pride and pleasure to all, and that provides a model for the habits of children. A clean environment adds to the value of all property, public and private. That repays the community for some of the cost of an effective program.

Recovery of materials including animal manure, trees and sludge and of energy, even on a modest scale, is another objective of solid waste management. The attainment of this objective depends on the habits of the people, who may already carefully salvage all materials of value and may already use all wastes with fuel value for home cooking or water heating. Further recovery may not be useful. Other sources of waste such as markets and public litter containers may be a sufficient source of recoverable matter to make salvage worthwhile.

The objective of aerobic composting of solid wastes is to produce humus which can improve food-growing soil by adding to its moisture holding capacity, its porosity, and, in a very limited degree, its nutrients. Where solid waste characteristics are favorable, composting produces a useful material. Usually one-half of the waste is not compostable. Therefore, there must be a disposal method for it.

The Materials That Make Up Solid Wastes

Indications are that used household commodities of all sorts are handled very frugally. Recovery and reuse are applied diligently to food stuffs and all manufactured materials. Depending on local conditions, vegetation, leaves, dead shrubs, branches and trees, husks, and fruit and vegetable peelings are a large waste component. Even these materials may be used as fuel and the fruit and vegetable peelings fed to animals. Against this background, the basic principles and practices of solid waste management will be examined to provide patterns for choosing plans applicable to a local community.

The chief materials that make up solid waste, particularly from a village home and its surroundings, are listed with comments in Table 11. The observations made emphasize recovery and re-use. Such practices minimize the quantities that would go into a community solid waste collection and disposal system. The extent of these practices will vary in accordance with the entry of a community into an energy-money economy. As that increases, disposable solid wastes increase.

Acceptable social and cultural behavior have a substantial influence on solid waste production. Where home and yard cleanliness are a norm, sweepings are generated daily as interior floors and dooryards are swept daily. The number, kind and proximity of domestic animals determines the animal manure on site. Local custom and practice influence the use of manure as a fuel or a fertilizer, or simply leaving it to dry out in a hot arid climate.

Table 11. Components of Solid Waste from a Rural Village Home

Material	*Comment*
Kitchen and culinary wastes	The quantity will be minimal; all possible will be fed to domestic animals, chickens, pigs, dogs and cats. This is putrescible matter, food for flies, ratsand cockroaches. In the solid waste lexicon, this and only this is garbage.
Discarded paper and paper products	A part will be salvaged for re-use; some will be used as fuel.
Discarded containers, glass,metal, plastic	All that can be cleaned will be salvaged; steel containers are fashioned into household utensils such as cups, water vessels, storage receptacles and pots.
Human feces	Where disposal is by means of container collection, feces is considered a solid waste material.
Animal manure	Where large animals are housed on the home site, animal manure is considered a solid waste material. The same applies to animal manure removed from village streets and roads.
Household discards	Worn-out clothing, furniture, bedding, cooking equipment; the quantities are usually small.
Sweepings	These come from the house, the yard and the street frontage; some part may be combustible.
Discarded building materials	Depending on condition and type, wood, brick, sheet metal and asbestos sheeting will be salvaged; combustibles will be used as fuel.
Ashes	The quantities will be small in tropical and semi-tropical regions as they will only be from cooking fuel; may be spread on home vegetable gardens as soil nutrients.
Dead animals	May be buried nearby without awaiting collection or may be left to scavenger animals.

Requirements for Collection

Collection methods vary with home practices and collection plans. If household and shop salvage are extensive, the wastes for community collection may be quite small. Collection should then be from public receptacles on a once a week schedule. Receptacles should be placed at intersections spread about 200m apart. A variety of locally available containers are possible.

The public receptacle system is less costly than door to door collection. It permits more economical use of vehicles, whether run by motor, animal or human power, and routing of collection is simpler. The loads per person vehicle are more easily controlled. However, the receptacles are open to vandalism and theft by people and scavenging by animals. Putrescibles will require that the receptacles be covered. The containers should be marked as public property and with some slogan or picture urging cleanliness.

Door to door collection requires that each household have a storage container. On collection days, it should be put at the front door, and covered so it is out of reach for animal scavengers. A study of waste quantities and the type of collection vehicle will determine whether collection on a particular route has to be once or twice weekly.

The choice of vehicles will depend on what is available at the least cost. For use in rural villages there are handcarts, pedal tricycles, animal carts and motor tricycles. The following points should be considered:

- For emptying containers by hand, the loading height of vehicles should not be more than 1.6m. A much lower height of 1m is desirable and easily attained in hand and animal drawn carts. The lower the loading height, the easier the work, the less risk of lifting injuries and the less spillage of wastes.
- Handcarts should be built for easy loading and unloading particularly if there is transfer to a larger vehicle. Handcart platforms for four to six 70 liter containers or for two 200 liter containers have been found to be satisfactory.

A survey will be the best guide to quantities of solid wastes being produced in a community. Even if it is approximate and possibly incomplete, it will be a better measure than can be found anywhere except through information from other villages nearby. Data may have been collected by a regional body such as a provincial agency or by a national public health or public works agency. Table 12 gives a wide range of solid waste characteristics which indicates the items which should be examined in a solid waste study. The range is too great to be of any value in planning a local rural village solid waste project. Particular attention should be given to the local patterns of salvage and re-use.

Alternatives for Disposing of Solid Wastes

The alternatives are: (1) recovery of re-usable materials; (2) incineration; (3) sanitary landfill; (4) composting; (5) for animal manure and human feces, anaerobic digestion to produce methane gas and to allow field-spreading of the digested material; (6) earthworm feeding.

Recovery

Salvage and recovery from solid wastes is a desirable practice. First, it must be determined if there is enough salvagable material being collected. In rural economies, recoverable materials are low in quantity at the outset although central markets may be a source of some salvagable items. Where salvage and recovery are to be done by a public agency after collection, there are three things to be considered. It will still be necessary to dispose of the remaining residues, which will be about one-half of the original collection by weight. There must be a market and use for the recovered materials. Finally, recovery on the scale of a rural village will be by manual labor.

Incineration

Incineration is more than open burning and it is not easily adapted to rural village waste. To have self-sustained burning, the waste must contain a minimum of 50 percent by weight of combustible or volatile material and a maximum of 50 percent moisture. These criteria are rarely met in rural villages where the only off-set may be combustible leaves, twigs, vines and branches. However, these may be valued and used as cooking fuel.

With burnable waste, an incinerator is needed. Locally made devices are rarely satisfactory. When insufficient air is produced, the result is incomplete burning with odors and smoke. The ash must be handled and a means provided for disposal. The usual method is to use it as fill material on-site. Incineration is not a satisfactory method for rural villages in developing countries.

Sanitary Landfills

The sanitary landfill is the most widely used method of disposal in developed countries. There are

Table 12. Characteristics of Domestic Solid Wastes

Volume and Composition of Solid Waste	*Reference 1*	*Reference 2*
Volume per capita in liters per day	0.5 to 10	1 to 80
Weight per capita in kilograms per day	0.25 to 1	0.2 to 3
Density in kilograms per cubic meter	100 to 600	100 to 500
Putrescibles in percent by weight	20 to 75	5 to 90
Paper in percent by weight	2 to 60	0.25 to 55
Glass in percent by weight	0 to 10	No Data
Metals in percent by weight	0 to 15	No Data
Plastics in percent by weight	No Data	0.1
Inert matter in pecent by weight	5 to 40	No Data

Reference 1. Flintoff, Frank, "Management of Solid Wastes in Developing Countries," WHO Regional Publication, South-East Asia Series, New Delhi, India, No. 1, 1976.

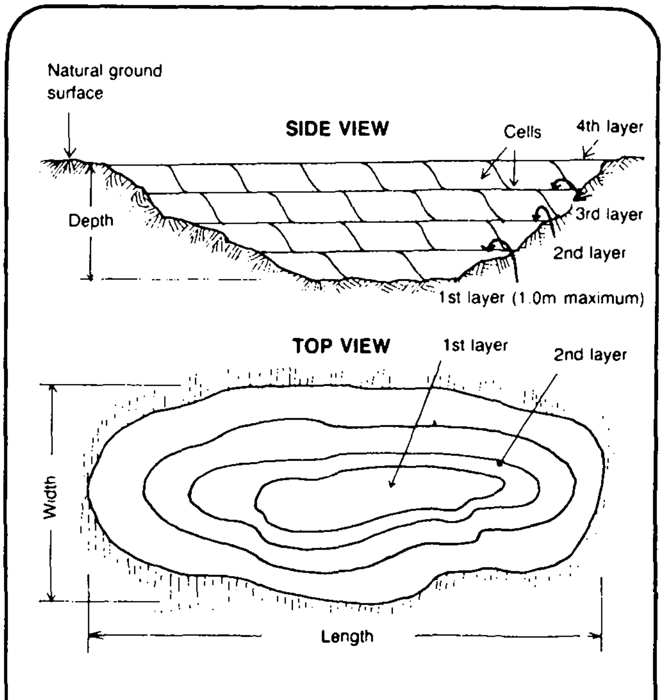
Reference 2. Report of WHO Expert Committee, "Solid Wastes Disposal and Control" Technical Report Series No. 484, Geneva, 1971.

means for adapting it to small communities with a minimum of mechanical equipment. A sanitary landfill differs from an open dump in four respects:

- The site is selected so that the wastes and their products are controlled, and so that the method can be applied economically.
- The wastes are compacted to conserve space.
- The wastes are covered daily, with rare exceptions, with 15cm of soil to control insects and rodents, to prevent fires and to discourage scavengers.
- After a final cover of 40 to 50cm of arable soil and after the provision of drainage, the completed fill area is available for a beneficial use. If the site is properly selected, the completed landfill can be an attractive and useful community property.

The sanitary landfill is a process of controlled burial. The requirements for it begin with the selection of a site. It should be within a short haul from the collection area, but distant from dwelling areas. A land area that will be improved by solid waste fill is desirable. Cover materials must be readily available. The best means of obtaining cover material is to excavate a trench or scoop out an area. The space opened is then filled with wastes, compacted by the best possible means at hand, and the excavated material is used to cover the wastes. If it is necessary to bring cover material to the site, the cost will be higher which may lead to neglecting covering of wastes.

The best soil condition for the site is loamy clay which is readily workable. This provides good cover and limits the movement of drainage from the fill. The groundwater level should be at least 2m below the bottom of the projected fill level. A stable all-weather road to the site is necessary so that waste disposal is not interrupted for more than two or three days during rainy seasons. Ownership and future use of the site and a surrounding 200m zone should be controlled. Upon completion, access to and use of the site must be limited by designating it as dedicated public land. The site should have planned beneficial uses.



Area Landfill

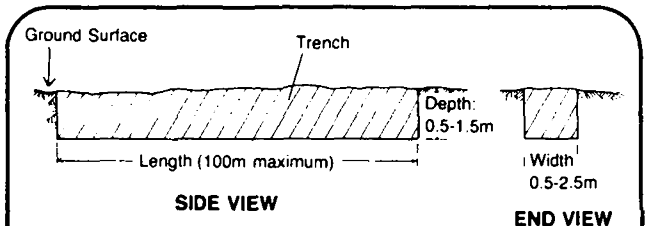
The area required depends on the amount of waste per person, the number of people served, the degree of compaction, and the depth of the fill. For 0.5kg per person per day, the wastes of 1000 people, compacted to 200kg per m^3, with 1m depth at the fill, will require only 0.2 hectare over a three year period. One hectare with 1m of fill will last for fifteen years for 1000 people. For small populations with low amounts of waste, the area requirement is small.

Three landfill methods are suitable for rural villages in developing countries. Any of the three can be adapted to mechanical or manual methods. These are the area method, the trench method, and the mound method.

An ideal topography is one in which there is an area about 2m below the surroundings. A depth of 1m would suffice. In many cases, earth cover must be brought from higher ground nearby. Compaction will be restricted to that caused by the delivery vehicles. Some compaction can be done manually by beating broad paddles against the waste pile.

The trench method differs from the area method as the source of cover material always comes directly from the trench that is cut to hold the wastes. The excavated material is set to one side of the trench for later use as both daily cover and final cover. The trench needs to be only 1-1½m deep since the fill rate for a rural village of 1000 people will be only 2-3m^3 per day. The trench can be hand dug.

The mound method requires cover soil from an off-site point as nearby as possible to minimize the cost and time for hauling. Sites which are difficult to excavate because of hardness, rock or wet soil conditions are suited to the mound method. The method is the same as building a road embankment. The waste is placed on the undisturbed ground surface, or the top soil cover can be skimmed beforehand and set aside for final cover. The waste is compacted by whatever means available, including animal drawn sleds.



Trench Landfill

Decomposition in a landfill is an anaerobic process. Bacteria, fungi and other biological organisms feed upon the wastes buried in a landfill. Initially, the reactions are aerobic with carbon dioxide and water the primary products. As the oxygen is exhausted in three to four months, depending on the moisture in the landfill, the action is by anaerobic organisms. This change is marked by a rise in the production of methane gas. The quantities of methane coming from a small fill generally are not enough to consider recovery. Nor are the gas quantities a hazard unless enclosed buildings are built directly over the fill or close to its edge.

Landfill sites are open to rainfall, surface drainage and, in poorly chosen locations, penetration by ground water. Water leaving the fill or dump will carry dissolved, mixed and suspended pollutants into the surrounding soil and rock formations. This mixture is called leachate. As noted, carbon dioxide is an end-product of both aerobic and anaerobic biological processes. It is readily soluble in water. The resultant carbonic acid promotes the solution of many materials in the wastes. The process also converts some solid organic materials to liquids which are carried by the water leaving the fill.

The composition of leachate is highly variable. There is evidence that the risk of pathogenic organisms leaving the site in leachate and moving more than a few meters through the soil is very slight. Extensive studies to recover enteric viruses in landfill leachate have been negative. As pathogenic bacteria have much poorer survival rates than enteric viruses in an alien environment, there is little risk of pathogenic bacterial passage from a fill. The greater risk is the disposal of toxic chemicals in substantial quantities in a dump or fill. Such poisons, notably arsenic, have been known to contaminate ground water. Movement will depend on the exchange capacity of the soil and the contact time. A "cordon sanitaire" and prohibition of groundwater withdrawal within the radius of one kilometer in the direction of groundwater flow is usually ample precaution against the travel of biological and chemical contaminants.

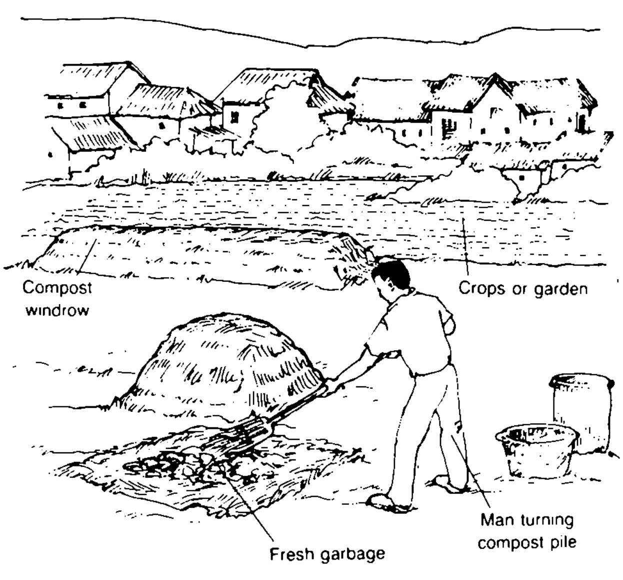
Uses of a completed landfill site are limited. It should be planted with grass as it is completed to prevent drainage and erosion problems and prepare the site for future use. Other than open sheds, no buildings should be placed on completed landfills since they will settle rapidly during the first few years and since there is a danger from methane gas. Methane gas is inflammable and explosive and the accompanying gases are extremely odorous.

Landfill sites are frequently used as playing fields. A fill serving 1000 people for about five years will be one hectare in area. One-half hectare accommodates a football field.

Composting

Composting is the natural way of renewing topsoil. It is a process by which bacteria and other organisms feed upon fallen leaves, dead wood, dry grass and other dead vegetation. The end-product of composting is humus. Composting is a feeding process and only the biodegradable portion of solid wastes, organic matter, can be converted to humus. Non-biodegradable materials such as glass, metal, sand, grit and plastic are not food for the organisms that create compost. They will have to be separated from the humus before it can be used to enrich top soil. It is best to do separation as thoroughly as possible before composting. However, it can be delayed until after the composting is completed. As in the natural process, composting of waste material can be anaerobic or aerobic. In the absence of oxygen, microorganisms capable of thriving under those conditions feed slowly on the biodegradable material in the solid wastes. Completion of this action requires six to 12 months. It goes on under sealed conditions, in a covered pit or in a closed container above ground and is a very malodorous process. Composting generates low heat which slowly kills the pathogenic organisms. This is the same biological process that goes on in a sanitary landfill or in an anaerobic stabilization pond. The Bangalore and Beccari methods of treating solid wastes are anaerobic composting. Neither one is widely used.

The aerobic process is the feeding of microorganisms that need oxygen for growth, reproduction and survival. A practical means of providing the necesary



Composting

conditions by manual handling is to place the biodegradables in piles of manageable size, 1.5m high and 2m in diameter. To provide the necessary oxygen, the piles must be turned inside out every three to seven days. Piles of this size can be turned by forks and shovels. The aerobic process requires about three weeks for completion. Failure to turn on schedule results in the anaerobic organisms taking over and vile odors and a marked slowdown of decomposition result. For best results, a moisture content of 40 to 50 percent by weight is needed.

Microorganisms must have nitrogen to grow. This need is expressed as a ratio of the carbon in the solid wastes to the nitrogen. Neither the carbon nor the nitrogen are in elemental form. Rather, they are in organic forms of carbohydrates, fats and proteins. There is always ample carbon for the microorganisms from dry vegetation and paper. The nitrogen must come from proteins in putrescible wastes, from food, fresh vegetation and animal and human feces. The optimum ratio of carbon to nitrogen is between 30 to 1 and 35 to 1 by weight.

Composting does not need any microbial starter. The variety of organisms in solid wastes is enough to start the action whether it is anaerobic or aerobic, just as natural decay processes get under way in dead matter. Aerobic composting generates more heat than the anaerobic process. Temperatures in the center of an aerobic pile reach 60° to 70°C; 55°C for a period of three to five days kills pathogens including *Ascaris lumbricoides*, the round worm. This parasite is known to be the most resistant human pathogen in the free environment. Turning is important to expose all pathogens to the high temperatures. Eggs and larva that may be on the surface of the pile must be turned into the newly formed center so they are exposed to the lethal temperatures.

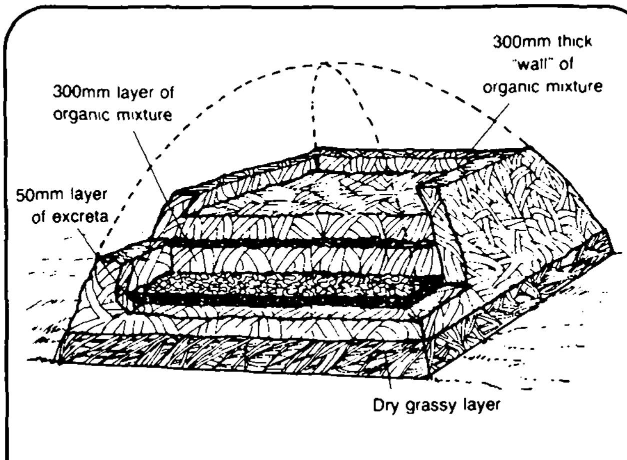
Frank Flintoff of the World Health Organization describes the properties, uses and nutrients of aerobic compost in this way:

> Compost is a brown, peaty material the main constituent of which is humus. It has the following physical properties when applied to the soil:
> - the lightening of heavy soil,
> - improvement of the texture of light sandy soil,
> - increased water retention,
> - enlarging root systems of plants.
>
> Compost also makes available additional plant nutrients in three ways:
> - it contains nitrogen (N), phosphorus (P), and potassium (K); typical percentages being N, 1.2%; P, 0.7%; K, 1.2%, but with fairly wide variations,
> - when used in conjuction with artificial fertilizers it makes the phosphorus more readily available and prolongs the period over which the nitrogen is available, thus improving nutrient take-up by plants:
> - all trace elements (micro-nutrients) required by plants are available in compost.

Note that the N, P, and K content of compost is low compared to chemical fertilizer which usually contains 8 percent each of nitrate, phosphate and potassium oxide. To obtain a reasonable degree of nutrient value and humus conditioning, compost must be applied to the soil at the rate of about 40 tons per hectare per year. Forty tons is about 60m^3 in volume, so a large bulk of material must be handled. The 40 tons will contain about 500kg of nitrogen. The annual yield of nitrogen from the composted solid wastes from 1000 people will be enough to cover only 2.25 hectares at the dose rate of 500kg of nitrogen per year. By weight, the finished compost yield is about 50 percent of the collected solid waste.

For aerobic composting in piles, the solid waste must contain enough putrescible matter and paper to support bacterial feeding. This should be about 60 to 70 percent by weight of the waste, including moisture. The carbon to nitrogen ratio should be about 30 to 1. If the waste is dry, if it contains a lot of sand and grit, or if there is very little fresh vegetable matter and food wastes, the waste is not suitable for composting. It can be made suitable by adding fresh feces from animals and humans. This should be considered only if large amounts of such feces are available regularly. The addition of feces or of large amounts of market wastes high in putrescribles will provide the needed moisture, nitrogen and readily available carbon.

Non-biodegradable material should be separated as carefully as possible. Cans, bottles and plastic containers are often salvaged by the householder or by a private house-to-house scavenger. If not, or if remains



Adding Excreta to a Compost Pile

of broken items are included in the solid waste, they must be removed at the compost site. This will have to be done by hand, spreading and raking the material on the ground or on long tables. This requires a lot of hand labor. Plastic film should be removed since plastics will not compost. All paper and dry vegetable matter must go to the compost pile. Water should be on hand to dampen the compostables.

It is best to reduce the size of the compostable material to increase the surface area upon which bacteria can feed and speed composting. Separation of non-compostables will break up some of the compostables, but it is very difficult to shred solid wastes without machinery. Large putrescribles should be cut up and matted paper should be loosened. With that much done, the building of the compost pile can begin.

A level site of hard ground that drains well is needed for pile building and turning. The piles should be sized for easy turning with hand tools, rakes, forks, and shovels. A pile at least 1.5m high and 2m in diameter is convenient to work and yet is large enough to retain the biologically generated heat that speeds composting, kills pathogens and prevents fly-breeding. Piles should be spaced about 3m apart for easy forming of a new pile from turned material. By the fourth or fifth day, the first turning is due. Piles should be turned every five to seven days thereafter for three or four weeks of high temperature composting and then be cured before use.

Before composting is adopted in any particular locality, test piles should be built to see how the composting process acts upon the local wastes. If the results are favorable, three things must be determined.

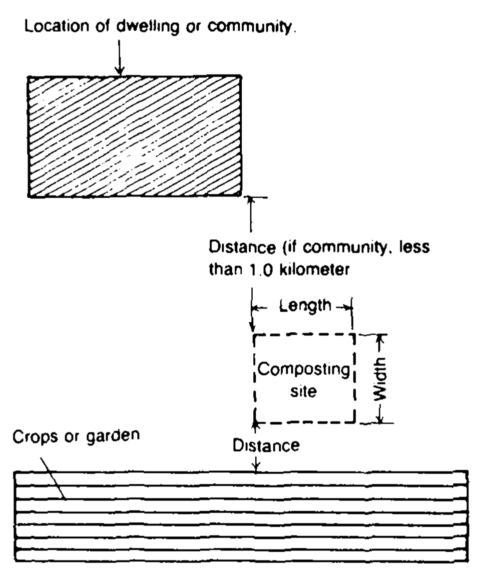
(1) What will be done with the finished compost? For a small village of a few hundred people or less, the amount of compost will be small. It can be used on public land or given to householders. The volume of finished compost from 500 people will be less than 1m^3 per day. If the wastes are high in non-compostables, the yield may be only 0.5m^3 per day.

(2) What will be done with the non-compostables? As the volume will be small from a village of 500 people, the residues should be buried on the composting site.

(3) Where will the composting site be located? It can be closer to the village than a sanitary landfill site. If composting is done correctly, there will be very few flies and no odors. For a population of up to 1000 people, an area of 100m by 200m will readily accommodate 20 compost piles, provide for separation and preparation activities, and have burial space for the non-compostables. The location should keep the hauling distance for the raw material and finished compost as short as possible. The area for the piles should be level, well drained and have a hard surface for easy handling and clean-up during turning. Water should be available at the site. Not only is water needed for dampening dry wastes, but it is needed for the workers to wash up as needed during the day, before eating and at the end of the day.

Composted solid waste is a dark, loose-textured material. Squeezed in the hand, it forms a firm ball with a moist surface. This is the humus that will benefit crop soil. Everything else, possibly one-quarter to one-third of the pile, depending on how carefully separation was done, is trash. If there has been no separation before forming the pile, the amount of trash will be larger. If the compost is to be put to beneficial use, the trash must be removed. There may be some salvage of bottles, cans and metal scrap, if these have not already been removed. It is not necessary to cover the compost during storage.

Compost must be adequately matured before it is used or it may keep seeds from germinating or rob the soil of nitrogen as decomposition continues. Compost should be cured for at least two weeks, or four to six weeks if possible, before using it. Use of finished compost should be planned.



Location Map for a Composting Site

The completion of the compost action can be judged by the appearance of the dark, odorless humus as it increases in the pile. At the end of the composting time, the temperature in the pile will drop. There is no longer enough food for the active organisms.

The yield from the pile method, using the pile size recommended, will be about 1m^3 of cleaned finished compost per pile. The weight will be about 500 to 600kg. At the usual application rate of 40 tons per hectare, the yield of one pile can be applied to about 125m^2 of land.

The choice of what to do with the finished compost will depend on the demand for it:

- The compost can be sold with the purchaser coming to the site for it;
- The compost can be given without charge to those coming to the site; or
- The village can use the compost on public land or deliver it to those who want it.

Disposal of Animal Manure

Animal manure is produced in all villages. Manure from cows and horses is produced at the rate of 10 to 16 tons per animal per year. Pigs produce from 300 to 900kg of feces per animal per year depending on their size and food intake. Chicken manure is too scattered to consider collection unless the birds are closely confined.

In a rural village, animal manure is found in the streets and roadways. This material becomes part of the public cleaning and collection where such service exists and the manure is handled along with collected solid wastes. Its nitrogen content will be a welcome addition to a compost pile.

Where cattle and goats are brought to the homesite each night, there is manure accumulation close to the dwelling. Because of its fly breeding capacity, such accumulations are a public health concern. There are four means that may be used to contain the hazard; the choice will depend on local custom and on the quantity.

- Use the manure as a fuel. Where this is practiced, the manure must be dried.
- Remove the manure for land spreading twice weekly before a fly breeding cycle is completed.
- If seasonal cycles prevent immediate land spreading, stack the manure for storage. Storage at the dwelling is not recommended as it must be done meticulously to prevent nuisances.

- Collect animal manure from households as a community service. If there are many dwellings with animal manure, solid waste collection work will be increased greatly. Whether the collection of manure is separate from other household wastes or not will depend on three things. The first is the value placed on the manure as a natural soil fertilizer. The second is the method used for the disposal of other collected solid wastes. The third is whether the manure collection is sufficient to consider anaerobic digestion for the recovery of methane.

The alternatives for community management of collected animal manure are:

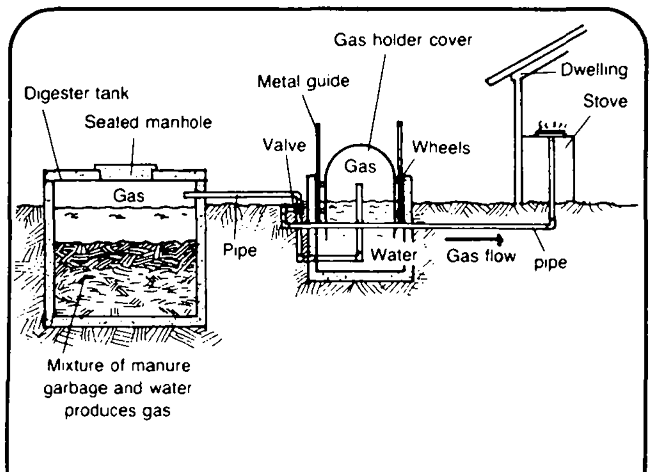
(1) Land spread immediately,
(2) Stack and store for land spreading as seasonal conditions require,
(3) Add to sanitary landfill,
(4) Add to compost piles,
(5) Build an anaerobic digestion facility for the recovery of methane.

Alternatives 1, 2, 4 and 5 conserve the value of the manure. In a sanitary landfill, method 3, the manure is simply buried along with other solid wastes from the community. In a compost pile, the manure is added directly to the other wastes. It enhances the process because it is readily used by the microorganisms for its organic nitrogen content. Alternatives 1 and 2 involve the community in a manure transportation, processing and distribution activity which requires considerable skill in organization and management. Alternative 5 is a method which is simple in concept but requires careful design and assembly of units and of fittings. It will also require resources, material and skills not usually found in villages of developing countries. Operation and maintenance of gas generators and the use of the gas require constant attention.

Bio-gas from anaerobic digestion of animal manure for the recovery of methane is most widely used in countries in the Orient. This process requires gas-tight construction either of separate units for digestion and for gas-holding or a combination digester and gas-holder in one unit. Such an installation requires knowledge and skill to build and to operate. It can be potentially dangerous due to a highly explosive mixture when air is mixed with methane gas in a contained space.

The process is strictly anaerobic bacterial action. Animal and human excreta are the feed materials. Other putrescible materials, fruit and vegetable wastes can be added in limited amounts. Large amounts produce acid conditions which slow down the bacterial action and may stop it altogether. There is no gas-producing value from sand, grit and inorganic sweepings. Nor will dry vegetation, straw and paper produce much gas. The addition of such materials, other than that which is part of manure and bedding clean-up, is a poor use of digester space.

Manure from farm animals may have various uses including methane production.



Biogas System

Table 13 summarizes information on anaerobic gas. Production is rather modest. A year's manure from a cow or a horse can generate from 350 to 600m^3 of gas. Assuming 3m^3 of gas per day is used this will supply a rural family for four to six months. The rate of gas production is very dependent on temperature. It is ten times as fast between 30°C and 35°C as it is at 15°C. The total volume generated at completion is the same, about 60m^3 per ton. The gas from anaerobic decomposition is mostly methane, but one third is carbon dioxide and a little is hydrogen sulfide. The methane content is lower than natural gas from wells by about 15 to 20 percent. The fuel value is high enough to compare favorably with oil and charcoal. A correctly sized unit with the required feed of manure in a warm climate can produce 2m^3 of gas each day with a fuel value equal to 3kg of charcoal or about 1.5 liters of kerosene. Methane is explosive in the range of concentrations from 5 percent to 14 percent in air.

A family's gas needs for cooking, lighting, water heating and running a two horsepower stationary engine is 2m^3 per day. It takes the daily manure production of 10 pigs, 35kg, to provide that much gas. A more generous supply of 3m^3 per day requires the manure of 15 pigs, 50kg each day. The equivalent would be the daily manure of two or three horses or two cows if all the manure were collected. The ownership of that many animals by a single family is very rare in most rural villages in developing countries. Methane gas generators can be built and operated in cooperatives that include several families.

Table 13. Characteristics of Anaerobic Gas: Production, Temperature Effects, Composition, Calorie Value and Equivalents, Family Requirements, Digester and Storage Requirements for Family Units

Temperature Effect on Gas Production and Digestion Time of 1 Ton

°C	*m^3 per day*	*Months*	*Total in m^3*
15	0.15	12	54
20	0.30	6	54
25	0.60	3	54
30	1.0	2	60
35	2.0	1	60

Production: With 50 percent conversion of carbon to gas, 1 ton of animal manure will produce 50 to 70m^3 per digester cycle.

Composition: Methane-66 percent; Carbon dioxide-33 percent; Hydrogen sulfide-1 to 2 percent

Fuel Value: 4,000 to 6,000 calories per m^3: equivalent to 1 liter of alcohol; 0.8 liter of gasoline; 0.6 liter of crude oil; 1.4kg of charcoal; 2.2 kilowatts of electricity.

Explosive Limits of Methane: Lower (minimum) 5 percent, Upper (maximum) 14 percent as a mixture with air.

Earthworm Feeding

Earthworm consumption of solid wastes is another natural process. In their natural cycle, earthworms feed upon organic matter of almost any sort. Their excrement, called castings, have very good soil amendment characteristics. Earthworms reproduce to replace and add to the worm population in the feeding site. The method, frequently called annelidic consumption, is in practice on a commercial scale in Canada, Japan and in the United States in California and Florida. The excess earthworms are harvested and marketed for fishing bait and for addition to heavy soils. Enough is known of the survival needs of two or three species of earthworms to put the method to use in those places where the required needs are known and can be controlled. Before the method can be applied to a different environment and different annelid species, the local earthworms' response to a solid waste feeding site must be determined on small scale plots. Local moisture, temperature and pH conditions must be known.

The solid waste for earthworm action should be high in organic matter, including paper and all forms of cellulose. Earthworms digest a very wide variety of organic compounds. They are not dependent on the putrescibles such as food wastes and manure. The composition of solid wastes in rural villages in developing countries, which is high in dry leaves, branches, and other plants, is fitted to earthworm consumption. Low putrescibles and low paper will not matter. Inerts of sand, grit and dust in excess of 40 percent by weight is not desirable. Glass, metals and plastics must be removed, preferably before building the feed bed. Earthworms eat from 80 to 115 percent of their weight each day on a wet weight basis. That is 200 to 300mg per day. At the 200mg rate, 5 million earthworms can consume one ton of organic material each day. Worm activity increases bacterial, fungal and enzymatic actions in the soil. The tunnelling of the worms increases soil aeration and the movement of water.

For survival and growth, earthworms need a moisture content of 30 percent in their surroundings. Departures of more than about 15 percent from this optimum are very damaging. A soil temperature of about 10°C is best for temperate zone earthworms and soil temperatures above 25°C to 33°C are lethal. Experiments would be necessary to determine proper soil temperatures for tropical and subtropical species. A pH in the neutral zone is required since acid conditions end worm action. To discourage the worms from migrating to escape to a favorable environment, a border of loosened earth should be provided around each feeding cell. This border is an escape zone if unfavorable conditions of moisture, temperature or pit develop. Initially, about 1000 worms per m^3 of in-place solid wastes are needed to start action. One thousand adult worms weigh about 1kg.

In hot dry climates, earthworm feeding will not work. Where there are frequent hot sunny days, shade or ground cover is needed to protect the worms. For solid waste use, worm feeding near the surface is desirable. Heavy rains which soak the feeding sites also flood the soil pores and worm tunnels causing the worms to come to the surface. There they become easy prey to birds, certain beetles and centipedes. These natural enemies also seek the worms in the ground. Other predators are moles, shrews and slugs.

Before this method can be used, there must be information on the life needs of local earthworms. Their responses to the changes of rainfall, sun, and soil conditions through an annual cycle must be known. Experiments on a modest scale of a few m^3 of wastes must be made. Of course, there must be enough local worms that can be gathered to start even a small test. Such small tests can be done in 100 to 200 liter containers, so that the worms cannot move away.

Summary

A summary of solid waste disposal options is given in Table 14. It shows the principal advantages and disadvantages of the six disposal options discussed as they apply to rural villages in developing countries. The following numbers are consistent with Table 14.

1. *Salvage and recovery* should be practiced in all situations. This rarely needs to be urged upon people who already re-use containers and recover combustibles for cooking fuel.
2. The main advantage of *composting* is the usefulness of the humus product. The input material must have enough organic material, putrescibles and paper to feed the bacteria. Sixty to 70 percent of organics by weight is needed to sustain the compost organisms. A carbon to nitrogen ratio of 30 to 1 is required.
3. Aside from initial salvage before burial, a *sanitary landfill* is a method to which all wastes can be added without preparation. Drainage must be controlled to protect water sources. Compaction saves land area. Good cover material is needed. A finished fill provides a recreation area such as a football field.
4. *Anaerobic digestion of animal manure* produces methane, an excellent energy for cooking, water heating and lighting. The building of a methane generating facility requires materials, tools and skills not usually found in rural villages of developing countries. A steady supply of animal manure is needed. Human feces and urine can also be used. Training is needed for operation. Replacement parts are needed for maintenance.
5. *Earthworm consumption of solid wastes* is a new method in limited use. Its product—more worms, their castings and humus—are very good for crop soils. There must be worms available locally and their characteristics must be known. Small test beds must be operated through at least one yearly cycle of rainfall and temperature changes. Inerts must be separated.
6. *Incineration* is rarely suited to rural villages in developing countries. The percentage of non-combustibles is high. A durable, well-functioning incinerator is difficult to build with locally available materials. Incineration may require supplemental fuel.

Industrial Wastewater Problems

The principal focus of this program guide is on the water problems of rural areas, including villages and small towns, in the Third World. As a rule, these types of communities are pre-industrial with little or no industrial activity. However, there is great interest in industrial development and there are many centers of industrial change and growth in the developing countries. This industrialization has already or will soon reach the types of communities with which this guide is concerned. It is therefore appropriate to discuss some of the problems of industrial wastewater which, before the present decade is over, may be relevant to rural and small town situations, and to suggest some general considerations of which leaders and doers in the water and health field need to be aware.

It has been noted elsewhere that the installation of an abundant high quality water supply in a town or village may, in itself, be an important factor in starting industrial activity. Among the first industries that are likely to start are those that prepare, refine or further process the agricultural or raw materials that have long been produced. Simple item manufacture may also be among the early industrial starters since they can take advantage of locally available raw materials and abundant seasonally unemployed farm labor. In many industrial production processes, there is a requirement for safe disposal of wastewater which frequently includes treatment.

Industrial wastewaters generated in small or large plants vary widely in character and flow among various industries, different origins within specific processes, and even from time to time for any given operation. The types and concentrations of potential pollutants in an industrial discharge depend upon many factors. These include the nature of the industrial operation, the raw materials employed, the chemical reactions carried out, the efficiency of utilization and recovery of raw materials and products, and the degree of control over water uses in the plant.

There often is a tendency to attempt to relate technologies and methods of attack on industrial wastewaters to those which have proven successful in

Table 14. The Advantages and Disadvantages of Solid Waste Disposal Options

Method	*Advantages*	*Disadvantages*
1. Salvage and Recovery	Should be used with all disposal methods; conserves materials.	Separation required at source or at disposal point; must have a use or market for the salvage; hazardous work; residues must be handled.
2. Composting	Produces useful product to enhance crop soil; can be done manually; a large area not needed; hauls can be short; manure and feces can be added.	Must have 70 percent putrescibles and paper; must separate and dispose of non-compostables; must have a market or use for the compost; must turn and dampen piles; requires much labor; some hazards in work; carbon to nitrogen ratio of 30 to 1 is needed.
3. Sanitary Landfill	All wastes buried at one time and in one place; can be done manually; depending on amount of salvage attempted, labor requirements are modest.	Site has limited use on completion; long hauls may be required; must protect against surface and groundwater contamination; proper cover material is needed.
4. Anaerobic Digestion of Animal Manure and Human Excreta	Makes use of collected manure; produces methane for cooking, water heating and lighting; residue is a valuable soil amendment high in nitrogen.	Digester and gas holder require materials rarely found locally; valves and piping needed; must have the appliances to use the gas; steady supply of animal manure needed; operation requires skill.
5. Earthworm Consumption of Solid Wastes	Not dependent on high fraction of putrescibles; produces more worms, castings and humus; product very beneficial for crop soil; can be done manually; land requirement modest.	Must have initial supply of worms adapted to local conditions as worms are sensitive to temperature, moisture and pH; must separate inerts, glass, metal and plastics; feed beds must be carefully prepared; must separate worms, castings and humus from remaining inerts at end of 8 weeks; must protect worms from predators.
6. Incineration	Reduces weight by 60 to 75 percent and volume by 85 to 90 percent; complete burning eliminates insect and rat attraction and breeding.	Must have 50 percent combustibles by weight; requires an incinerator unit; smoke and odors are frequent.

coping with domestic discharge. This can lead to serious mistakes in evaluating industrial wastewater characteristics, problems, and solutions. The characteristics and amount of an industrial wastewater usually bear no relationship to the population near the industry, nor of persons employed by the plant, except for usually minor contributions by sanitary wastes and flows used for hygiene of plant workers. The bulk of industrial flow, and pollutional materials in that flow, vary radically from industry to industry and are related to the type of operation, especially raw materials employed, finished products produced, types of processes used and production rates.

Many of the processes and systems commonly used for municipal wastewater treatment have potential in the industrial wastewater field. However, application of the technology should be approached with great caution because industrial wastewater usually differs significantly from municipal sewage, including types of constituents, their concentrations, variations in flow characteristics, and presence of substances which can interfere with treatment processes. Valuable clues about the approach which should be taken can come from reviewing experiences of others with wastewaters of similar characteristics.

Similarities in types of systems used to treat municipal and industrial flows arise only because the same general technology often can be employed for treating a wide variety of wastewaters. Biological treatment, for example, can accomplish certain changes in characteristics of domestic wastewater and often can be used successfully to accomplish similar changes in certain industrial wastewaters. On the other hand, biological treatment may be totally inappropriate for other types of industrial wastewater, or may be suitable only with radical changes in design.

Types of Industrial Wastes

The types of industrial operations which often lead to discharge of potential pollutants through water include transporation of raw materials and waste products, separation of substances which must be removed during production of finished products, chemical reactions carried out in an aqueous solution, and various cleaning operations.

Process wastes are industrial discharges which are directly related to processing of materials within manufacturing operations. These flows may contain raw materials, as well as finished products and intermediates produced during manufacturing. In most industrial plants, process wastes contain the bulk of potential pollutants discharged, although they often may not include most of the water flow. They usually offer the greatest potential for causing stream pollution problems and are wastewaters from which constituents frequently must be removed.

Uses of water can vary widely with the type of manufacturing or processing operations. Some industries may use no water in handling and processing materials and, therefore, may produce no process wastes. This category, sometimes referred to as "dry" industry, includes operations such as blending powders, forming and shaping metal, and plants based on using other solvent systems, for example, "dry cleaning" of clothing.

Other establishments use water for hydraulic transportation of materials. For example, in some regions, the lumber industry uses natural streams, flumes and ponds to transport and store logs. Some food-processing operations use water to transport vegetables and remove waste products. Mining often uses substantial amounts of water for hydraulic transportation of ore. The pulp and paper industry uses water to transport chips and fibers during pulping operations and formation of paper.

Some industries are based on separating substances in raw materials which cannot remain in finished products. For example, fruits and vegetables are processed to remove skins, seeds, shells, and vines before packing and marketing. Pulping operations separate cellulose fibers, needed to make paper, from lignins and other constituents of wood. Some manufacturing uses water to purify manufactured products, with dissolved impurities discarded in wastewaters. In other types of industrial operations, chemical reactions are carried out in water-based systems to accomplish certain changes in materials. The use of water as a medium in which reactions take place forms the basis for much chemical manufacturing, textile dyeing, and many other industries. Sometimes, wastewater flows may originate in removal of water from the finished product through evaporation or drying. These flows frequently contain substantial concentrations of many constituents.

Finally, almost all industries use water for cleaning and housekeeping. The food and dairy industries, for example, require large quantities to clean food, storage containers and processing equipment. In the cotton industry, large quantities of water are used for cleansing and rinsing cloth. In wool processing, an early step is scouring to remove grease, oil and other impurities from fibers before making or dyeing the yarn or cloth.

Wastewater flows may originate from several sources within industrial plants, including sanitary wastewaters, process wastes, cooling waters, boiler waters and storm runoff. These usually differ widely in characteristics and in methods used for collection, treatment and disposal.

Solving Industrial Waste Problems

In a study of a pollution problem, the first step is to conduct an inventory of wastewater discharges throughout the plant to determine their sources, quality characteristics and flows. Basic environmental data about the watercourse to which the waste is to go should be collected to permit discharges from a particular source to be examined as part of the entire problem along that stream.

Sampling and analytical methods are of crucial importance. Selection of proper sampling location, timing and techniques must be done with great care to ensure that the samples collected are responsive to the needs of the program. Standard analytical methods frequently are not applicable to industrial wastewaters and should be used only after confirming that data produced by them actually are valid for the wastewater in question. The problem most commonly encountered is presence in industrial wastewaters of interferences which may not have been considered in development or selection of the "standard" technique.

An approach to solving industrial waste problems is based upon exploring several alternatives in a rational sequence. The steps include:

(1) attempts to eliminate or reduce the problem through in-plant actions,
(2) control and optimization of wastewater discharge locations and patterns,
(3) discharging wastewaters, with or without pretreatment, into municipal sewage systems, and
(4) industrial wastewater treatment.

In-Plant Actions

The in-plant approach should be tried first because, if it proves possible to modify manufacturing or other operations to a point which eliminates the wastewater flow, then none of the other alternatives need be pursued. Efforts must be made to bring about in-plant changes to minimize wastes. A detailed inventory of wastewater sources within the industrial plant is needed as a resource in subsequent investigations.

Where feasible, wastewaters should be eliminated. Unfortunately, this is seldom feasible, although it has been accomplished by a few industries. In many instances, it is feasible to reduce wastewater discharges significantly. There is a difference between reductions in flow and reductions in pollutional constituents. Flow reductions usually are helpful, but not always. Reductions in pollutional constituents are always desirable.

Frequently, substantial benefit may be realized through changes in character of the wastewater by modifying in-plant operations. This can be accomplished by changing manufacturing processes or by substituting different raw materials or chemicals in them.

In considering in-plant modifications for improved wastewater control, it should be recognized that a change in a manufacturing process does not necessarily have to yield a profit to make it financially attractive to the company. It should cost less than alternative methods for coping with the wastewater problem, such as treatment at the end of the pipeline.

Combining Wastewater Discharge

Equally careful consideration should be given to combining wastewaters from different manufacturing operations. That can be accomplished by combining flows from multiple out-falls or by providing mixed equalization basins for combination of flows released at various times, as well as from different locations.

Proper location and design of outfalls may help minimize impacts of discharges on receiving streams. In some instances, major benefits may be realized by installing storage facilities with programmed releases to conform with the assimilative capacity of the stream or municipal sewage system.

Industrial wastewaters remaining after in-plant reductions should be examined for opportunities to minimize problems through segregation of wastewater into streams requiring different handling. Combinations of wastewater which can be accomplished advantageously should be made and wastewater discharge should be used to take full benefit of whatever dilution may be available.

Discharging into Municipal Sewers

Some industries have the option of handling their own wastewater discharges separately or releasing flows into municipal sewage systems for joint treatment and disposal. This should be considered carefully where the option is available. Frequently, it may be more economical to combine industrial and municipal wastewater flows for joint treatment than to treat them individually for separate discharge. In evaluating combining treatment, attention should be paid to toxic pollutants that end up in sludge as well as those remaining in discharged water. Sludge pollutants may create serious problems for sludge re-use or disposal. After exploring all of the other alternatives, it usually is necessary to consider treatment of the remaining flow before discharge. Many options are available for treatment processes.

Discharge into public sewers is sometimes the only alternative for industries located in metropolitan areas. They may have no direct access to a surface watercourse. Sometimes access is available, but industries may be prohibited by laws and regulations from discharging into watercourses which flow through cities and towns. Limited pre-treatment on site, such as settling or aeration, can be done.

Some industries are too remote to have reasonable access to public sewers, or they may be prevented from discharging into a public system because of capacity limitations of sewers or treatment plants. In some instances, the municipality may be unwilling to assume responsibility for treating wastewaters from an industry.

For those industries which have the option of discharging into a public sewerage system or disposing of wastewaters by direct discharge into a watercourse, the question should be explored carefully. There are many advantages to a typical industrial plant in discharging its wastewaters into a public system. The responsibility for its treatment and disposal is then with persons and organizations specializing in that type of activity. This leaves maximum time for the industrial personnel to concentrate on production or other activities in which they have special expertise.

In some instances, joint treatment may yield substantial savings through economy of scale, where the industrial wastewater is compatible with the treatment system employed by the city or town. Potentially harmful impacts which can result from discharge of industrial wastes into public systems should be explored carefully. Those impacts include hazards to operating personnel, damage to sewers and treatment facilities, overloading or upset of treatment plant operation, and discharge of objectionable materials to receiving streams when they are not adequately removed by the treatment plant. Special efforts should be made to establish reasonable rate structures to charge industry for receiving and treating its wastewater.

It is vitally important that proper controls be established to regulate discharge of industrial wastes into public systems. Monitoring should be established to ensure that those controls are met on a continuing basis by each discharger.

Where industrial wastewater may create a problem in the public system, it may be necessary to require changes in flow characteristics or quality to avoid harmful effects. The controls may be accomplished through in-plant modifications or through pre-treatment of the industrial wastewater before discharge into the sewage system.

End-of-Pipeline Treatment

End-of-the-pipeline treatment is a last resort for coping with industrial wastewater problems. Construction and operation of treatment facilities are always possible, but usually involve major expenditures. Further, after commitment has been made to this investment, it seldom is possible to recover much of the cost through subsequent in-plant changes to reduce loadings or alleviate impact on the receiving stream. The major savings which might be realized through alternatives to treatment usually must be instituted *before* installation of treatment facilities, allowing appropriate modifications in plans for those facilities.

There are many processes and technologies available for treating industrial wastewaters. These include physical, chemical and biological systems which are capable of removing various and particular types of pollutants. The types of processes available in each category range from those which are relatively simple and require little mechanical equipment to others based on complex technology. The selection of the best combination of processes must be done carefully. The treatment processes must be fitted to the characteristics of the wastewater to be treated, to the specific water quality goals to be met by treatment, and to local availability of materials, equipment and human resources.

SOURCES
CHAPTER FIVE

This chapter was written primarily from materials prepared for use by the AID Knowledge Synthesis Project. Also useful was *Waste Stabilization Ponds,* Earnest F. Gloyna, Geneva: World Health Organization, 1971.

RELATED TECHNICAL NOTES
CHAPTER FIVE

SAN.G	Overview of Sanitation
Methods	
SAN.1.M.1	Simple Methods of Excreta Disposal
SAN.1.M.2	Simple Methods of Washwater Disposal
Planning	
SAN.1.P	Planning Simple Excreta and Washwater Disposal Systems
Design	
SAN.1.D.1	Designing Slabs for Privies
SAN.1.D.2	Designing Pits for Privies
SAN.1.D.3	Designing Privy Shelters
SAN.1.D.4	Designing Aqua Privies
SAN.1.D.5	Designing Bucket Latrines
SAN.1.D.6	Designing Compost Toilets
SAN.1.D.7	Designing Sumps, Soakage Pits and Soakage Trenches

Construction

SAN.1.C.1	Constructing Slabs for Privies
SAN.1.C.2	Constructing Pits for Privies
SAN.1.C.3	Constructing Privy Shelters
SAN.1.C,4	Constructing Aqua Privies
SAN.1.C.5	Constructing Bucket Latrines
SAN.1.C.6	Constructing Compost Toilets
SAN.1.C.7	Constructing, Operating and Maintaining Sumps, Soakage Pits, and Soakage Trenches

Operation and Maintenance

SAN.1.O.1	Operating and Maintaining Privies
SAN.1.O.4	Operating and Maintaining Aqua Privies
SAN.1.O.5	Operating and Maintaining Bucket Latrines
SAN.1.O.6	Operating and Maintaining Compost Toilets

Methods

SAN.2.M.	Methods of Combined Washwater and Excreta Disposal

Planning

SAN.2.P.1	Planning Combined Washwater and Excreta Disposal Systems
SAN.2.P.2	Estimating Sewage or Washwater Flows
SAN.2.P.3	Determining Soil Suitability

Design

SAN.2.D.1	Designing Subsurface Absorption Systems
SAN.2.D.2	Designing Cesspools
SAN.2.D.3	Designing Septic Tanks
SAN.2.D.4	Designing Sewer Systems
SAN.2.D.5	Designing Stabilization Ponds
SAN.2.D.6	Designing a System of Two or Three Stabilization Ponds
SAN.2.D.7	Designing Mechanically Aerated Lagoons
SAN.2.D.8	Designing Non-Conventional Absorption Systems

Construction

SAN.2.C.1	Constructing, Operating and Maintaining Subsurface Absorption Systems
SAN.2.C.2	Constructing, Operating and Maintaining Cesspools
SAN.2.C.3	Constructing Septic Tanks
SAN.2.C.4	Constructing Sewer Systems
SAN.2.C.5	Constructing Stabilization Ponds
SAN.2.C.7	Constructing Mechanically Aerated Lagoons
SAN.2.C.8	Constructing, Operating and Maintaining Non-Conventional Absorption Systems

Operation and Maintenance

SAN.2.O.3	Operating and Maintaining Septic Tanks
SAN.2.O.4	Operating and Maintaining Sewer Systems
SAN.2.O.5	Operating and Maintaining Stabilization Ponds
SAN.2.O.7	Operating and Maintaining Mechanically Aerated Lagoons

Methods

SAN.3.M	Methods of Solid Waste Management

Planning

SAN.3.P	Planning Solid Waste Management Systems

Design

SAN.3.D.1	Designing a Landfill
SAN.3.D.2	Designing a Composting System

SAN.3.D.3	Designing a Solid Waste Collection System
SAN.3.D.4	Designing a Biogas System

Construction

SAN.3.C.4	Constructing a Biogas System

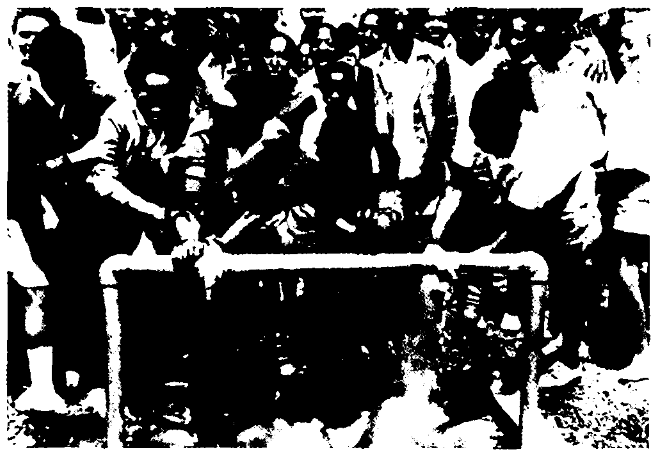
Operation and Maintenance

SAN.3.O.1	Operating and Maintaining a Landfill
SAN.3.O.2	Operating and Maintaining a Composting System
SAN.3.O.3	Operating a Solid Waste Collection System
SAN.3.O.4	Operating and Maintaining a Biogas System

PART THREE. EFFECTIVE WATER SUPPLY AND SANITATION PROGRAMS

Part One of this manual summarized the problems that unsafe water supplies and sanitation practices pose to human health. Part Two described some of the technical solutions to these problems. Part Three addresses the question of how to match the solutions to the problems through comprehensive, effective water supply and sanitation programs.

Chapter Six deals with planning water and sanitation programs at national, regional or community levels. It is an overview of how a planner or other person in charge of developing such programs should proceed. The following chapters of Part Three address three specific aspects of water and sanitation programs that are so important they often determine whether a program succeeds or fails. Chapter Seven deals with community participation, Chapter Eight with developing human resources, and Chapter Nine with the economics of water supply and sanitation programs.



Reaching the point of turning on taps for a new water system requires planning, community participation, training and financing.

CHAPTER SIX
PLANNING WATER SUPPLY AND SANITATION PROGRAMS

SUMMARY

The planning of water supply and sanitation programs must occur within a political situation that is realistically assessed by the planner. The approach chosen should reflect the political realities of the area. Variations depend largely on the extent to which planning approaches are expert-biased or user-biased. Generally, the most successful water and sanitation programs are user-biased because this approach ensures community understanding and support of the program. The approach that is most likely to result in an efficient and successful program is a step-by-step process that involves the community extensively at every stage of project planning and implementation. The key factors in water supply and sanitation program planning are total costs, institutional and human resources, and community participation.

The planning process occurs in seven steps:

(1) Recognizing the Problem
(2) Formulating Goals
(3) Collecting and Analyzing Data
(4) Generating Alternatives
(5) Appraising and Selecting Programs
(6) Making New Programs Work in Practice
(7) Evaluating Programs

The selection of a water supply system must be appropriate to the needs of the users.

CHAPTER SIX
PLANNING WATER SUPPLY AND SANITATION PROGRAMS

Water and sanitation program planning occurs in a political and social setting which must be understood before the detailed work of preparing specific plans aimed at raising standards in a given geographical area can proceed. The first two sections of this chapter describe some of the broad socio-political factors which influence and limit the planner's work in water and sanitation. They also explore some of the myths which surround the planning process and the dangers which proceed from taking these myths too seriously.

Later sections of the chapter describe the mechanics of program planning in great detail. These procedural details must be read throughout in light of the reservations set out in the first two sections. Textbook descriptions of planning procedures tend to be written as if men and women, and particularly "men and women in organizations," were wholly rational creatures whose thoughts and acts were at all times dominated by the operation of pure logic. A much more realistic hypothesis is that a great deal of social behavior, including the behavior of planners and of the large number of people and institutions they interact with, is heavily influenced by emotional factors of many kinds.

To summarize, the bulk of Part Three refers to the *content* of planning, while the first two sections of this chapter aim to correct this imbalance by looking at planning as a social process in which groups and organizations ranging from international agencies to local villages use political and social means to achieve their objectives. "Political behavior" is used in a limited technical sense to refer to the ways groups handle problems of conflict. These conflicts may sometimes be quite open and explicit but often they are not.

Political Setting

The political dimensions of the planning process often are sources of conflict. The following analysis greatly oversimplifies a complex subject as a means of dealing briefly with it and of identifying what seem to be the types of conflict likely to influence water supply and sanitation program planning. The most common of these are as follows:

- **The external/internal dimension.** The main example of this is the differences in perception and objectives between international agencies or the administrators of bilateral aid programs on the one hand and national governments of developing countries as the potential recipients of aid on the other.
- **The bureaucracy/grass roots dimension.** This refers to major potential conflicts of interest and objectives within a single country between national or regional governments and local communities. This "vertical" dimension and the differences of views associated with it is similar to the external/internal dimension but in one critical respect it is different. The latter involves two groups who are similar in kind, while one of the parties on the vertical dimension—the local community—is radically different from either of the others. The local community whose conditions the planner seeks to improve tends to develop its views in a more informal and social way than the national bodies with which it deals, but its representatives tend to be much less articulate than their opposite numbers.
- **The professional dimension.** Conflict can arise from this source at all levels within the planning system except possibly the smallest local community. In particular, conflicts of perception and objectives tend to arise between the health specialist and the water supply and sanitary engineer.

The External/Internal Dimension

The objectives of international or bilateral agencies in setting priorities for the distribution of their resources and in planning how these might best be used are inevitably different from those of the potential recipient countries who are intended to benefit from an aid program. The planning process must recognize the possibility of conflict and make adequate provision for coping with or resolving it.

Some of the reasons objectives are likely to differ, possibly leading to conflict, are as follows:

- Different time scales may mean that the two parties are looking for results in different time periods.
- Criteria for measuring success or progress may be different.
- The need for flexibility in planning is likely to be perceived as more important by the recipient than by the donor.
- Possible adverse effects of the plan, if it is successful, on other parts of the national economy are likely to be of higher priority for the recipient country (for example, impact on the local labor market).
- The control of resources such as equipment and out-of-country specialists tends to be a high priority matter for donor agencies while the need to reduce limitations tends to be more important to recipients. These contrasting emphases on resources on the one hand and limitations on the other are a potent source of conflict within the planning process, particularly as the plan is being implemented and its outcomes monitored.

Local residents often work with officials to complete a well project.

There are two interesting examples of the kind of action which has been taken by donor agencies to help resolve problems arising through conflicting perceptions or objectives. First, regional projects and programs, based on the development of regional resources capable of serving the needs of several countries or part of a large country, can be a means of securing greater flexibility in responding to local needs. This has been the approach to human resource development and training in the Caribbean.

Second is the increased attention being given by United Nations agencies in particular to the need for key human resource development studies to go along with technical ones. Human resource quality and availability are likely to be the largest single local limitation in the implementation of a plan which looks fine on the drawing board but needs trained people to give it life.

The Bureaucracy/Grass Roots Dimension

Some of the differences of perception described above also apply in the vertical dimension between national bodies and local communities. Certainly different time scales apply and criteria for measuring success tend to differ widely. Perhaps the most important of the factors is the contrast between the national emphasis on the importance of resources and the local concern with limitations. The possibility for misunderstanding and conflict in this context should not be underestimated.

The two main factors in the vertical dimension are, however, somewhat different in kind and certainly in importance compared with those already listed. They are also closely related. These factors are perceptions and communications. Perceptions of "superior knowledge" on the part of national administrators and technical experts can sometimes stray well over the boundaries justified by administrative experience and technical qualifications. These perceptions, often rooted in a culture's superior/inferior status habits, are reinforced by difficulties local people may experience in voicing their feelings on the subject of water supply and sanitation and even in producing information which may be of direct practical use to the planner.

Methods of communicating within the offices of a national ministry of water supply and sanitation, which are basically bureaucratic, and methods of communicating within local communities, which are essentially social and informal, are as different from each other as they can be. It is not surprising that difficulties and misunderstandings arise between the two groups since they have such radically different ways of communicating. The bureaucratic version is formal, recorded in writing, and in the broadest sense technical in content. The local system is informal, unrecorded and mainly social in content.

The increasing attention being given to community participation in the development of improved facilities which people will understand and use recognizes the importance of this subject. But if this problem is dealt with by manipulation, i.e., using rank, economic power and other means of applying pressure to reinforce the old philosophy that the people at the center really do know best, such programs are likely to fail.

The Professional Dimension: The Doctor and The Engineer

The "professional dimension" exists at every level of the system. It occurs within the aid agencies, nationally between ministries of health and ministries of water supply, and locally between individual doctors and engineers. As in the case of the other two dimensions there are problems of perception, differing objectives and communications. One of the conventional solutions in many developed and some developing nations to bridge gaps of professional (mis)understanding is the steering committee.

By putting people of different professions on steering committees to monitor major projects from the feasibility study onwards, it is too readily assumed that this will in some magic way solve the professional communication problem. If this is all that is done, the situation may even be worsened. What is needed, in addition, is some provision for learning to take place by both groups within the steering committee system. This in turn requires very careful thought about the structure of the committee and its proceedings. One possibility is to provide an aid to learning by attaching to the group someone who is professionally in the learning business, just as the other two groups are in the health business and the engineering business.

Any description of the political setting for water supply and sanitation planning on a world-wide scale oversimplifies a very complex subject. The problems identified here are essentially those arising from relationships within social systems rather than between individuals.

Even so, it is possible to summarize the political dimensions discussed here in tabular form. Their end points can be tabulated as shown in Table 15.

The process of coping with or resolving the conflicts which this table highlights is on-going and involves the groups and individuals on one side of the table becoming more aware of the issues of concern to those on the other side.

Program Design

In designing a water supply and sanitation program, there are several alternative planning approaches that may be used. Each planner must choose his or her own approach but this section provides some basic principles and concepts to aid in making this choice. To maintain consistency and allow comparison, human resource development and training plans will be used as illustrations. The approaches and concepts described are applicable to all types of plans, whether general or specific.

Table 15. Political Dimensions of the Planning Process

External (concern with resources)	*Internal* (concern with limitations)
National Bureaucracy (concern with systems)	*Local Grass Roots* (concern with social values and practicality)
Engineering (concern with things)	*Health* (concern with people)
Overall concern with *QUANTITY* of data, materials and equipment	Overall concern with *QUALITY* of life

Alternative Planning Approaches

The four approaches to the design of a program discussed here are not, of course, the only options open to the planner. The range of possibilities and combinations is endless because there are many possible versions of each approach. The four approaches are key points on a spectrum along which there are many alternative positions for the two key parties to the process: the party which provides the funding, the know-how and exercises ultimate administrative control, and the party which is to benefit from the program.

There are, in fact, far more than two parties involved in the design process. In the simplest of cases, an external funding agency, one or more consultants and contractors, a national and/or regional government and the final user are all involved. For the purpose of this discussion, all organizations other than the final user are being grouped together.

The spectrum of alternative design approaches ranges from the authoritarian extreme to the democratic extreme. The authoritarian program provides for as much as possible to be *done for* the final user, whose main role is to get in the way of the experts as little as possible. At the democratic extreme, the highest priority is given to involving the final user organization to the extent of its staff first learning to do what the expert would otherwise do and then doing it.

Within this spectrum the four main planning approaches are:

Approach 1. The expert designs and does it for the client.

The program design provides for the "outside experts" to do literally everything, except possibly the most basic manual tasks which require no special learning.

Approach 2. The expert designs and does it for the client but teaches "them" how to maintain it.

The DOING is as in approach 1 except that someone is taught how to operate and/or maintain the system which has been installed.

Approach 3. Expert and client design and do jointly.

In the course of this joint activity, the client learns how to plan, implement, operate and maintain the system.

Approach 4. Expert teaches from the beginning and the client designs and does.

This is the best arrangement from the viewpoint of the client because it creates the maximum opportunity for learning and transfers control to local hands at the earliest possible moment.

Expert bureaucratic reaction to this range of choice tends to be, and often is, to try and operate as close to Approach 1 as possible. The case for doing this is that it secures maximum initial performance so far as the *quantity* of output goes, it ensures optimum use of hardware and technology, it makes the best use of time, it is systematically recorded for posterity, and for program start-up it appears, by far, the most cost effective approach.

The practical advantages of this approach are clearly understood. They also are usually clearly articulated by those in favor of Approach 1 who themselves operate in bureaucratic systems where these kinds of criteria for judging effectiveness are used in many situations.

The case for Approach 4 or even Approach 3 often loses by default partly because its advantages are difficult to quantify. The more important reason that these approaches often are not used is that potential advocates for them, usually clients, are often relatively inarticulate. Sometimes, they only feel that there is something radically wrong from their point of view but do not know quite how to put it into words. Approach 4 is so infrequently used as a basis for program design that it is not well-developed and there are too few examples of it to show people.

The advantage of Approach 4 is that it builds resourcefulness into the local situation. Even if the quantitative results of the new system are less than those which might have resulted from Approach 1, what *is* achieved is understood, is operated and maintained effectively, and the potential is created for multiplying the new way of doing things by the use of local resources and local skills. The objectives of Approach 3 or 4 are much more extensive than those of Approach 1 or 2. They are also more long-term, in the sense that the benefits of using the former strategies occur over a much longer period of time. The objectives of Approach 3 or 4 include the intangible aim of developing in local people a sense of ownership in the project so that they feel "it is *our* scheme" not "it is *their* scheme."

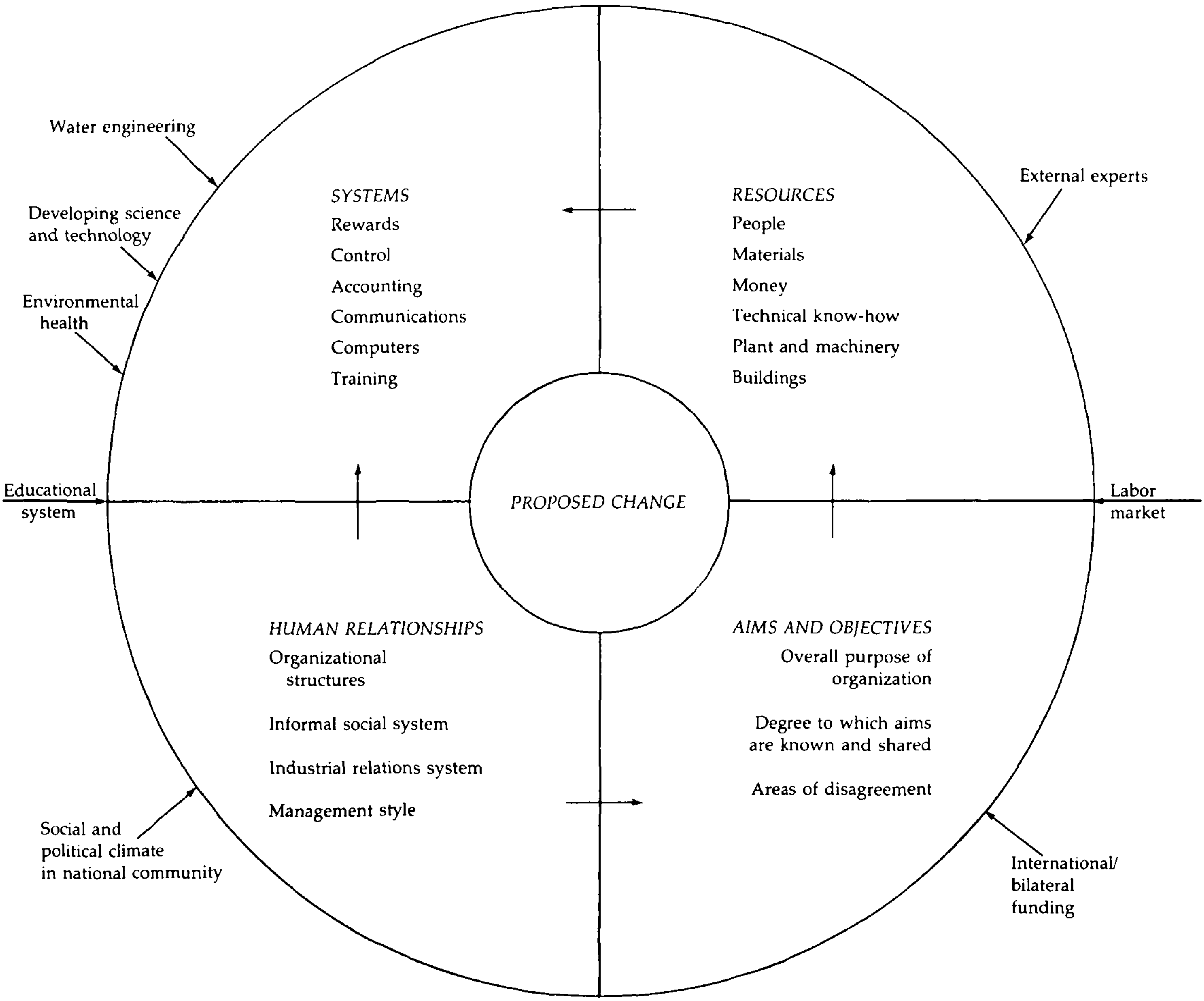
The above description makes clear the central problem of choosing a planning approach where the criteria for measuring success are so different for two of the main approaches. Approach 1 addresses productivity, costs, systematic recording, and optimum use of time. Approach 4 emphasizes local resourcefulness, commitment and ownership. Who in his or her right mind, it might be asked, would opt for Approach 4? The answer lies in the inescapable fact that, at some stage, local people must run systems designed and installed by experts. There is some evidence that the closer planning comes to Approach 1, the greater the problem at the final hand-over stage. Dependency relationships can be as satisfying to the expert as they are frustrating to the client, but they are not everlasting. Choosing an option more like Approach 4 may in the long run be the most cost effective approach after all.

Selecting a Planning Approach

The following simple models are suggested as aids in the process of thinking about program design and selecting from alternative design approaches. Their main purpose is to provide some of the insights needed to use Approaches 3 and 4 confidently.

Model 1. "The wheel." The "wheel" can be used to examine the total organizational environment within which the new water and sanitation program is to be introduced. In this model, shown in Figure 4, the organization within which the proposed change will occur is shown as a large circle. Its circumference represents the contact between the organization and the wider environment in which it operates, for example, a national water supply corporation in a single country. A smaller circle at the center of the large circle represents that part of the organization in which the planned change is to take place.

Figure 4. Model 1: The "Wheel"



All the key factors both inside and outside the organization which are likely to influence the proposed change can be shown in this model. Of the four groups of factors used in the model to describe an organization, most of all is known about the *resources* available. Records on this subject are extensive and people within organizations feel most comfortable when dealing with this subject. As a result, far too many decisions about proposed change are initiated in the resources area without necessarily taking into account limitations in other areas.

Until recently, far less was known about the *systems and procedures* of an organization than about the quantity, quality and disposition of its resources. Now there is more understanding about how organizational systems work and how different systems affect each other. Not only has knowledge about systems increased, but the range and complexity of the systems used has grown rapidly and in most organizations this has been greatly increased by the use of the computer. This, in turn, means that a great many more decisions about change in an organization are initiated in the systems area. The limitations which may arise from other areas, including resources, are not necessarily taken into account.

In the next segment of the "wheel" is an area called "*human relations.*" This term denotes all the intangible relationship factors which determine motivations and morale within organizations. Again, systematic knowledge in this area has increased greatly in recent years. Still, a great deal less in general is known about these factors than the previous two groups. Human relations factors are also heavily culture dependent so what is known about one culture is not necessarily valid in a different one. Organizations often initiate change in this or other areas without adequately assessing in advance its likely effect.

The final segment is called *aims and objectives* and groups together all those factors related to the overall identity of the organization and how its members perceive that identity. It does not deal only with the official written "constitution" of the company or the annual restatements of business or public service objectives. It also includes the different perceptions which individuals and groups may have of the organization as a whole and its mission in society. When change is proposed, the degree and nature of these differences in perception may be much more significant than any of the official doctrine about organizational purpose.

Change initiated by action in any one segment of the organization will only succeed if the changes in the other three areas which will inevitably follow are consistent with the intention of the plan. The inability to recognise these interactions causes most plans to fail. Planning approaches 1 and 2 tend to be initiated in the resources/systems segments, and often underestimate the consequences in the human relations and aims and objectives segments.

An important point to keep in mind is that the least is known about the factors in organizational development that have the greatest effects on attempts to plan change. Much less is known about how to describe human relations in organizations than about how to record cash flow. It is the deep knowledge of simple things that allows expert-based approaches at the authoritarian end of the planning spectrum to be used. But it is the complexities of social behavior and the problems of local perceptions of identity and ownership which can frustrate these planning approaches in the long run.

The "wheel" does not point out how to avoid these kinds of frustration but at least it helps to ensure that no one is too surprised when they occur. If used in the early stages of the planning process, a model of this type may help select a better planning approach. In general, it also is a reminder of where effort should be put inside an organization. Usually, improving organizational records and systems are far less important than improving human relationships and clarifying misunderstandings about aims and identity.

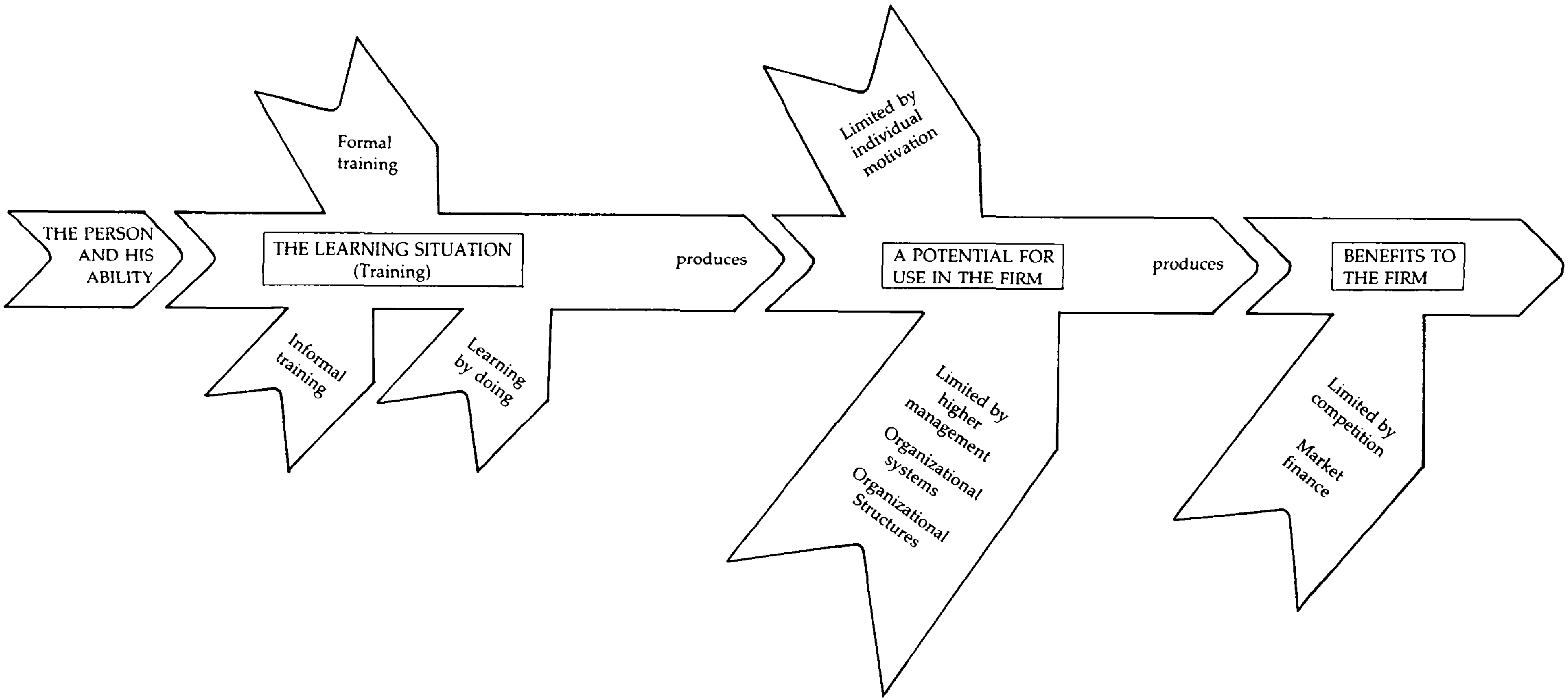
Model 2. Resources and Limitations. Earlier in this chapter, external experts were contrasted with user organizations by stressing the former's preoccupation with resources and the latter's concern with local limitations. A model has been developed to describe the relationship between resources and limitations where organizational change is being planned. This model was developed as a training concept because the resource being studied at the time was staff training, but the basic model applies to any form of change. A training example is used in Figure 5.

This model shows quite simply that the benefits to an organization from training, for example, will be limited in three main ways: by individual motivation, by internal limitations within the organization, and by external limitations within the local markets for labor and products. Training does nothing but create a *potential* which may be only partly achieved or, in some circumstances, not achieved at all.

In these circumstances, there are four ways to improve the situation: improve the size or quality of the initial training effort, try to influence the individual's motivation, try to change the organization's systems, and try to manage the external environment better.

Program design plans in the water supply and sanitation area may be frustrated in precisely this kind of way. What this model suggests is that diminishing returns are likely to set in at a relatively early stage if attempts are made only to improve the resources. Instead, work should focus on the limitations, particularly those within the organization since they can be influenced. It would be a much better idea to anticipate these possibilities at an earlier stage in the planning process, which means in general somewhat more emphasis on limitations and changing them and rather less on resources.

Figure 5. Model 2: Resources and Limitations

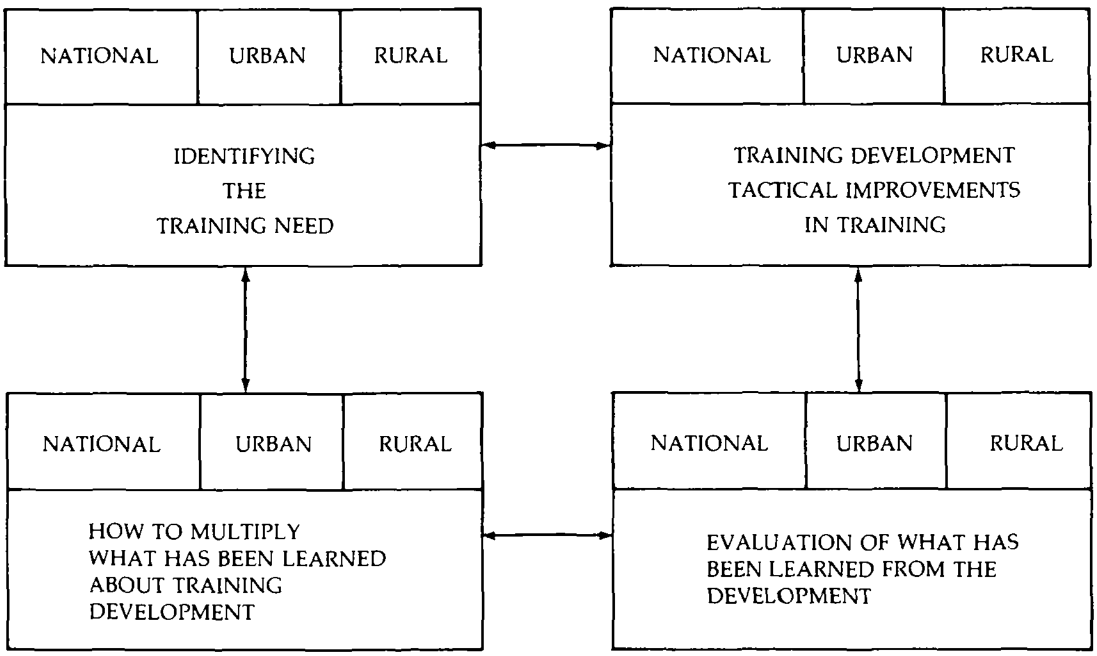


Model 3. The Training Development Process. If anything close to Approach 4 is used in designing a new water supply and sanitation program, there must be a parallel investment in improving the quality of the national training delivery system. This system must be made self-sustaining as quickly as possible. Although training is addressed in some detail in Chapter Eight, one model of the training development process is included here to emphasize its importance to Approach 4.

This model, shown in Figure 6, illustrates the basic stages of the training development process which can take place at any of four levels: the individual undertaking, the rural sector, the urban sector, and the overall national system. An approach is needed that improves the overall quality and relevance of the total training system on a continuous basis. The goal is to make the system not only more efficient but also more sensitive to need and more capable of producing better solutions in the future. This model is about *multiplying* what is being learned within the organization about training development so that the total training system is constantly being improved through actual experience.

This discussion has not attempted to provide a wide- ranging list of alternative planning options. Instead, the options have been deliberately restricted to highlight the contrast between expert-based approaches which are technically sound but socially suspect, and more social learning-based approaches which look more risky but possibly have more long-term potential for success. The models should be useful in pointing out the issues involved in choosing an approach to planning social change.

Figure 6. Model 3: Training Development



The remainder of this chapter is devoted to the detailed procedures required in planning an environmental health program. The planning process can be divided into seven steps: (1) recognizing the problem, (2) formulating goals, (3) collecting and analyzing data, (4) generating alternatives, (5) appraising and selecting programs, (6) making new programs work in practice, and (7) evaluating programs. Each of these steps will be discussed in turn.

Step 1: Recognizing the Problem

The first step in water and sanitation planning is to identify the problems or conditions that need to be changed. The related processes of problem identification and goal formulation (Step 2) are the main roots from which a water supply and sanitation program grows. For effective planning, problems need to be well-defined in terms of their extent, magnitude, and importance. Unless a problem is clearly perceived and understood, it is difficult to obtain approval from individuals and institutions required for eventual plan implementation.

National Needs and Sector Studies

There are several different approaches to the process of recognizing water supply and sanitation problems. These are complementary to each other rather than alternatives. At the most general level are the formal comprehensive studies of national needs which are used to set out long-term policies, development timetables and implementation strategies. Characteristic of these studies are the sector investigations carried out by the World Bank and other international lending institutions. World Bank studies of the water supply and waste disposal sector at the national level, for example, identify problems and constraints first, then analyze goals necessary for a national plan, and finally, make recommendations for organizations, policies and practices required to achieve the goals.

Investigations of this kind are usually intended by the international agencies concerned to provide a data base for decisions regarding level of funding required, the relative importance of urban and rural development, the quality of service needed and technical options available. They do not normally lead to specific action programs ready for immediate implementation, notwithstanding the fact that they involve the use of a considerable amount of expensive high-level manpower. The World Bank estimates that even a limited sector study in a small country may require up to six person-weeks of effort and involve at a minimum an engineer, a financial analyst, and an economist. In longer studies, a human resource development and training specialist is often added to the team or a detailed human resource development investigation may be commissioned separately.

The fact that sector studies at the national level do not usually lead to specific action plans for immediate implementation should not be taken to mean that such plans cannot or should not be made. What it *does* mean is that a wrong assumption is often made by planners. This wrong assumption is that because water supply and sanitation services are operated on a regional and local basis, and "national needs and requirements" are argued to be no more than the sum of local and regional needs, national needs will for the most part be catered for in the course of dealing with local and regional needs. Alternatively it is assumed, again quite wrongly, that if there are "national needs" which must be ministered to separately and directly, exactly what these needs are will only in some mysterious way be revealed *after* local urban and rural plans of action have been worked out.

In practice, there are a number of "key result areas" in most sector studies where it is essential that objectives be set and action taken at the national level, more or less immediately. Failure to do this is often a reason for things going wrong at lower levels at a later stage. The examples that follow are all taken from the human resource development area because it is here that failure at the problem identification step to recognize and act on national level needs is often most damaging and yet, regrettably, most common:

- Forecasts of significant increases in the demand for particular categories of high level technical human resources (for example, civil engineers) can only be properly made at the national level. Preliminary action can also be taken to initiate those early parts of the educational planning process which are particularly time-consuming.
- Organizational changes may be needed, such as a central training and development unit to serve as a "focus organization" for human resource development in the water sector and to advise and assist local undertakings from an early stage in the human resource development aspects of their plans.
- Wider ranging proposals to recruit and train training staff may be initiated at the national level in anticipation of local needs which might otherwise take much longer to fulfill.

Another example of problem identification at the general level can be found in the national decade plans being prepared as part of the International Drinking Water Supply and Sanitation Decade. In theory, these plans contain not only a needs assessment for the water supply and sanitation sector but also an investigation of the linkages between water supply, sanitation, health, agriculture and urban and rural development that are necessary to achieve decade targets. As in the case of sector studies, these plans generally spell out recommended policies, strategies and goals but do not develop specific action programs. Again, there is no conclusive reason why this should be so. Certainly human resources implications of a similar kind are often likely to arise and to require relatively early action. Broad decade-type plans, as well as the more conventional sector studies, are often used in the preparation of national development plans which occur in a cyclical manner every three to six years. Personnel requirements again are high. The World Health Organization estimates that it takes two to five weeks just to carry out the needs assessment portion of decade plans.

In looking at the outcomes and possible uses of national level studies, it should be stressed that they may also be a source of information on linkages between urban and rural needs and requirements. The recognition that common problems exist may be valuable in avoiding unnecessary duplication of hardware, staff or know-how.

Below the general level of sector studies and national decade plans is the program level. At this level, action-oriented sets of projects and activities are developed in detail. Programs must operate within the policies and strategies established at the national level and are also directly supported by any services created as a result of judgments made there. Problem identification at the program level therefore should lead to the formation of specific objectives, which in turn are linked directly to individual project designs and to the types of results desired.

Guidelines for Problem Identification

Some guidelines are available for identifying water supply and sanitation problems. The primary purpose of environmental sanitation is to eliminate the causes of communicable disease (see Chapter Two), identified by the World Health Organization as unsanitary water supply, contamination from human excreta, and insect vectors of disease. WHO adds, however, that as the community develops there should be a progressive expansion of sanitary services to provide better standards of health and improved conditions of living.

Linking water and sanitation problems to essential human needs is another useful approach to problem identification. A recent USAID study in rural Jordan identified the following five-level hierarchy of fundamental human needs:

1. physiological needs,
2. safety needs,
3. social needs,
4. ego needs,
5. self-fulfillment needs.

In this ranking, the simpler but more urgent physiological and safety needs must be met before the more complex ego and self-fulfillment needs can be achieved. This hierarchy was then used to develop the following ranking of basic human needs in the rural areas of Jordan:

1. basic material needs (food, housing, clothing, water)
2. health needs (curative and preventive care)
3. education needs (knowledge and skills, special and adult education)
4. income and economic opportunity needs (employment and income maintenance)
5. personal adjustment and social participation needs (child care, family planning, recreation, cultural and religious services, family counseling and support, community organization, participation in decision making, participation in community work).

By combining a hierarchy of human needs with the idea that development activities should progress through distinct stages of priority, it is possible to define general priorities of problems. An early attempt at this was made by the American Public Health Association, which proposed the following stages of environmental health activity:

- ensuring the elements of simple survival,
- prevention of disease and poisoning,
- maintaining an environment for efficient human performance,
- preservation of comfort and enjoyment of living.

These stages can be viewed in terms of importance or urgency, with simple survival ranking the highest and comfort the lowest. In addition, they provide some indication of the likely sanitation-related problems contributing to each stage. Thus, simple survival in stage 1 is probably related to inadequate water quantity, while disease prevention and poisoning in stage 2 is likely to be largely due to problems of water quality and excreta disposal. Stages 3 and 4 are more complex and probably relate to all of the above problems as well as to additional issues of accessibility to water supply and costs of sanitary services.

Water and sanitation problems should be identified using both a supply approach and a needs approach. The supply approach involves a review of health statistics, physical and biological environmental factors, and socio-economic conditions in order to understand the complex interrelationships between people and their environment. The needs approach involves defining problems on the basis of felt and expressed needs. In practice, the needs approach is sometimes more workable, both for defining problems and for influencing the officials who make decisions.

In summary, problem identification at the national, regional and local community program levels should be specific and factual, address the basic needs of the people, reflect the relative degree of urgency between problems, and encourage subsequent action. The following procedure for identifying and describing water supply and sanitation problems is suggested as a general guideline for the purpose of regional and national program planning. Within these guidelines, details and variations necessary for specific conditions can be developed as needed.

1. Pre-define the range of relevant water supply and sanitation problems. Be sure this range is specific to the type of programs that can be developed. Since programs can be either broadly based or narrowly focused, it would be a waste of resources to be overly concerned with excreta disposal practices if the subsequent program will deal only with the expansion of piped water supplies. However, such concerns *would* be appropriate if a comprehensive program of piped water supply, wastewater and excreta disposal, and health education is anticipated. Consider both the supply and needs approaches in defining the range of relevant problems. Some of the major factors to consider are, first, the basic human needs of the people likely to be directly affected by the program; second, the current operational practices of the organizations active in the area; and third, the policies of the national and international funding institutions that will be required to support the program.

2. Estimate the relative degree of urgency or priority of water supply and sanitation problems. Each country is likely to have a different set of priorities, depending upon its stage of development, available resources, and current policies. A very poor country with a low level of development may give priority to problems of water sources inadequate for basic subsistence and to the spread of classic waterborne diseases. A more developed country may decide that incomplete coverage with piped water supplies and the beginning of industrial water pollution are the urgent problems. Rank the water supply and sanitation problems, with due attention to their interactions, according to their general order of importance so that subsequent action programs can be directed at the most pressing needs.

Highest priority may be given to unprotected water sources that are responsible for the spread of waterborne disease.

3. Collect sufficient information to define the problems adequately. This information will be used to identify the presence and general extent of problems but not to assess their full magnitude. Avoid extensive data collection in this phase since the nature of the desired program is still unknown. Information may be available from some, or all, of the following sources:

- statistics - census data on population, education, employment; health statistics on mortality, morbidity, life expectancy, medical care, and medical facilities;
- reports and files - project reports, special studies, technical publications, annual reports, notes, memoranda, and correspondence contained in official files;
- statements of experts - government administrators, technicians, and field workers; university researchers; officials of international development organizations; missionaries;
- statements of local people - community development groups, village councils, water users' organizations, traditional leaders;
- personal observation - visits to problem areas; observations of water supply sources, water usage, excreta disposal facilities, and health facilities' workload; informal discussions with people regarding their perceptions of problems.

4. Analyze the information and define the problems. As indicated earlier, only the presence and general extent of problems and not their specific magnitude need be determined at this point. The level of analysis depends on the country and on the type of program likely to result. In general, include only the most important statistics and data. Concentrate on qualitatively identifying the priorities of the existing problems.

5. Present the findings in a systematic manner. The identified problems should call attention to an obvious need for action. If further authorization is needed to continue the planning process, the problems must be presented in such a manner that the necessary approvals can be readily justified. Therefore, document the findings in a brief report with the following basic format:

(a) State the basic goal or policy of water supply and sanitation that is most appropriate. Examples could be the elimination of cholera, the reduction of distances that water must be carried, or the protection of water sources.

(b) List the water and sanitation problems that have been identified.

(c) Review the sources of data that have been used.

(d) Describe each of the water and sanitation problems listed in (b) and indicate their relative priorities with regard to the goal stated in (a).

Using the Guidelines

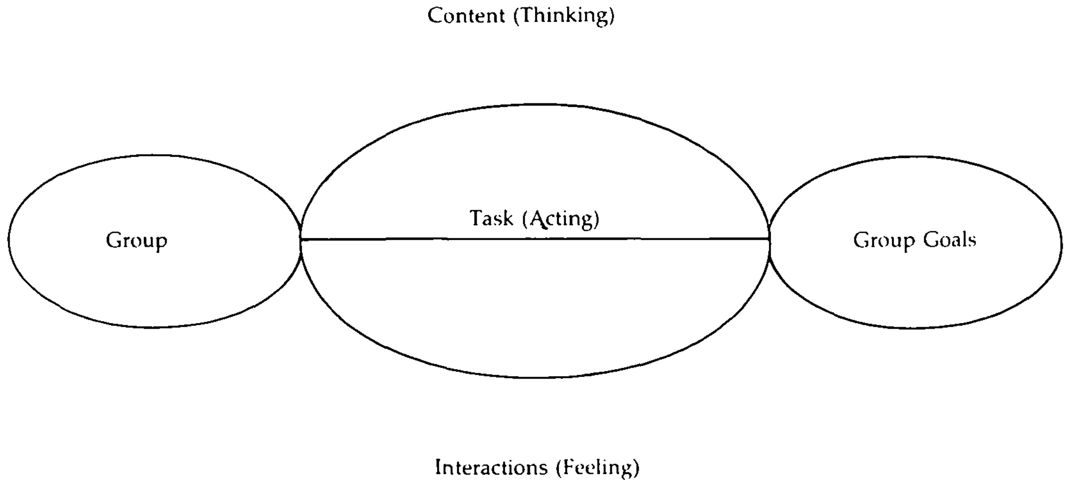
The steps in problem identification describe *what* has to be done. All of these steps must be gone through but exactly *how* may vary greatly. In this respect, one of the main choices to be made is the extent to which the people likely to be affected by the program are to be involved in the work of the study. The two main arguments for providing as much scope as possible for such involvement are, first, that full involvement in the process of thinking through the nature of the problems to be overcome is more likely to lead to local commitment to the final objectives of the program. Second, participation in the study is a valuable learning experience leading to the development of skills and insights which will be needed at the program implementation stage.

In addition to the direct involvement of local people in the study, there should be some systematic attempt to establish the nature and strength of local perceptions and feelings about any external or national level judgments which may be made about local priorities in the area of water supply and sanitation. Wide divergences of view can exist in this respect yet never be articulated unless a deliberate attempt is made to identify them. It cannot and must not be assumed that significant differences of view in this area will in some fashion automatically become known.

When groups of people are engaged in a common task—in this case, the identification of environmental health problems in a given region—the group process and communication within it goes on at three different levels which all interact. People have knowledge, such as technical data, about the subject matter which they communicate to each other. This is the *thinking* level of the planning process. People also take action within the process. They have meetings, make decisions, write minutes, and give instructions to subordinates. This is the *acting* level of the planning process. Finally, people react emotionally to the situation. They resent experts, they are afraid of possible effects of the plan on their jobs and futures, they feel threatened in a variety of ways, they may display anger and frustration or repress them. This is the *feelings* level of the process. An alternative way of describing these three aspects of group activity is to say that group work can be considered from three viewpoints: its content (the thinking level), its tasks and procedures (the acting level), and its interactions (the feeling level).

Local residents capable of representing the interests of users should be involved in both the study and planning process.

Figure 7. Levels of Group Activity



This is not just a theoretical model of how groups of people behave in the process of deciding on which problems they are going to address. It is a practical reminder that obstacles to success may arise at any one of the three levels of group behavior and will have to be dealt with. The three levels of group activity in performing any task may be illustrated as shown in Figure 7.

Keep in mind in collecting data as a basis for defining problems that it is essential to separate facts from opinions and weight the latter accordingly. In this area there is a danger that the expert/amateur distinction can confuse the issue. A "statement by" a technical expert is often treated as a fact while a "statement by" a layman on the same subject is only an opinion.

A fact may be defined as a piece of information that can be verified independently, of which many people can be made aware, and about which they can agree without too much trouble. An opinion is usually a collection of facts heavily tainted by a persistent, emotionally-based attitude which may be held by a single individual or shared by a group.

A useful test to distinguish between the two is to look for evidence of justifying behavior which is usually strongly present where opinions are being expressed, however plausibly dressed up as facts. There is no reason to assume that opinions are more likely to be held by amateurs than experts in any given technical field. This latter view is, of course, an opinion!

Figure 8 summarizes the process of problem identification. It may be useful in thinking through all of the steps in that process and how they fit together.

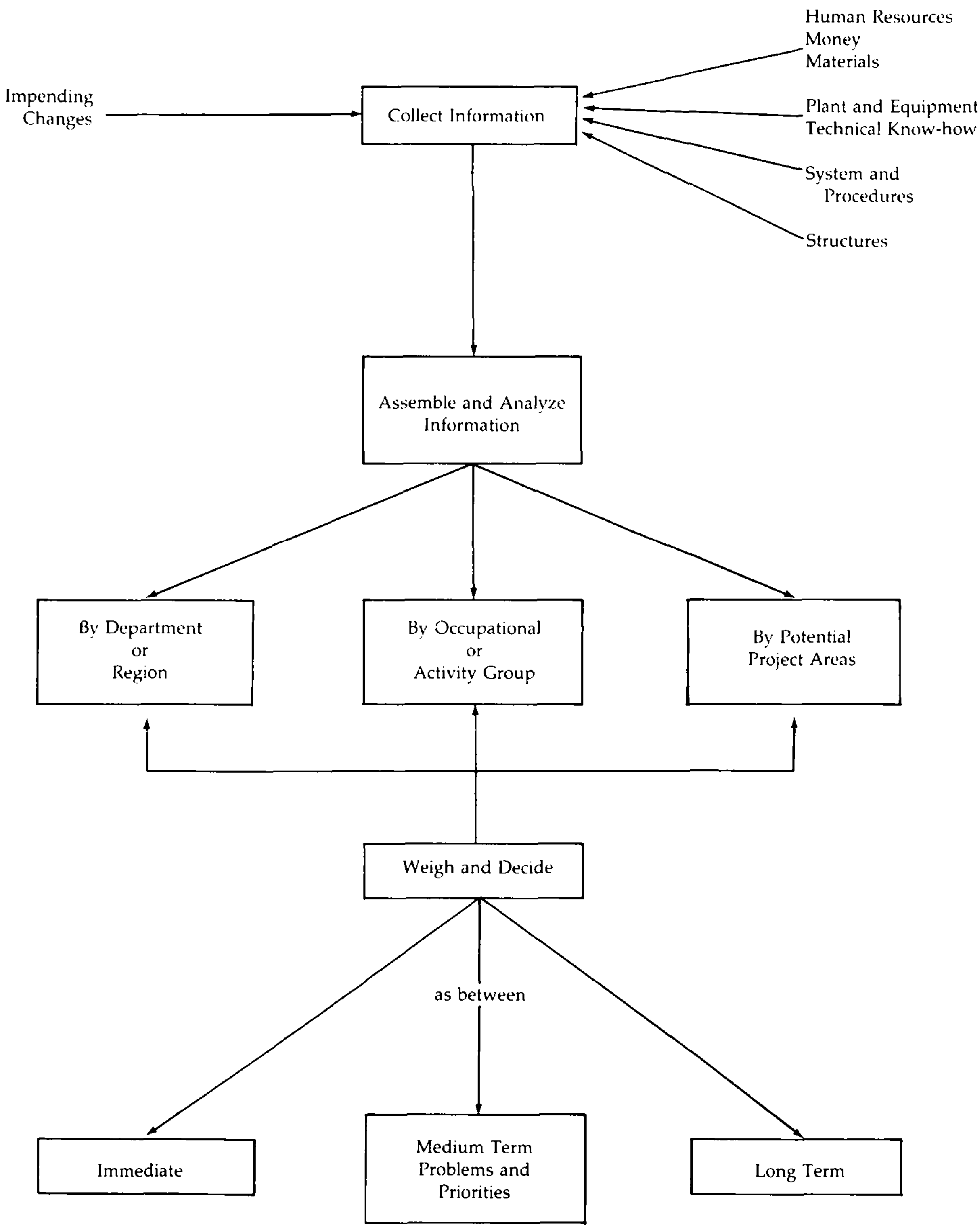
Step 2: Formulating Goals

Goal formulation is the process of establishing specific objectives for a water supply and sanitation plan. This is the second of the two main bases supporting water and sanitation planning. Objectives arise out of a desire to reduce or eliminate the problems identified in the first planning step. The result of goal formulation is a statement of what will, or should, be accomplished by the plan. In general, this statement occurs within the context of existing goals and policies of government. When such goals and policies do not exist, it is difficult to show official justification for a program intended to address problems.

To be effective as a means of both justifying and guiding subsequent actions, the process of formulating goals must be broad-based. It should include a review of the general framework of goals and policies controlling water and sanitation activities. It should also include a clear statement of the purpose of the resulting plan and identify measurable intermediate and final points for assessing progress in the subsequent implementation stage.

As is true for most steps in planning, goal formulation is an evolving process. Its outcome is shaped by balancing problems, needs, policies, and resources. The goals and objectives relevant at the program planning level vary in their degree of detail. Program planning objectives are more specific than overall national health goals ("complete physical, mental, and social well-being") yet less detailed than individual project targets ("provide 60% of the population of community

Figure 8. Process of Problem Identification



X with water supply through house connections and the remainder with commual standposts by 1985 at a total cost of $500,000"). To ensure that goal formulation is closely linked to the development of the plan, the different levels of objectives must be clearly defined in a measurable context.

As shown in Table 16, the range within which objectives are targeted varies from specific inputs to outputs, then purposes, and finally general goals. The achievement of objectives at any lower level should cause at least a partial achievement of goals at the next higher level, although as objectives shift from specific inputs to general goals, the level of detail and the amount of control exercised by the planner decreases.

Corresponding to these levels of objectives are particular types of actions. Thus, at the input level (bottom of Table 16), goods and services are identified. A project plan describes the activities intended to produce these results. At the next step, the output level, the program plan is the corresponding procedure for action. This plan outlines the steps necessary to achieve a broader range of specific outcomes. Continuing upwards, the purpose level represents the primary reason for the program. The purpose of a plan is achieved or not achieved under the guidance of strategy, which is one of several distinct ways of integrating overall goals into a plan. And finally, the goal level refers to a greater end to which all lower levels should contribute. Goals are eventually achieved through policies, which are officially adopted courses of action.

Table 16. Hierarchy of Objectives

Objective Level	*Type of Action*	*Sources of Information*
Goal	Policy	National Development Plan Official documents Statements by political leaders
Purpose	Strategy	National Development Plan Official documents Statements by administrative officials Operational practices of institutions
Output	Program Plan	National Development Plan Official documents Statements by technical officials Operational practices of institutions Identified problems
Input	Project Plan	Feasibility studies Official documents Statements by technical officials Operational practices of institutions Existing projects

Effective planning requires that the action procedures—project plan, program plan, strategy, and policy—be defined in terms that are as explicit and measurable as possible. Quantitative measures showing numerical changes are usually the best, followed by qualitative measures showing either the direction of change or preferences for one outcome over another.

Sources of information for the formulation of objectives for goal, purpose, and output levels are highly diverse. Some objectives can be derived directly from the problems and needs identified in step one of planning. Information on the general framework of acceptable objectives, however, sometimes can be obtained from past plans and official documents, from discussions with government representatives, and by inference from the practices of development organizations. It is unlikely at the preliminary stages of any program planning effort that there is already a well-developed set of relevant objectives for all three levels. This forces the planner to develop an appropriate set of objectives on the basis of government policies, institutional practices, statements by officials and technical experts, and his or her own understanding of the problems and needs of the affected area.

Remember that the ultimate purpose of goal formulation is the development of a plan which effectively addresses the problems previously identified. Suppose that a country has the basic goal of improving environmental health by providing safe and acceptable water supplies to the entire population by the year 2000. Furthermore, suppose that several government organizations have been made responsible for the development of urban and rural water systems, but that progress toward the ultimate goal has been slow because of a shortage of funds.

In response to these conditions, suppose that a regional water planner has recently conducted an investigation and found that approximately 50 rural communities are using water supplies that meet none of the national standards for water quality, source protection, or per capita consumption rates. It is officially decided that a plan will be prepared recommending the provision of improved water supplies to these 50 villages. To be approved and funded, however, the plan must show that a water supply program addressing the problems identified in the villages effectively contributes to the national goal of improved environmental health.

The process of goal formulation for the above example can now be carried out in the following steps. Refer to Table 17 for details of each level of objectives.

1. **Select a potential solution to the problem.** The first step is to find a solution to the water supply needs of the 50 villages. It is decided that the plan, which is not yet fully developed, will call for the construction of an improved water system in each village. Depending on water source conditions and the type of settlements, the systems will range from treated and piped

Table 17. Summary of the Goal Formulation Process

Objective Level	*Objectives*	*Measures*	*Targets*
Goals	1. Improved environmental health	1. Water supply coverage	1. 75% coverage by 1980 2. 100% coverage by 2000
Purpose	1. Improved water quality	1. Fecal coliforms in water samples 2. Salinity in water samples 3. Walking distance to water 4. Per capita daily consumption	1. No fecal coliform 2. Not exceed 500 mg/l 3. Not exceed 0.5 km one way 4. Average of 40 liters/cap/day
Output	1. Construct 50 improved water supply systems	1. Number of systems 2. Number of population served 3. Water supply capacity	1. 10 in 1982; 20 in 1983; 20 in 1984 2. 5000 in 1982; 20,000 in 1983; 30,000 in 1984 3. 400,000 l/d in 1982 1,600,000 l/d in 1983 2,400,000 l/d in 1984
Input	1. Construct individual water supply projects	1. Cost 2. Time 3. Personnel	To be determined at project design stage

water supplies with communal standposts to untreated, but protected, shallow wells with hand pumps. At the input level, the construction of individual water systems represents the form of action. Specific measures of cost, time, and personnel are left for the detailed project design phase. At the output level, the plan itself is the action mechanism. Relevant measures of this objective could include the number of systems completed, populations served, and total water supply capacity. Specific targets for each of these measures can be used to establish, and later monitor, the rate of progress.

2. Define the primary purpose of the program. Objectives at the purpose level represent the primary reasons for the program. In this case, they include improvement of water quality through source protection and treatment, reduced water-carrying effort through greater accessibility to supplies, and overall increased per capita water consumption. Each of these objectives can be made measurable. For example, measures might be no fecal coliforms found in water samples, no house more than one-half kilometer from a protected source of water, or an increase in water consumption to 40 liters per capita per day. The emphasis on achieving one type of objective over another is termed "strategy."

3. State the overall goal of such programs. One or more national goals under which water supply and sanitation programs can be developed should be identified. It should now be possible to see that the achievement of objectives at the purpose level contributes, although only partially, to the national goal of improving environmental health through 100 percent water supply coverage. Measures of progress toward the national goal could be the number of people or villages expected to receive acceptable water supplies under the planned program. Table 17 illustrates one method of summarizing objectives, measures, and targets.

Throughout the process of goal formulation, as at every stage of the program planning process, a developmental—step-by-step—approach should be used. The planners and technical experts who initiate the process of goal formulation and see it through to satisfactory completion should use the process as a learning experience to develop the skills and build the confidence of local people who will have to live with the consequences of the plan when it has been executed. This will help ensure that they are able to repeat the process themselves in the future with a progressively diminishing need for external help and guidance. They are also likely to be more aware than the experts of potential limitations in the local situation. These limitations must be considered in setting overall goals and precise targets, particularly time-related targets. The learning opportunities which the process itself provides cannot be simulated at a later stage.

Step 3: Collecting and Analyzing Data

The third step in planning water supply and sanitation programs is data collection and analysis. This provides the basis for finding solutions for problems in accordance with some controlling objectives. Data collection and analysis is a process of answering specific questions on current problems, future needs, available resources, and possible solutions. The key aspects of this process are selecting the right questions to ask and using the appropriate level of effort to obtain the answers.

Data collection and analysis is an evolving process. It tends to occur at many points in the overall planning effort. The bulk of formal data collection occurs as part of step 3, but usually some initial information is collected during the problem recognition phase, and additional data is often required when the planning process reaches the point of generating alternatives. Very detailed data is usually required in the design of individual projects within the overall program, and follow-up evaluation data is needed in the final evaluation step.

In major planning efforts, data collection and analysis is often divided into two distinct phases. Preliminary data supporting the problems identified in step 1 is enough for most regional planning purposes. In very large programs or in planning situations involving unexpected problems, a second data collection effort sometimes is undertaken to resolve questions arising in the generation and comparison of alternatives in steps 4 and 5. It is important to remember that the development of water and sanitation programs is a continuing cycle of formulating questions and finding answers. This cycle occurs throughout all steps of the planning process, although the current step is the most concentrated phase of data collection and analysis.

Types of Data Needed

Data collection varies according to the types of programs to be developed. For most programs involving new construction or improvements to existing water supply and sanitation facilities, some form of sanitary survey is usually required. A typical community sanitary survey will cover some or all of the following matters:

1. Description of area:
   (a) location, topography, climate;
   (b) geology and hydrology, especially soil conditions, and yields of water sources;
   (c) population;
   (d) industries and agriculture.
2. Medical and sanitary data:
   (a) general health of the population, with emphasis on water-related communicable diseases and infections (intestinal infections, helminth infestations, trachoma, and conjunctivitis);
   (b) mortality and morbidity data;
   (c) organization, personnel, budget, and activities of sanitation agencies;
   (d) existing sanitary conditions, especially distribution and use of latrines and water supplies, as well as conditions of solid waste disposal, food sanitation, insect control, housing, and school sanitation;
   (e) sociological and cultural patterns, especially community organization, customs and beliefs, and health education.
3. Resources available:
   (a) general economic level and per capita income;
   (b) assistance in training and health education;
   (c) housing, transport, vehicle repair facilities, and power sources;
   (d) local construction materials;
   (e) local skilled labor;
   (f) self-help resources.

In addition to the basic information they provide, sanitary surveys are useful educational tools that acquaint technical personnel with the customs, beliefs, and interests of the people. This understanding of local concerns is essential for the successful development of community participation activities.

Because water supply and sanitation planning includes such a wide range of activities, no single document covers all aspects of data collection and analysis. A good example of the level of detail that should be considered, however, is found in the World Health Organization recommended procedures for general health project planning. In this approach, the bulk of data collection and analysis occurs after the terms of reference of the project are determined and immediately before the specific project objectives are formulated. A situation analysis phase is used to collect and analyze raw data in the following six categories:

- population statistics and projections;
- disease statistics and trends;
- existing policies, programs, and priorities;
- socio-economic conditions and trends (relevant factors may include education, water supply and hygiene, excreta disposal and sewage, local government, communications, and transportation);
- health resource inventories and projections (relevant factors may include organizations, budgets, facilities, human resources);
- current health technologies.

Following the situation analysis phase, a problem projection phase brings together the population, disease, policy, and socio-economic information into a final projection of health problems over the planning horizon. This results in quantitative predictions of the incidence and severity of selected diseases on projected populations over desired time periods.

Recent planning guidelines published by the Office of International Health of the U.S. Public Health Service provide a general discussion of environmental health planning, but do not give details regarding specific variables or actual data collection. Nevertheless, the issues included in these guidelines cover many of the important planning inputs, as follows:

1. General environmental health assessment issues:
   (a) sanitary survey, consisting of description of area, medical and sanitary data, and resources available;
   (b) observation and monitoring activities, including sampling and surveying, criteria and standards, facilities and manpower.

2. Rural water supply assessment issues:
   (a) inventory of communities;
   (b) establishment of problem areas;
   (c) sanitary survey of existing water supplies.
3. Rural wastewater and excreta disposal assessment issues:
   (a) census of existing facilities;
   (b) observation and oversight activities;
   (c) present and future capacity of facilities.
4. General planning factors:
   (a) government support and commitment;
   (b) institutional infrastructure, especially co-ordination between and among ministries;
   (c) community participation, with particular reference to willingness to participate, the capability to contribute to the costs, and the capability of managing the system;
   (d) financial resources, both domestic and foreign.

Similar models of data collection and assessment for environmental health planning can be found in the procedures of a number of national and international organizations. Unfortunately, they either do not deal specifically with water supply and sanitation programs or they omit any discussion of data collection procedures and actual field measurement.

Appraisal procedures used by the major national and international development assistance organizations usually constitute a formal review of an already-formulated program or project proposal. As such, these appraisal techniques are designed more to assess the scope and feasibility of existing proposals than to formulate new ones out of the raw material of problems, policy objectives, and data. Typical of these procedures are the appraisal techniques used by the World Bank, the U.S. Agency for International Development, and the British Overseas Development Administration to assess the technical and economic feasibility of capital projects. It is usually claimed that appraisal procedures should be used throughout the planning process and that the social, institutional, and human resource issues are important to overall project success. In practice, the appraisal guidelines of the major development organizations concentrate almost exclusively on the measurement and analysis of technical and economic factors.

If in fact it is in the social, institutional and human resource development areas that projects most often experience difficulties, and a most plausible case can be made that this is so, this arrangement does not make much sense. Appraisal procedures should give much more attention to social factors in judging the feasibility of major capital projects. This need not require the design of any complex new social assessment questionnaires. The appraisal process would be improved if, as a matter of course, the following three questions were asked of every project and the answers to them sought with the same degree of persistence and energy applied to technical and financial matters:


Establishing current problem areas is a key part of program planning.

- What, if any, social, institutional or human resource factors might get in the way of people doing the things locally which the project requires them to do?
- Exactly what is the nature of these limitations and what is the relative degree of seriousness of each of them?
- What, if anything, can and should be done to limit the effects of these factors on the achievement of the objectives of the project in relation to its timetable?

The above process should involve the local institutions and individuals concerned in thinking through these issues for themselves and coming up with their answers to the questions. In the social area, some kind of self-appraisal, which should be a continuous process, is vital.

Guidelines for Data Collection

Several points should be kept in mind in setting up the data collection and analysis phase of a water supply and sanitation plan. Remember that data collection is the process of selective questioning and gradual understanding. It is an input to the plan. It is not itself the plan, nor is it the subsequent project design. The following guidelines for data collection are recommended:

1. **Before all else, determine what questions need to be answered.** Do not pose any questions that are not necessary to develop the program.

2. **Select data variables carefully and sparingly, depending on the type of program being planned.** Avoid selecting so many data variables that the few important ones will be poorly assessed.

3. **Give most of the data collection effort to the important variables.** Avoid the temptation to collect a lot of data on unimportant variables even though the data may be easy to obtain.

4. **Collect only enough data to answer the questions and to develop the plan.** Do not collect any data that will not be used in the plan.

5. **Use quantitative statements wherever these are appropriate.** Wherever specific dimensions, quantities and trends can be used they should be used and their sources identified. Vague generalizations must be avoided, particularly in the area of human resources.

This need to base technical, financial and human resource aspects of the plan on reliable quantitative data should not be used as an excuse for not making qualitative judgments in important social and institutional areas. It is true that data of this kind can rarely be expressed in the form of numbers, quantities or measurements. It should be recognized explicitly that social and institutional variables are qualitative in nature. They should be discussed separately from the quantitative data and the sources of information on which survey assessments of them are based should be described in considerable detail. Examples of areas needing qualitative assessment of this kind are the level of understanding and/or support in the local community for a proposed plan, the effectiveness of the communications system between institutions and individuals concerned with the plan, and the resourcefulness and overall competence of specific institutions involved, identifying areas of specific weakness.

To omit judgments on factors of this kind because they are subjective and cannot be measured in meters and centimeters is to risk throwing out the baby with the bath water. Qualitative variables of great importance must be included in the data collection process and identified for what they are—subjective judgments. Indeed, it is a bad mistake to try and pass off qualitative judgments as quantitative measures by using social science techniques. It is quite easy but often totally misleading to disguise qualitative data as quantitative by reporting the former as percentage responses to questionnaires.

Setting Up the Data Collection and Analysis Effort

The following is a suggested four-point procedure for setting up the data collection and analysis phase of the plan. The general framework should be applicable to most water supply and sanitation program planning. Some suggestions regarding specific data needs are included:

1. **Refine the problem assessment.** This involves determining the exact nature and magnitude of the problems initially identified in step 1. For most water supply and sanitation programs calling for new facilities, a sanitary survey is necessary. The problems must be defined in terms of the policies and objectives established in step 2. For example, if only 50 percent of the current population is served with adequate water supplies and it is national policy to provide everyone with acceptable supplies by 1990, then the problem, simply defined, is to serve the remaining 50 percent of the population in the years remaining before 1990. To reach this conclusion, however, it may be necessary to inventory existing water supplies in order to estimate the number of people already receiving adequate water. On the other hand, if the objective is to serve only 75 percent of the population by 1990, the problem definition is changed but the need to inventory existing water supplies probably remains the same. The product of this activity should be a problem description that is sufficiently well-defined to allow a prediction, and eventual measurement, of overall plan success.

2. **Project future needs.** Projections of future needs are necessary to determine the magnitude of problems both with and without the plan. Such projections should draw heavily on the data already collected, but usually require extensive additional statistical analysis. In general, four types of future projections are needed:

(a) Demand projections: changes in population growth, areal extent of systems, new areas of system development, water usages, and per capita and non-domestic water consumption;

(b) Supply projections: changes in water quantity and quality, system accessibility, and system reliability;

(c) Attitude projections: changes in public attitudes toward service levels, water consumption, excreta disposal practices, water rates and self-help contributions;

(d) Health projections: changes in morbidity and mortality, especially with regard to water-related and sanitation-related diseases.

3. **Determine available resources.** Many different types of inputs are needed to prepare and implement

environmental health programs. Successful programs require materials, equipment, money, and human resources as well as an institutional infrastructure and community support. Information should be collected on the availability of resources likely to be used in the program. Typical categories of resources are as follows:

(a) Technology: range of existing technologies; degree to which technologies are understood by and acceptable to communties;

(b) Materials: availability of construction materials, such as pipes, cement, timber, pumps, and engines; availability of operating materials, such as fuels, spare parts, and chemicals;

(c) Tools and equipment: types of hand tools and mechanized equipment available for project construction;

(d) Human resources: availability of managerial, technical, supervisory, and operational personnel for both the planning and implementation of the program and its subsequent operation; training institutions; training programs;

(e) Institutional support: existence of government agencies or other organizations capable of undertaking the planning, implementation, management, and administration of the program; availability of logistical support in the form of transport, supplies, and maintenance;

(f) Community participation: local acceptance of proposed program; community participation in program planning, implementation, and operation; willingness of people to provide contributions of money and labor;

(g) Finance: availability of domestic funds from regular budget, special appropriations, national development bank; availability of external funds from bilateral and multi-lateral international organizations; water rates, user fees, and special assessments.

4. **Suggest potential solutions.** In the process of collecting and analyzing data, possible courses of action or solutions to problems usually present themselves. It is normal for the planner to approach a problem with a possible solution, or range of solutions, in mind. The initial plan for data collection often is based on preliminary ideas the planner draws from key national policies, technological choices, and resource limitations, among other considerations. New potential solutions may arise, however, as data collection proceeds and subsequent collection may need modifications. The planner should remain open to and encourage new ideas during the data collection and analysis phase. New solutions or variations on those being investigated may be suggested by any of the following issues:

(a) Technological issues: level of service; piped versus non-piped water supplies; water treatment; water distribution by communal standpipe, private yard standpipe, or inside house connection; individual versus communal excreta disposal facilities; the role of communal showers, clothes-washing slabs, cattle troughs, village industries, and home gardens; number of project sites; degree of population coverage; phasing of construction; local manufacturers versus imported equipment; labor-intensive versus capital-intensive systems;

(b) Financial issues: the question of water rates and special assessments; the role of self-help; the need for external funding;

(c) Community participation issues: the need for a local water and sanitation committee; local felt needs regarding levels of service, siting, and timing;

(d) Institutional issues: legal authority; the adequacy of existing organizations versus the establishment of a new organization; designation of a lead agency in programs involving more than one ministry;

(e) Human resource issues: present availability of, or training capability to produce, required personnel to design, construct, operate, maintain, and manage the proposed system.

The failure to adequately assess data and plan appropriate solutions to water supply problems can result in the users continuing to follow their previous habits.

Step 4: Generating Alternatives

Data collected in the previous step should be used to formulate alternative solutions to the problems being addressed. The planner may have begun the data collection phase with one or more possible solutions in mind. Other potential solutions may have arisen during the course of data collection or analysis. Whenever potential alternatives become apparent, the planner should remain receptive to new solutions so that all reasonable alternatives are considered.

Generating alternative solutions is not always an easy task. Pressures of time, limitations of planning staff and funds, and personal preferences may cause only the most obvious solution to be selected at an early stage of the planning process without any serious consideration of possible alternatives. Comprehensive water supply and sanitation planning requires a broad view of potential plans. In practice, this means that all realistic alternatives should be formulated and then assessed so that the best possible solution can be selected. As indicated above, some alternatives may have been considered or may have appeared spontaneously during the early phases of plan preparation. To ensure that a reasonable range of alternatives is available for comparison, alternative solutions should now be generated in a more formal manner.

Guidelines for Generating Alternatives

There is little guidance in planning literature or operational practices of the major international development organizations on methods of formulating alternative water supply and sanitation plans. Most of the existing literature reviews the technological choices or discusses the pros and cons of key planning issues. More specific guidance is needed on actual methods of developing alternative plans to meet needs.

The key inputs in almost any water and sanitation program are total costs, available institutional and human resources, and community participation. Total costs, including both capital and operating components, are so crucial in plan selection that they must always be considered in formulating alternatives. Institutional and human resources are the primary vehicles for carrying out a plan and must be included as inputs. If these resources do not exist or are inadequate for the task, plan alternatives must provide for their creation or growth. Community participation is the essential input of the program beneficiaries. Without the active support of communities in planning, implementing, and maintaining water and sanitation facilities programs, plan alternatives that require changes in people's behavior are unlikely to succeed.

A useful approach to generating alternatives is to first review the overall problem in terms of regional needs and the capability of government or some other development entity to meet it. This review could take the following form:

1. Review the problem definition (from step 3).
2. Review the future water and sanitation needs of the region (from step 3).
3. Review the overall objectives and specific targets which the program must achieve (from step 2).
4. Review the available resources, especially those involving institutional support and community participation (from step 3).

Once these aspects have been considered, a list should be compiled of all potential solutions developed during the data collection and analysis step. This listing and the above four points should be reviewed together to see if any major aspects of the problem or of future needs have not been included in the alternatives. If so, either make appropriate changes in existing alternatives or develop new ones.

The development of new alternatives will be more effective if the following points are used as preliminary guidelines:

1. **Meet all of the needs arising from the problem.** This will provide a base to use in comparing alternative plans. Do not be overly concerned with costs or the availability of resources at this preliminary step. It is better to encourage innovative ideas than to remain stalled on what may appear to be overwhelming current problems. Be concerned with the overall logic or reasonableness of an alternative. Mentally try to modify the nature, size, and phasing of alternatives to see if new and more effective solutions can be found.

2. **Minimize costs without reducing benefits.** This will allow a straightforward comparison of alternative plans. Review the various program inputs to see if costs can be reduced through changes in program scope, implementation, timing, personnel, or materials. Both initial capital costs and recurrent operational costs are important in ultimate plan selection. Wherever possible, consider less costly non-structural alternatives, such as health education, technical assistance, and direct home owner subsidies as a substitute for expensive capital works. Try to reduce initial costs by phasing programs over distinct time periods and by delaying less essential program components to later phases. In general, labor intensive methods of project implementation are preferred over capital intensive approaches. Labor intensive methods provide employment, build up needed skills, use less imported materials, and usually result in a more understandable and readily acceptable level of technology.

3. **Use existing institutions and available human resources.** This will generally involve fewer institutional changes and less program investment and result in lower overall costs. Remember that any major

changes proposed in existing organizations are likely to meet frustrating administrative inertia and possibly even strong political resistance. This will require patient and detailed explanations being given to the local people involved. These explanations should be followed by a more intensive process of social education and expert inputs to help bring about institutional change in a way acceptable to local opinion but at a rate consistent with the plan's timetable. If existing institutions and human resources are obviously inadequate for a desired alternative, identify the specific areas requiring change. For example, a new water supply maintenance unit may need to be established or fifteen new health inspectors may need to be trained.

4. **Use proven methods of community participation.** Community support for water and sanitation programs is absolutely essential, but social patterns and traditional levels of community involvement are highly variable and cannot be predicted easily. Methods for obtaining community participation that are effective in one area may not work in another. Determine what procedures for promoting local support and developing community leaders have been effective in the past and try to incorporate them into the plan. Consider new approaches to community participation only if all past experiences have been unsuccessful or if the existing approach is unsuited to the proposed alternative.

A final set of alternative plans should be prepared from the various potential solutions identified here and in the data collection step. This set of plans should be kept small in order to minimize the subsequent amount of analysis in the program appraisal and selection step. It is important to avoid presenting alternatives that are very similar. The general rule is that each alternative should represent a distinctly different approach or should differ substantially in scope, timing, or costs. Minor variations of approach or program design are best left for detailed consideration within a given alternative or, possibly, for later resolution during the implementation phases. An example of an issue warranting separate alternatives is the question of whether to base a program on piped or non-piped water supplies. Conversely, an issue better suited for consideration within a single alternative is whether to use one type of hand pump over another.

The final set of alternatives probably should not exceed more than three to five potential plans. If the number is higher, insufficient thought probably has been given to selecting a realistic set of alternatives. Additional effort should be devoted to narrowing down the alternatives to a smaller set that can be properly analyzed before the final plan is selected. In some cases, too few alternatives may be presented. This may mean that potentially worthwhile solutions have been missed. The extreme case would be the formulation of only a single plan alternative. This limits the ultimate choice to either accepting or rejecting the proposed program. Although some programs may require a specific type of approach, in practice there are almost always relevant alternatives that can be developed.

Descriptions of plan alternatives should be complete and contain all information needed to allow full analysis and final selection of the plan. Each alternative should be presented in a similar format so that comparisons can be readily made. At the least, each alternative description should include the following topics:

1. Overall description of plan, including nature, size, location, timing, preliminary design indicators, and costs;
2. Description of implementation phases, including design, community mobilization, personnel training, and construction;
3. Description of operational phases, including operation, maintenance, and evaluation.

Step 5: Appraising and Selecting Programs

After alternatives have been generated, their relative merits should be assessed. The basic purpose of the appraisal process is to assist decision-makers in selecting a program with the best possibility of successful implementation and operation. This involves a comparison of alternatives to determine which best satisfies the objectives set out in step 2, the preferences of the affected communities, and the program requirements of the institutions likely to be involved in program support. Program appraisal is a measuring and balancing of the merits of one program alternative against those of another.

This process is rarely simple and straightforward. Major programs have a range of objectives and several different interest groups to satisfy. Because program alternatives may differ greatly and the future effectiveness of each may be difficult to assess, there usually is no clear-cut method of selecting the best alternative. Program appraisal requires a good deal of sensitivity to the key issues in any given program. Then professional judgment about the types of analytical procedures used to compare the effects of alternative programs on these issues must be applied.

Program appraisal deals with both the planning process and the issues critical to ultimate program success. There are three important aspects of the planning process. The first is the initial organization of the planning effort, including collection of background information, projections of populations and service needs, and preliminary formulation of the program concept. The second aspect is the planning of the implementation or construction of the actual system. This includes engineering design, community involvement, institutional support, financial costing, construction scheduling and all other factors necessary to establish the program. If several distinct phases for program expansion are proposed, each phase should be considered separately.

The third aspect of the planning process is developing procedures for the routine operation and conduct of the program. This includes methods of identifying, selecting, and designing projects as well as procedures for overall program budgeting and management. Because planning involves the control of inputs over different time periods, all three aspects must be kept in mind during the appraisal process. For example, community participation is important during the initial program formulation phase as well as in the subsequent implementation and operation phases. However, community approval of and involvement in any one phase is no guarantee of similar community responses in any other phase. The appraisal, therefore, should ensure not only that the necessary inputs are present but that they also occur at the right time.

There are many areas of program planning that require appraisal to ensure success. Programs deficient in one or more key areas are likely to fail, no matter how well-conceived they are in other areas. For example, a plan that is technically feasible and economically sound but is not accepted by the intended users is destined to fail, no matter how well its systems look on paper. Similarly, a lack of institutional support or trained personnel or even effective revenue collection mechanisms are the seeds of weakness that will produce, at best, program inefficiencies or, at worst, outright program failure. While it is difficult to anticipate all of the issues affecting program success, experience has shown a number of major areas that commonly influence the outcome of water supply and sanitation planning.

Health workers should discuss the project with local residents and officials.

Factors in Program Appraisal

For appraisal purposes, the key factors in program success can be classified into technical, social, political, economic, financial, natural, physical and legal categories. Each alternative should be appraised in all of these areas before final program selection is made.

The following specific factors should be considered in the appraisal process:

1. Technical:
   - general
   - supply water systems
   - sanitation systems
2. Social:
   - population
   - attitudes to and knowledge about water supply and sanitation
   - community experience
   - community resources
   - community acceptance
3. Government and Politics:
   - sources of power and degree of stability
   - government economic policies
   - planning policies and control of the economy
   - government services and facilities
   - local government functions in relation to economic development
   - methods of central taxation
   - structure of political life
   - impact of politics on management
4. Economics and Finance:
   - general economic setting
   - level of economic development and trends
   - distribution of wealth and size of gross national product
   - economic condition of water/sanitation sector
   - financial system
5. Natural and Physical Resources:
   - natural—what water is available and where
     - source development methods
     - climate
   - physical—transport facilities and system
     - communications
     - housing
     - technical services
     - pollution problems
6. Legal:
   - labor legislation
   - institutional authorization

Technical appraisal is a review of the overall technology of the proposed physical system. It is intended to answer the question of whether or not the alternative will supply the desired level and quality of service at minimum cost. A comprehensive technical appraisal includes a review of technology identification and selection, engineering design, implementation and operation, and overall costing as indicated by the list in Table 18. Among the more important technical considerations in water supply and sanitation are the environmental factors of climate, water quality, soil conditions, and site locations, and the engineering design factors of material strength, structural integrity, mechanical operation, and system capacity. Since cost is an essential feature of engineering design, the technical appraisal must include a review of both the functional soundness and the costs of the physical system. Each individual alternative should, as far as possible, provide a "least cost" solution for the method proposed. However, the existence of a large number of non-technical components in a program may make a full cost analysis impossible at this point.

There are several ways to conduct technical appraisals. Alternatives may be ranked according to one or more of the technical considerations indicated above. Wherever possible, both function and cost should be considered. In engineering analysis it is common to hold one constant and then minimize or maximize the other. The technical appraisal could rank the alternatives on the basis of cost for a given level of performance or on the basis of performance for a given level of cost. In practice the former is the more common engineering procedure in water supply and sanitation planning as programs are normally designed to provide specified services at the lowest possible cost.

No single characteristic adequately reflects all technical aspects of program planning. Table 18 is a checklist of the more important technical items that should be reviewed in the appraisal process. The purpose of such a checklist is simply to help ensure that an alternative is technologically capable of providing the desired service or product at minimum cost. In addition to the general background items common to both water supply and sanitation development, separate design and operational characteristics unique to one or the other of the systems also should be considered. The initial technical question in water programs is whether piped systems will have communal, yard or house connections. For sanitation programs, the initial technical questions are whether communal or household facilities will be built and whether water will be used in excreta disposal.

Table 18. Checklist for Technical Appraisal

General Information

Program area:
1. areal extent
2. existing water supply and sanitation facilities
3. types of water uses
4. per capita water consumption
5. project sites

Population projections:
1. total population
2. population distribution
3. population in need
4. population served

Water Supply Information

Initial concept: piped or non-piped sytems (if piped, extent of communal, yard, and house connections)

System design:
1. water sources
2. transmission and pumping
3. treatment
4. storage
5. distribution
6. wastewater disposal

System operation:
1. quantity
2. quality
3. reliability
   - water source
   - system components
4. assessibility
   - operating personal
   - users
5. wastewater disposal
6. operation schedule
7. maintenance schedule

Sanitation Information

Initial concept: communal or household; water-using or non-water-using

System design:
1. superstructure
2. pit or tank
   - structural integrity
   - treatment capabilities
3. transmission facilities
4. ultimate disposal site or drainage field for wastewater
5. method of treatment or disposal of solids (feces or sludge)

System operation:
1. reliability
2. accessibility
   - maintenance personnel
   - users (including small children)
3. capacity
4. environmental protection
   - ground water
   - surface water
   - surface soils near facility
   - surface soils above drainage field
5. operation schedule
6. maintenance schedule

Table 19 is a checklist of the more important social items to be reviewed in the appraisal process. Most of the social factors, unlike the technical factors, require the planner to make subjective judgments that are essentially qualitative. If political and economic factors are included under the "social" heading, an appropriate general formula for program appraisal is to say that the program selected must be technically sound and socially acceptable. A program can fail on either score. A plan which is technically sound but socially unacceptable and therefore unworkable is just as inadequate as a plan which is socially acceptable but technically unsound.

Table 19. Checklist for Social Appraisal

Population (ethnic groups)
- –type
- –distribution and location
- –population characteristics and density
- –economic characteristics
- –areas and communities of greatest need

Knowledge, Attitudes and Practice Toward Water Supply and Sanitation

Social Acceptance:
1. water supply
   - –responsibility
   - –communal use vs. private use
   - –distance
   - –water uses
   - –quality
   - –quanity
2. sanitation (excreta disposal)
   - –location
   - –privacy and modesty
   - –separation of the sexes
   - –anal cleansing
   - –use of water
   - –excreta re-use

Felt needs:
1. priority of water supply and sanitation
2. levels of technology

Willingness to pay:
1. contributions during construction
2. contributions during operation
3. water rates, taxes, and assessements

Health education:
1. needs
2. means for providing

Community Experience
1. local organizations
2. local leadership
3. local decision-making
   - –planning
   - –implementation
   - –operation
4. self-help efforts
5. recent community projects
   - –health education
   - –water supply and sanitation
   - –other

Community Resources
1. leadership
2. skilled personnel
3. unskilled personnel
4. commitment to water and sanitation improvements

Community Acceptance of Program Alternative
1. planning stage
2. implementation stage
3. operational stage

A major limitation on the planner's range of options is the resources likely to be available to the program over the time period covered by the plan. It is important to stress that where, as is often the case, a shortage of money means a shortage of hardware, the development approach to planning has a special contribution to make. If local people are involved in a project and taught to make it work, their sense of commitment can help compensate for many shortages in plant and equipment. The choice of planning options between labor intensive and capital intensive methods of project organization is meaningless until a decision has been made on the extent to which the project style will be expert-biased or user-biased.

Step 6: Making New Programs Work in Practice

In later chapters on community participation and human resource development, the subject of how to make programs work is treated in detail in relation to these special areas of planning activity. This discussion of step 6 describes in a general way the overall process of program implementation in terms of the things that have to be provided for, and in what sequence, if any program is to work in practice as it is described on paper.

In all cases there are six activities which must be carried out to establish a program. More than one of them may be done by the same individual or organization, or one activity may be performed by two or more organizations working together, but all six roles must be adequately filled. The six activities are:

1. There must be someone to *introduce* the new ideas which the program contains.
2. There must be someone to *back* the program politically and administratively as well as financially.
3. There must be someone to *steer* the program.
4. There must be a *pacemaker* for the program.
5. There must be someone who will *review* the program.
6. And ultimately there must be someone who will *maintain* the program's output.

The effectiveness of program implementation depends on how carefully and comprehensively provision is made for the performance of these activities.

Although most of the information needed to decide who should be responsible for each activity has been discussed elsewhere, it may be useful here to summarize briefly the criteria which should be used in allocating these responsibilities.

Introducing New Ideas

This activity is normally carried out by experts, often engineers, and is perceived as having mainly a technical content. This approach is fine as far as it goes, but it does not go quite far enough. In particular it is important to consider two other factors. First, the people who initiate new technical ideas are not always highly skilled at presenting them to non-technical people. Second, most projects involve the introduction of new ideas in the socio-political area and gaining acceptance for these often proves most difficult in program implementation. This is particularly true if the impact of these new ideas on local life and culture has not been fully thought out in advance. It will probably be necessary to make provision for repetition and time for absorption of new ideas so that the community residents can become comfortable with them.

In determining who is to introduce new ideas within the program it may often be necessary to consider what advice and/or training ought to be given to technical experts in "presenting skills." It may be best to use a different type of expert for communicating new ideas in the social area. Most programs take the social area into account but it is still too often assumed that technical experts, without special training, are highly effective communicators of both social and technical material. The verdict in most cases is, at best, "not proven."

Backing the Program

The most important need as far as backing is concerned is for local political support, not just adequate funding by some external agency. This means much more than allocating the local resources provided for in the plan at the time required. It must be determined in advance whether there is adequate *local will* to overcome the limitations and problems that will arise as the program begins to operate.

Providing adequate backing for the program must almost always be a joint activity involving a number of people and organizations. Despite the view held by some people, adequate external aid injected into a given program will not, by itself, generate all the momentum the project needs to succeed.

Steering the Program

This is essentially an administrative task to ensure that the flow of materials, training of people, preparation of paperwork and other details is coordinated and that the different parts of the program work together in harmony. This is another joint task for project management working with a local steering committee.

Pacemaking Within the Program

There must be provision within the program for energizing its different parts. The people involved must be motivated and the systems must be made to work by trouble-shooting when parts are not supplied or other problems arise. This is the key senior expert role in program implementation. It requires the undivided, full-time attention of someone whose technical knowledge and judgmental ability as a manager are so far beyond reproach that he or she can afford to be occasionally quite unpopular—a state of affairs which is inevitable within the pacemaking role.

The developmental approach advocated here implies that, as a project continues, the pacemaking role should transfer as far as possible from the expert(s) to the local counterpart(s). As this happens, the expert can switch over to support the reviewing and steering activities. A key measure of the extent to which the developmental approach is working is whether or not pacemaking activity is assumed by local people after training.

Reviewing the Program

In the step 7 discussion of evaluation, it is argued that program review should as far as possible be provided by regular feedback mechanisms which are included in the plan from the outset. As far as possible, evaluation should seek to improve current project implementation rather than help other planners improve future plans. There will probably be external review, in addition, which will be required by the agency paying for the program.

Maintaining the Program

Provision for maintaining the system established by a program is covered within the developmental approach described above. Local users should be equipped with the skills, the system and the will to carry out the necessary maintenance tasks for themselves.

Step 7: Evaluating Programs

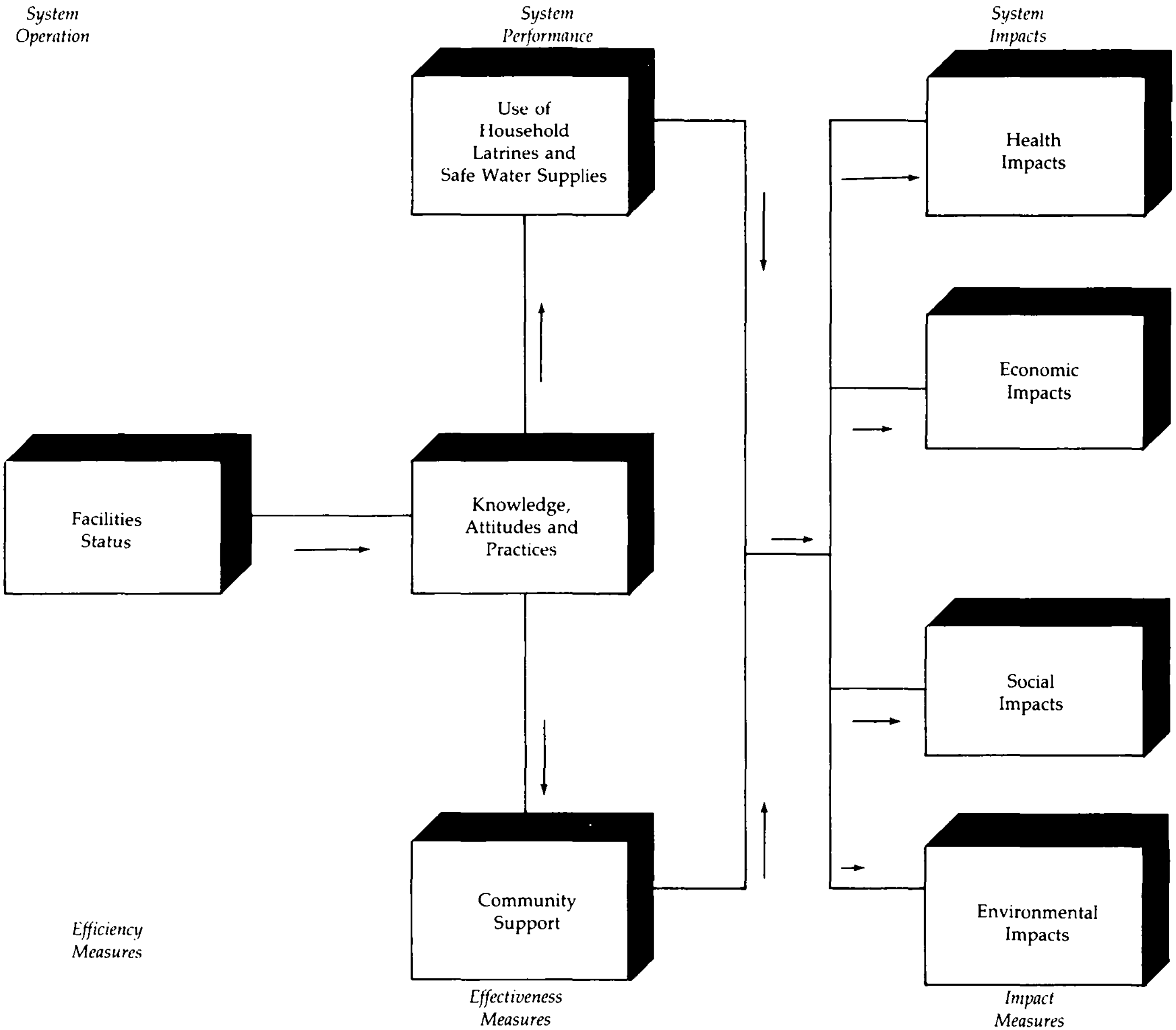
Program evaluation involves measuring outputs against goals to see if the program has achieved what it set out to do. Evaluation can be applied at all levels of program operation from community to national and even international.

A useful definition of evaluation is "any act of obtaining feedback on the operation and effects of a particular program which helps to control and improve the program to more completely produce a required result." The wording of this definition is deliberately chosen to shift the emphasis from the commonly held view of evaluation as being that of assessing the quality of program and project planning and execution to that of controlling and improving the planning and operating processes. This definition of evaluation is used in what follows. In many situations, it is important to avoid the attitudes and feelings that are related to the "inspection" or fault-finding approach to evaluation. Many developing countries still have "inspectors" and systems that date back to colonial times. This tends to generate and perpetuate tension between central and community units of organization.

Guidelines and Procedures for Program Evaluation

It is essential that the people implementing a pro-

Figure 9. Assessment Model for Water and Sanitation Impacts



Source: Adapted from "Social and Economic Preconditions for Water Supply and Sanitation Programs," by Dennis B. Warner, Water and Sanitation for Health Project, Technical Report 10, November 1981.

gram be closely involved in determining the criteria to be used in judging its performance. The process of determining evaluation criteria should be an integral and early part of the planning process, not something tacked on at the end. Evaluation techniques should be seen and used as aids to improve the quality of decision-making within the program and not as security checks which inhibit rather than encourage initiative and problem solving. To this end, it must be recognized that there are different levels of evaluation, as well as different measures.

The people affected by a program should be involved in designing the evaluation procedure and determining the criteria. It has already been noted that the planning strategy should provide for as much direct involvement of local people and organizations as possible. This particularly applies in the case of evaluation criteria and how they are drawn up.

Thinking about the criteria to be used in reviewing progress and improving performance is an important extension of the learning process to which people are being exposed through their involvement in the planning activity. If people are involved in deciding on the specific items that will be used to measure and judge the validity and effectiveness of a project or a program, the chances that they will cooperate in using the results to improve the planning and operating processes are greatly increased.

Evaluation criteria should be designed as early as possible and should incorporate ways of measuring or judging realistic expectations of the benefits which the user communities have a right to see attained. Not only is program evaluation often based purely on accounting procedures, it has often involved the most primitive kind of accounting approach such as "historical costing." Evaluation criteria tend to be thought up after everything else has been done, with evaluation procedures designed to fit whatever system and procedures have already been provided. This means that evaluation data is collected so long after the event that while the results may be interesting to know, they are of no practical use in influencing results, making improvements or guiding further development of the services desired and provided.

Measures for Evaluation

One of the major difficulties in evaluation is measuring the linkages between water and sanitation facilities and their intermediate and ultimate benefits. The failure of many evaluations to find anticipated benefits is probably due to a lack of understanding of these linkages and the conditions necessary for their operation and measurement. There are three levels of impact that can be used as evaluation measures:

- Initial stage, involving water supply quantity and quality and sanitary facility improvements, as well as greater accessibility to and reliability of services.
- Intermediate stage, involving the degree of usage of the facilities, resulting in immediate benefits, usually time and energy savings and improved hygienic practices.
- Ultimate stage, involving the long-term, desired benefits of improved health, reduced health costs, greater agricultural output, improved social well-being, and improved environmental quality.(These are frequently difficult and expensive to measure and require long-term records kept in accordance with rigorous and well-designed definitions and categories.)

Evaluation often distinguishes between the changes that occur in physical facilities, behavioral patterns, and, finally, ultimate impacts. These changes and the linkages between them are summarized in Figure 9, which classifies system outcomes into operation, performance, and ultimate impact measures.

As shown in Figure 9, system operation is the immediate, or direct, consequence of project development. This is an efficiency measure in which almost all of the project inputs and system outcomes are under the control of the engineer. The engineer's immediate concerns are for the physical status and functioning of the water and sanitation facilities, which can be assessed in terms of accessibility, quantity, quality, and reliability. These factors can be assessed in straightforward physical units.

System performance, however, is a more complex consequence of the use of facilities. This is an effectiveness measure in which the continuing use of the system by the community determines its success. Project planners are directly concerned with system performance, but while they can specify the technical inputs for system operation, they cannot control the use of the system by the community. To achieve a high level of use of the facilities, health education and internal social interaction are needed to provide new knowledge and generate new attitudes and behavior in the community to bring about proper care for and use of the facilities by families and individuals and adequate support of the system by community political and social institutions.

Performance outcomes are the immediate benefits of the project. They include both behavioral and institutional changes. The former may consist of changes in water use, consumption rates, and defecation habits and other sanitary practices, while the latter may include changes in local committees, support organizations, and maintenance procedures. The important point is that the construction of water and sanitation facilities is not sufficient in itself to produce system performance benefits. There must also be health education plus actual use of the facilities plus a community response to the need for support of the system. If any of these inputs are missing, the linkages to the final impact stage will probably fail to occur.

System impacts are the ultimate consequences of project development. To the policy-maker, these are the long-term benefits that water and sanitation projects are intended to achieve. They can be classified into health, economic, social well-being, and environmental quality benefits. The essential characteristic of these impacts is that they are dependent on behavioral and institutional changes occuring in the community. Under optimal conditions, long-term benefits may arise directly out of performance impacts without the need for additional inputs or assistance. In most cases, however, there will be need for a variety of complementary inputs to allow the effects of the water and sanitation program to reach the ultimate impact stage.

As mentioned above, system impacts are the true benefits of water and sanitation interventions. In the health sphere, these may include reductions in fecal-oral diseases (cholera, typhoid, dysentery, ascaris), insect-borne diseases (malaria, filariasis, onchocerciasis) and skin and eye infections (scabies, trachoma). Economic impacts include decreased water costs, reductions in medical expenditures, and increased agricultural productivity. Social well-being impacts include greater convenience, improved social status, increased community involvement, and strengthened community institutions. And finally, environmental quality impacts may consist of improved surface drainage, higher quality ground water, and decreased rodent and insect populations.

The quantitative measurement of these benefits is not easy or inexpensive. This is largely because of the long time span over which the benefits are achieved and the fact that water and sanitation are only two of many variables—economic, social and political—that also affect their achievement. Evaluation requires careful planning, keen observation, extensive records, much human involvement, great integrity and balanced judgment. It is a highly useful tool but it is only a tool by which to generate more reliable and useful decisions about resource allocations and the operating details of processes whose objective is the achievement of a sustainable high quality of life for people—in the frame of this guide, for rural and small community people.

SOURCES
CHAPTER SIX

This chapter was written primarily from materials prepared for use by the AID Knowledge Synthesis Project. Useful in the evaluation section was "Social and Economic Preconditions for Water Supply and Sanitation Programs," Dennis B. Warner, Ph.D., P.E., Washington: Water and Sanitation for Health Project, Technical Report 10, November 1981.

CHAPTER SEVEN
MAKING COMMUNITY PARTICIPATION WORK

SUMMARY

Community participation is one of the most important factors in determining the success or failure of a water supply and sanitation program. Social and cultural attitudes toward water supply and sanitation technologies will weigh heavily in determining whether the new facilities are used or simply sit idle. To ensure that the facilities are used and maintained, it is essential that community members be involved in the planning and execution of all projects.

To achieve this goal, the national plan must have a community participation component that is carefully designed and scrupulously carried out. This is not an easy achievement and will require a community participation strategy that is adhered to in all projects undertaken by a water and sanitation program. There are a number of different techniques that may be used to achieve effective comunity involvement and the community participation strategy should make use of those most appropriate to a given country and a given community.

Community participation involves far more than contributions by community members of time, money and labor in building a facility. For community participation to succeed, local people must be involved in decision-making. This will be a valuable asset to the project designers since local people will have much useful information and wisdom to contribute and since the ultimate success of a project depends on the extent to which the facilities are used by the community. A community participation effort also affords an opportunity for community education including health education, which may be essential to give villagers the information and understanding they need to make intelligent decisions and to effectively use the facilities when they are completed.

Community residents often participate in well construction but other types of community participation are needed also.

CHAPTER SEVEN
MAKING COMMUNITY PARTICIPATION WORK

Planners and economists know how to develop schemes and projects, health specialists know about the illnesses related to water supply and sanitation, and engineers know how to build systems. But for planners, health specialists and engineers to know how to plan, why to use, and how to build water and sanitation facilities is not enough. People must use them.

The social and cultural factors influencing people's reactions to changes in water supply and sanitation techniques must be understood because these factors ultimately determine the acceptance and use of the systems. The success or failure of water and sanitation programs depends on this understanding. The human dimensions must be taken into account if changes are to occur in behavior patterns and traditional beliefs, if customs are to be challenged by new ideas, and if new technologies are to be accepted and used.

The key to dealing with social and cultural factors affecting a water supply and sanitation program lies in community participation. Successful community participation will aid in the design and construction of new facilities and in their acceptance, use, operation and maintenance.

The Need for Community Participation

The commmunity is the primary resource in water supply and sanitation programs and projects. Technology is the facilitator to meet community needs and desires. It has little value unless it is used by people for their own benefit. When planners or technicians enter a community, they are not the experts—the people who live there are the experts. They have already defined their own needs and wants independently of outsiders and they have established their own set of priorities. They understand leadership systems, how decisions are made among families, and how gossip networks operate to accept or reject change, whether it be a new kind of plow or a new system for birthing babies, a new water supply or a new way to dispose of excreta.

Anyone hoping to bring about change in a community must value it as a group of people who already have a working system of technological and natural resources intimately tied with human organization and behavior. To use these resources, the planner must observe the community, obtain basic information on how it works, what it wants, what it needs, and what it believes that it needs. Every community is different and the people in the community do not always agree. But engineers, health specialists, planners and economists must learn about the human issues of change in a community before they can hope to introduce new technologies and have them used. Effective community participation makes change in a community a partnership of mutual respect in which insiders and outsiders participate in decision-making and action. Figure 10 shows the role of the sanitary engineer and the public health specialist, the economist, the behavioral scientist, and the community, and the ways in which they interact in the process of planning an environmental health program.

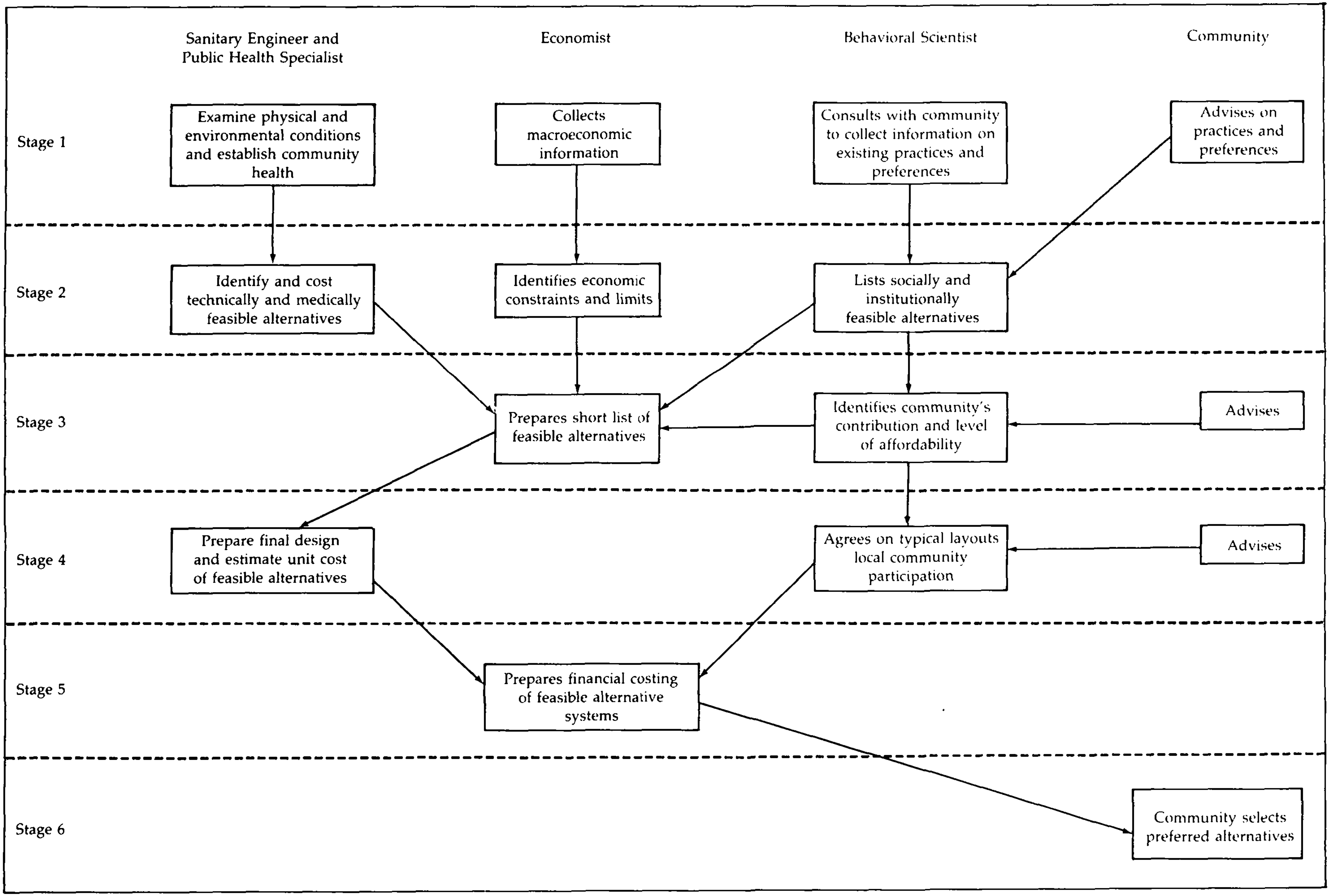
Water supply and sanitation programs that do not involve the communities for which systems are designed will almost certainly fail. In a village in Central America, government efforts from 1930 to 1944 and from 1958 to 1974 to impose latrine use had a success rate of only 11%. However, in two other Central American villages, 65% and 85% of the villagers used latrines they built themselves under their own leadership. An extreme example of non-acceptance by a community is illustrated by an East Asian and a West African city. In both cases, sewers were built but residents did not choose to connect to them and the sewers are largely unused.

Even more disturbing, considering that most communities feel that they need water, is the frequent failure of recipient communities of water supply projects to take responsibility for pump or fountain maintenance. Statistics indicate that 35 percent to 50 percent of pump installations in developing countries are inoperable three to five years after they are put in place. Potable, safe water is not always preferred over the traditional source. Where a germ theory understanding of disease is lacking or rejected, motivation to change traditional water use practices may be nonexistent. Many villagers in Sri Lanka, Kenya, Bangladesh and Latin America reject well water because the iron gives the water a disagreeable taste and turns the tea black.

Successful design and implementation of a water and sanitation program do not depend only upon successful community participation. Technical expertise and other services not available in the community must be provided by national, state, and local government or other institutions. The community worker conducting interviews and the technician designing and supervising installation of facilities are generally employees of the agency responsible for water and sanitation in the area. Other services which the agency may provide are materials, water resource surveys, or well-drilling teams.

There is no guarantee of complete satisfaction, but through joint participation by the community and the planners, goals can be defined for an individual community. Outside experts can be used efficiently as a valuable resource rather than a marginally useful expense.

Figure 10. Recommended Structure of Feasibility Studies for Sanitation Program Planning



Source: Adapted from Kalbermatten, *et. al*, "A Planner's Guide."

Through personal contacts and dialogue with the ultimate users, the goal of community participation is to match technology with the users' preferences and resource limitations. Satisfying householders' needs in an acceptable manner and at a cost they are willing to and can afford to pay must be considered in the planning process.

The means of communicating with a community are really rather simple: observe, ask, listen, ask, and listen again. Doing this effectively is somewhat more complicated. "Take me to your leader" is not enough to make community participation work.

Approaches to Community Participation

The approaches to community participation can be divided into categories that closely correspond with the four planning approaches discussed in Chapter Six:

- Approach 1. The expert designs and does it for the client.
- Approach 2. The expert designs and does it for the client but teaches "them" how to maintain it.
- Approach 3. Expert and client design and do jointly.
- Approach 4. Expert teaches from the beginning and the client designs and does.

This is not surprising since the four planning approaches are based on the relative degree of community involvement in each. The first two community participation approaches are the "do to" and "do for" approaches. They correspond to planning "Approach 1 - The expert designs and does it for the client" and "Approach 2 - The expert designs and does it for the client but teaches 'them' how to maintain it." Both these approaches are characterized by the absence of any direct community participation in the decision process. They differ only in that in the "do to" case, the program has been developed beforehand, while in the "do for" case, the target groups are studied and programs are adapted to their special requirements, preferences and problems.

The opposite of these two approaches occurs in water and sanitation programs based on the definition of needs by the community itself and the organization of cooperative action to meet these needs. This "do by" approach implies that the villages or their leaders can identify their common problems, reach a consensus on their priorities, and find suitable solutions with limited or no outside assistance. This approach has no corresponding planning approach for the very good reason that if such an independent approach can succeed, no outside assistance is required. The "do by" approach is, with rare exceptions, not possible because of lack of resources, information or expertise.

In most cases, a compromise is required via the "do with" approach which encompasses both planning "Approach 3-Expert and client design and do jointly" and "Approach 4-Expert teaches from the beginning and the client designs and does." In this case, planners develop the program together with the community for which it is intended and implement it with full community participation at every point along the way. This is the most effective approach to community participation.

Community participation is any process by which people are involved in making or implementing decisions which affect them. Many times, water supply and sanitation programs involve the community as contributors of manual labor and this is the full extent of participation. While this is certainly a common and valid type of community participation, it is not the whole story. A better measure of community participation is the degree of involvement in decision-making. By viewing participation in this light, it becomes clear that community participation is an active concept that treats people as an integral part of the process by which development takes place, not as targets of a delivery system. This concept can be expressed with a simple question: Are things being done *to* people or *for* them, or are things being done *by* people and *for* themselves?

This is not to say that communities must do everything alone in order for community participation to occur. Outside individuals and groups will play a catalytic role and a highly supportive one. There will be some activities that can only be carried out efficiently by outsiders. The emphasis should be, so far as possible, on the community learning by doing in a process that views the community population as a valuable resource that should be given the opportunity to participate in solving mutually defined problems. This requires that technical experts accept and respect the knowledge and attitudes of people toward their own water and sanitation problems.

It is possible to go too far with this approach by letting communities make decisions without adequate information on and understanding of the issues at hand. In order to make reasonable decisions, people must be aware of the opportunities and options available to them and understand their implications. Community participation can be a way to facilitate this awareness, but it is neither easy nor automatic. There are several reasons that community participation often does not work and some prerequisites to help make it work.

When agencies say that community participation does not work, a closer examination of the situation often reveals that community participation was taken to mean only manual labor. People may have been asked to contribute labor for an installation they did not feel a need for, did not ask for, do not understand how to use, and do not understand why they should use. Water supply and sanitation facilities are often built with large amounts of local labor without the community ever having been asked to participate in the planning of the facilities. Not surprisingly, the results are usually facilities that sit idle and eventually cease to function.

Community participation must involve more than just the leaders of the community. Everyone should be involved, including minorities, new residents, women, and all economic classes, castes and ages. Many programs have failed because only a few people have been consulted. It must be kept in mind, however, that insistence on equal representation of all segments of the population may be inconsistent with political and cultural realities.

Women and young people are particularly important because of their traditional roles in water supply and sanitation. It is usually the women who will maintain, or fail to maintain, the new system. More importantly, perhaps, they will be critical factors in incorporating new behavior patterns into daily life styles and in training their families in improved personal hygiene. Young people are increasingly important in community improvement programs because they act as communicators with their parents and may be more tolerant of change than their elders. The greater the participation of the entire community in making decisions and developing new facilities, the greater their motivation to accept, use, operate and maintain them.

The "do with" approach to community participation requires a great deal of communication during the initial planning phases. Communication fosters effective community participation in improving the use of currently existing facilities and in choosing technologies that are better than the present method. It also helps to ensure that the plan is compatible with the values, attitudes and institutions of the users. Communication can help make the transition from "their" system to "our" system. It should be kept in mind that it is easier to change technologies than to change behavior, and it is more difficult to determine cultural acceptability than technical feasibility.

Communication should not all flow in one direction, from the users to the experts. The "do with" approach allows great opportunity for educating the community to the problems it faces and their possible solutions. Community members should learn from the experts at the same time the experts are learning from the community. Effective communication will allow the parties concerned to educate each other and to change their values and attitudes so that a consensus is reached on the shape the plan should take.

The community should be involved from the planning stage onward. Community residents should assist in the selection of sites, provide information regarding reliability of water sources, help plan and be kept informed of the construction programs, and be consulted about the levels of service expected and the users' contributions in cash, materials and labor. In many rural areas, the community must also take the responsibility for operation and maintenance of the system.

Women are often the determining factor as to the acceptability of a water supply system.

The community should be involved in all aspects of system development, not just construction.

Community Participation at the National Level

As noted in Chapter Six, community participation is political. In fact, it is the most political aspect of planning because it directly involves the relations between the national government and its people. It can also change the relative roles of different levels of government. When communities begin to articulate their needs and learn to organize, they challenge the status quo. Success in the eyes of the community may be considered failure by the planners, particularly if there was a blue print which the planners do not feel was followed closely enough.

The national plan should recognize and reflect the importance of community participation but this alone is not enough. There must also be a consistent and stable national policy on community participation. This should take the form of a realistic community participation strategy to which government and the communities are committed over a period of time. In order for operational programs to make effective use of procedures worked out by community participation support programs, the whole approach and strategy must be included as a part of the national plan. It must be incorporated into the budget both for activities at the community level and for continuing training, research and evaluation. The barefoot doctor scheme in China did not emerge full-blown from a meeting of a high level committee in Peking. It resulted from a process of study and discussion of daily health problems within more than one million study groups across China and was based on experiences going back nearly fifty years. True, a model was publicized by the newspaper and radio, but the leadership did not require that this model be used. Instead, it asked local groups to study a number of models to see if one of them would fit the community's own health needs. In China, this process generated community dynamism and self-reliance.

To create widespread public enthusiasm and enlist continuing community participation, the policy must receive the support of the whole government. It cannot be the policy of just one ministry but must be supported by all ministries working at the community level. Coordination is needed at the national, provincial and district levels, but it is essential at the community level where national representatives converge to work directly with local people. The community participation policy should take into account existing community organizations and their training programs.

Most countries have a wealth of experience, good and bad, in community development, self-help, and other forms of public participation. After careful analysis of existing resources, people and institutions, specific targeted training can be designed so that these resources can be mobilized. Using existing governmental personnel at field levels is never easy. Recognizing the limitations, both political and administrative, to expanding community participation, the benefits can far outweigh the costs when long-range overall impact is considered.

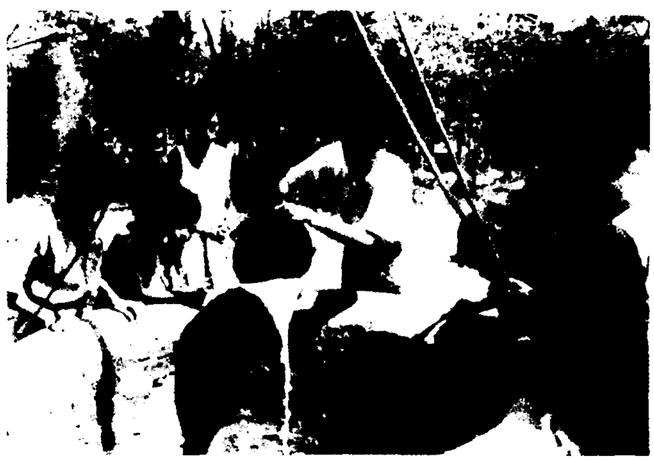
It is important to understand that village priorities for projects will vary widely. For some, water and/or sanitation will be requested first; in others, a road, a health center, or a cooperative store may be top priority. The key to successful and continuing community participation is a nationally approved plan for responding to needs as expressed by the communities and building with them on their new awareness and pride.

For communities that do not feel water supply and sanitation are a first priority there is the opportunity, within community participation programs, to conduct an education campaign on water supply and sanitation. Special instructional units related to personal and environmental hygiene should be developed as part of community participation training.

Programs for supplying water and sanitation to meet basic needs should be closely coordinated with environmental control and primary health care programs. There should be a long-term national policy, at least in broad outlines, which ideally will not change even with governmental changes and political shifts in power. A close sharing of plans and objectives at the national level should facilitate cooperation at the provincial, district, and village levels.

New programs of ministries of health in most countries have major components aimed at increasing community involvement. Most already have trained, or are in the process of training, primary health care workers who are the link between villagers and the official health system. Planners and administrators should work closely with community volunteers and health committees to design and implement projects in water supply and sanitation, and to prepare mutually supportive educational materials.

Non-governmental groups have trained staff and volunteers who can add depth and breadth to water and sanitation planning and implementation. Recent international and national policy statements indicating strong support of the work of non-governmental organizations at the village level are a further indication of recognition of the value of community participation. Such a policy gives a framework for incorporating these human resources—trained staff and volunteers—into efforts for water supply and sanitation.



Health workers are often a critical factor in community involvement.

Measures to implement the community participation policy should be consistent with the objectives of the program. For instance, in implementing water supply and sanitation programs, support and subsidies should be available to allow response to requests from villages and to strengthen other community action and village efforts. The more closely activities are linked to existing community organizations and to other local groups working for community improvement, the better.

Consistent policy with continuing support for community participation should continue for a specific period of time. After this period, adjustments and revisions can be made based on a careful evaluation of successes and failures to improve and expedite the next period of continuing activity. Evaluation is essential for planning, implementation, use, maintenance and further development of programs. It is one form of dialogue in which agency representatives and planners learn of the needs and resources of the communities at the same time they are helping people become aware of alternative solutions to meet needs.

As noted in Chapter Six, participatory evaluation by the community itself should be an integral part of the program design and a mechanism for learning, choosing and strengthening community participation. The community people are involved not as *subjects* or *objects* of research, but as genuine participants in each stage of the evaluation.

There are several ways to effect better coordination among ministries and maximize community participation. First, a working panel made up of field personnel from ministries and voluntary agencies involved in water supply and sanitation programs should be created. Among the activities of such a panel might be:

- responding to requests from villages for water and sanitation assistance and deciding on the most appropriate follow-up;
- allocating funds (for supervisory volunteer personnel) to cover costs of transportation, per diem, and special training;
- reviewing progress of on-going projects; and
- cooperating with the efforts of a research, training and evaluation group and receiving continuing information on the results of studies and evaluations.

Second, a carefully designed referral system should be developed to ensure that requests for assistance from communities are addressed appropriately and that suitable action is taken regarding communities in which water and sanitation assistance appears to be needed but is not a community priority. Figure 11 is a diagram showing how such a referral system might work.

Third, water supply and sanitation seminars and workshops should be held in the training centers of the various organizations, governmental and voluntary, who are engaged in community development and other self-help activities. Special training modules should be designed for use at these workshops.

The development and implementation of a community participation strategy are of critical importance in the long-range success or failure of water and sanitation programs. In 1975, the World Health Organization and the United Nations Children's Fund studied alternative approaches to meeting basic health needs in nine developing countries: Botswana, Costa Rica, Indonesia, Mexico, Senegal, Vietnam, Sri Lanka, Western Samoa and Yugoslavia. The study concluded that social considerations must be taken into account not only in designing technology but also in creating an administrative structure to manage the introduction of technology to the community.

Further, the study found that in the nine countries studied:

- At the village level, preventive and curative health services that are adequate in coverage and are sufficiently used by the population have been achieved where the population concerned has taken *major responsibility* with government support in the effort.
- Major responsibility implies a great deal of self-reliance not only in decision-making with respect to priorities for health care but also in the provision of resources (human resources, facilities, logistic support and probably funds) needed to bring health services into line with defined priorities.
- The greater the participation of the community in the development of primary health care services, the greater their motivation to accept and use these services.

These same conclusions should apply to water and sanitation programs.

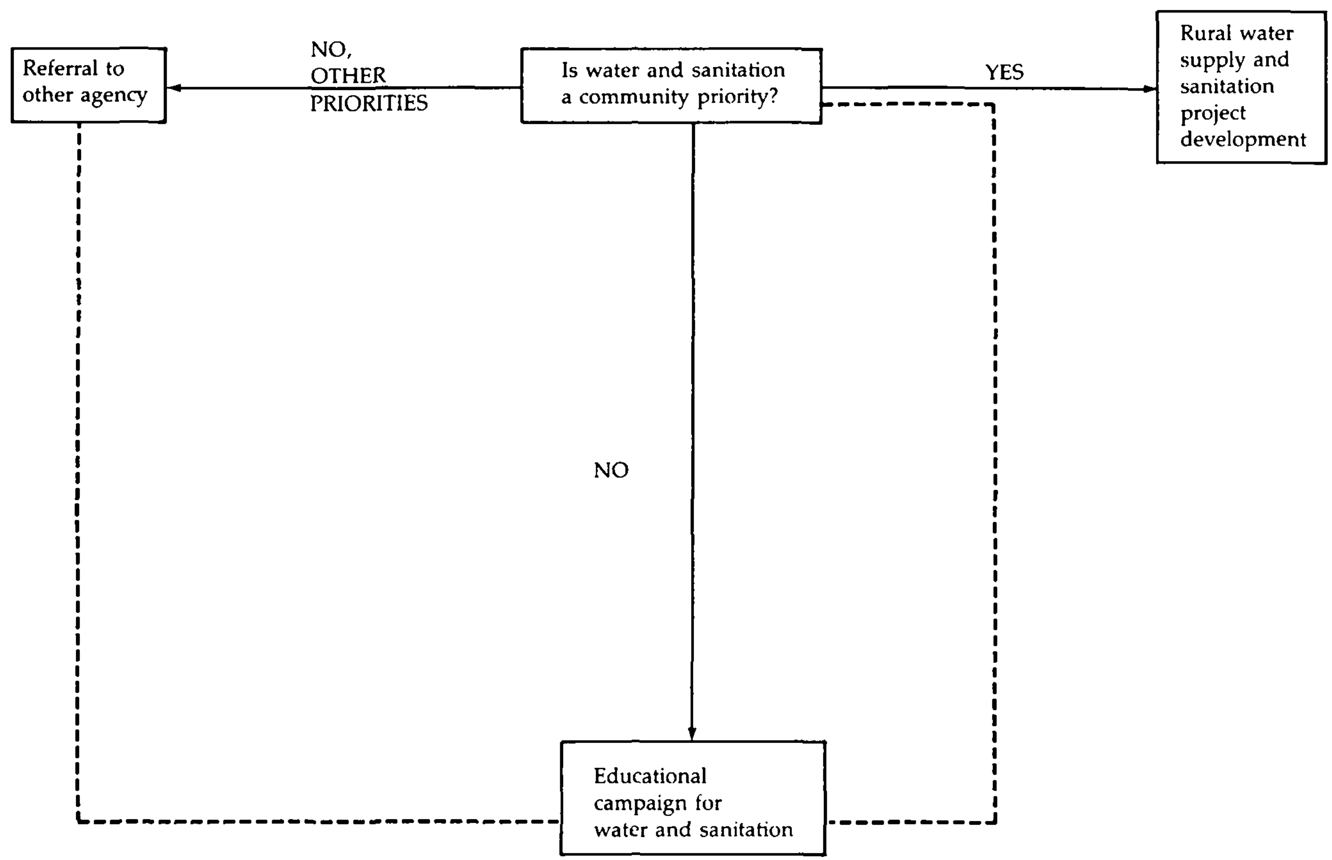
Developing a Community Participation Strategy

Go to the people.
Live among them.
Learn from them.
Serve them.
Plan with them.
Start with what they know.
Build on what they have.
...in projects that are simple, practical and economical.

Y.C. James Yen
Rural Reconstruction and Development

Probably the most important of the national level activities described in the previous section is the development of a community participation strategy. The foundation of that strategy must be respect from the outsiders for the people of the communities. Villagers should be respected for their:

Figure 11. Diagram of Referral System



Source: Whyte, "Extension and Community Participation in Water and Sanitation in Developing Countries."

- Pride. Like all humans, community residents take pride in themselves, their families, and their community.
- Intelligence. Even though they may have received little formal education and may even be illiterate, villagers have learned a great deal through their senses, through oral history, and through their experiences.
- Wisdom. Community residents know about their environment and how to survive against great odds.
- Logic. They are pragmatic and their decisions are made according to their perceptions of the realities of the framework they have spent a lifetime developing.
- Altruism. They are often willing to make personal sacrifices for the future well-being of their children and other family members and of their community.

There are three key decisions to be made in developing a community participation strategy: who the major actors in community involvement will be, what kinds of interaction with the community will occur and how this interaction will take place. In order to make the first of these decisions, the available human resources for a community participation program must be assessed.

Assessing Human Resources

Involving community members in project planning is difficult. While many factors may hamper efforts to have the community participate in project implementation, probably the most important inhibition to participation in planning is lack of relevant information and communication. The community participation strategy will have to make special efforts to overcome this problem. The availability of paid staff and volunteers trained in community participation techniques is crucial for the success of the program. Planning and implementing community participation strategies face many obstacles both from within and without the community. Dedicated workers with skill in working with community residents can do much to overcome these obstacles.

A "do with" strategy of community participation requires a significant amount of time-consuming consultation with community members. Making optimum use of scarce resources requires that national water supply and sanitation agencies coordinate their activities with other organizations that already have trained or trainable community participation facilitators at the village level. These facilitators are usually experienced in promotion and extension activities and they are the crucial link between the agency and the community. They have been or can be trained in working with communities in planning environmental health programs.

There should be a national inventory of the human resources available and the institutional and other limitations within which they must function. This inventory should seek to answer the following three questions:

1. What past and present experience is there with community development, both governmental and private?
2. What is happening in the development of a primary health care system?
3. How many trained people are there, where are they, how much are they paid and what institutions or other opportunities are there for training untrained personnel?

Effective water or sanitation system development requires implementation of community participation strategies.

Information-gathering is probably the single most important way to establish a dialogue between community residents and national agency personnel. This, in turn, stimulates community involvement. Planners gain understanding of the human and behavioral factors that influence whether users will accept, properly use, and maintain water supply and sanitation facilities introduced into their communities. Both constraints to change and incentives for change can be explored during this time.

Once these questions have been answered, there should be a careful analysis of the existing resources—both people and institutions—so that specific targeted training can be developed as needed to mobilize these resources. Training should be based on an analysis of the ways in which existing resources can be useful in gaining community acceptance of and involvement in a water supply and sanitation program.

Interacting with the Community

Probably the most useful technique for interacting with the community is gathering information for use in planning the water and sanitation program. This has merit on its own, because the information collected will be useful in the planning process, and it creates an entry point into the community for two-way communication and education.

The information gathered from the community should be aimed at encouraging community participation in and acceptance of the program. The types of information that should be elicited include:

1. The needs of the community for water supply and sanitation improvements in relation to other development priorities as perceived by the community members;

2. The desire of the community for such improvements as expressed in terms of willingness to pay for them through cash contributions and/or labor and materials;

3. The community's preference for private or communal facilities. For example, do the latter represent opportunities for socializing or do they lead to crowding and quarreling? What are the permissible groupings? By age, sex, lineage, ethnicity, or others? Can water be shared even if private sanitation facilities are preferred?

4. The community's perceptions of health, sickness and nuisance as they are affected by water supply and sanitation practices;

5. The community's attitudes toward convenience as measured by latrine or standpipe location, abundance or capacity of water supply systems, and reliability of service;

6. The community's water quality preferences in terms of color, taste, odor, temperature, and other relevant factors;

7. The community's water use preferences in relation to drinking, cooking, bathing, washing of clothes and dishes, cleaning, and watering domestic animals and crops;

8. The community's reaction to aesthetic features of sanitation alternatives such as superstructure color and materials or squatting plate or stool design;

9. The community's preference for material (water, paper, leaf, stone, corncobs) for anal cleansing, their method of disposal of these materials and the reasons for their choice;

10. The community's attitude toward conservation, re-use or reclamation (biogas, composting, fertilizer, aquaculture, stock and garden watering) of wastes;

11. The community organization that might logically assume responsibility for a project and, if none exists, the customary way of forming one;

12. The community's perception of the importance of local autonomy which might be lost if a higher authority provided funding, fee collection, construction, operation and maintenance of the improved facilities;

13. The community's reaction to people joining and supporting "unity and progress" groups; and

14. The community's confidence in local or visiting political and technical authorities.

The purpose of gathering this type of information is to get people to talk, not simply to answer specific questions. Gathering information about socio-cultural factors and materials required by engineers and planners is an important part of the educational process for everyone involved. Not only do community members learn information-gathering techniques, but they also learn a great deal about their own community, its problems, and possible solutions to them. Planners and engineers get the information they need on perceived and actual situations and on possible community reactions to alternative solutions.

As noted in Chapter Six, there is no single best field method for developing community participation and the dialogue necessary for making successful changes in the social system. The more sophisticated social science research instruments, designed primarily in the language and categories of the industrialized world, are not necessarily the best way to determine attitudes and practices in water use and excreta disposal. A combination of techniques which involve observing, listening and questioning, both structured and unstructured, is the most effective way to obtain reliable information on water and sanitation needs and to explore appropriate solutions.

The field methods used to achieve this dialogue must be flexible enough to relate to local populations and organizations as well as to the overall situation and the information needed. An approach which takes into account the perceptions of the environment by the community people, as individuals and as a part of a cultural group, and the perceptions of experts and officials is best. The most useful techniques in determining existing attitudes and practices, as well as in designing more acceptable and effective programs, are those in which the local people are most involved in the identification of community needs and priorities. When problem-solving approaches are substituted for or used in addition to a structured questionnaire, the result is dialogue between community users and the facilitators and planners involved in project promotion and research. Much useful information is generated in addition to answers to preconceived questions.

Face-to-face communication raises awareness of present practices and alternative opportunities, and it defines problems and priorities. Ultimately, joint analysis by the community and the planner leads to greater understanding of needs, resources and alternative solutions. Figure 12 illustrates this interchange in which dialogue becomes a process of search and retrieval.

A survey questionnaire alone is inadequate to the task. Along with community knowledge, practices and beliefs, which survey questionnaires may reveal, there is a need for detailed information on individual behavior, attitudes and hopes. Within the three main approaches of asking questions, listening, and observing, there are a number of specific techniques that can be used in addition to a questionnaire.

1. **Interviews.** In most community studies, in addition to the basic survey questionnaire, structured interviews with local leaders are used. A more open-ended, unstructured interview can also be used to obtain useful information from community leaders and innovators. The dialogue resulting from interviews in communities gives leaders an opportunity to explain local needs and resources as they view them and allows outsiders to learn about possible alternatives, including past projects that were unsuccessful.

When used in these ways, the interview becomes an exchange of information and not just an extractive process. In interviews with other knowledgeable people, such as midwives, healers, and storekeepers, new clues to problems, needs and resources often surface. This information is sometimes more valuable than that obtained from community leaders. Interviewing selected families or categories of people, such as mothers, can be very useful. Interviews should include women since they are knowledgeable about water use and responsible for training children in personal hygiene and sanitation. The most reliable answers to questions on sanitation will come from those who are most concerned about sanitation. If, for example, land tenure or employment weighs heavily in unstructured parts of the interview, sanitation problems will get little attention from the householder.

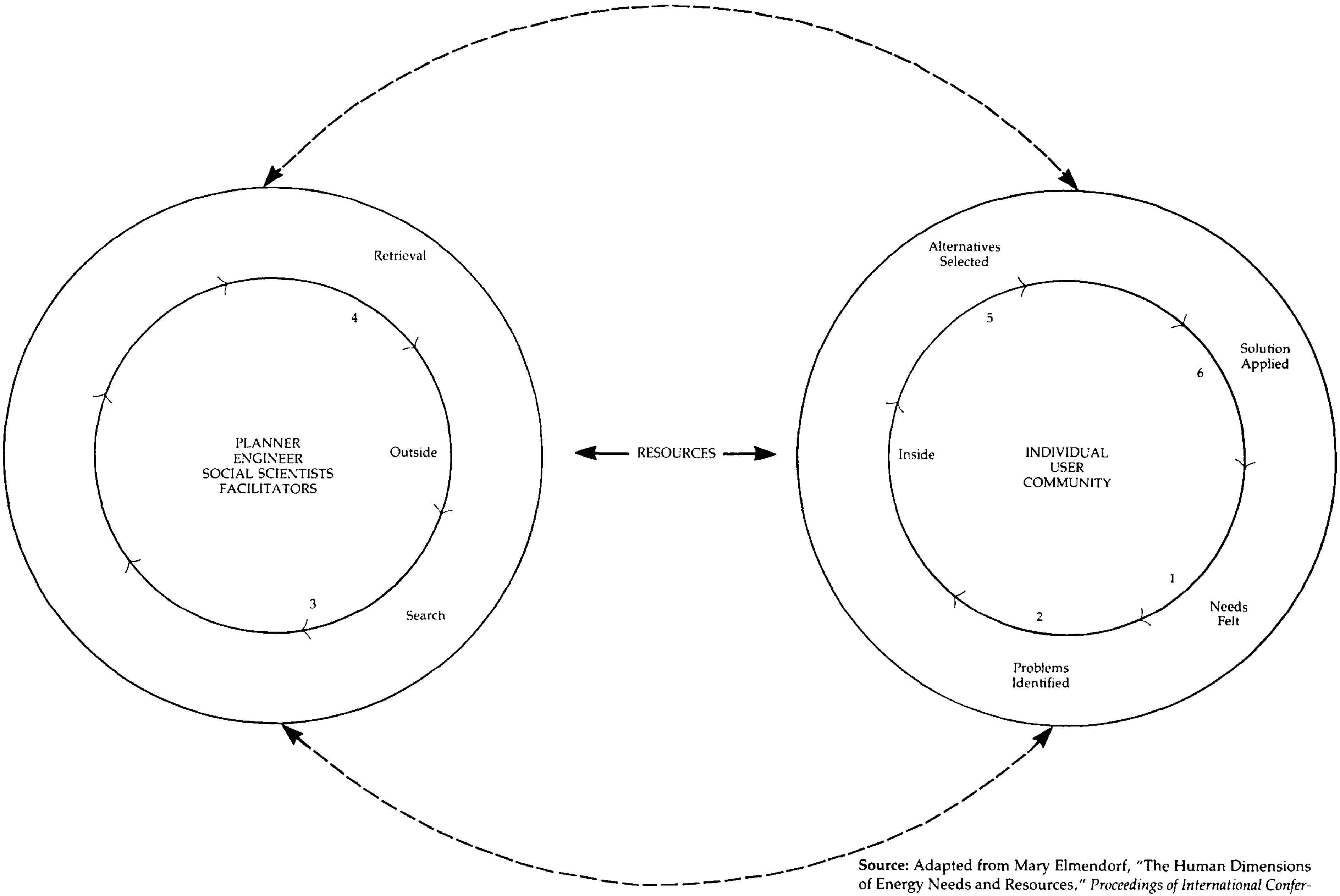
2. **Surveys.** If sociological surveys are needed, they should be based on the results of preliminary interviews and prior observation. In each case, the basic survey questionnaire should be revised to include local terminology and categories meaningful to local people. Additions and modifications should be made to the questionnaire to suit local conditions. In random samples of households, care must be taken to ensure that enough households are included and that they are representative of the social, ethnic, and income groups of the community. Usually, information gained in unstructured, preliminary interviews can be used to select representative households.

3. **Observation.** Observation, which can be direct or indirect, structured or unstructured, is a basic tool for understanding the human dimensions of needs. Public behavior, such as the number of trips to draw water and the time needed to do it, is much easier to observe and analyze than practices within the privacy of the home. If access to the home can be gained, information on water use habits can be obtained through direct observation of dishwashing, clothes washing, and food preparation activities, combined with informal discussion of water use and observation of habits of personal hygiene. Latrine use can be verified through indirect observation. Outsiders should note if paths to latrines are well beaten or overgrown with vegetation, if recently used hygiene material is present, or if there are odors.

Surveyors should seek to identify the water source in use and its quality and quantity.

4. **Map-making.** The preparation of a wall map, noting households, streets and community resources, particularly those being analyzed, is an extremely useful tool. Mapping is one of the first tasks recommended to get an overview of a community. For instance, in Chan Kom, Yucatan, the bi-lingual students in the sixth grade social science class, working with their teacher and the researcher, made a household survey and prepared a village map indicating homes with and without water and sanitation services. The map continues to be used as a basis for planning. The same approach has been used successfully in Burma. In Quiche, Guatemala, the community located places for shared standpipes by measuring distances between homes with a bicycle wheel and placing poles with flags at mutually agreeable places to be checked by the engineer for feasibility. The chosen spots were placed on the village map.

Figure 12. A Dialogue Approach to Problem Solving



Source: Adapted from Mary Elmendorf, "The Human Dimensions of Energy Needs and Resources," *Proceedings of International Conference on Survey Methodologies for Energy Assessment*, National Academy of Sciences, 1980.

5. **Participant Observation.** In participant observation, the researcher lives with and participates in the daily life and activities of the people being studied. As a specialized technique, participant observation, which encompasses observing, listening, and asking questions, used to be considered primarily an anthropological method for understanding foreign cultures. More and more it is being used as a tool for obtaining information on basic needs within a community. The researcher's own perception and experiences condition the collection and interpretation of information. On the other hand, non-local researchers have some advantages since they can maintain an attitude of ignorance that enables them to ask simple questions.

Participant observation allows the collection of information that may correct long-standing but erroneous assumptions. For instance, the usually accepted attitude about Latin America has been the least possible contact with human excreta, the better. This attitude seemed to eliminate many of the possible appropriate technologies, such as composting latrines. However, participant observation study of San Pedro, Guatemala, found that the villagers have a traditional technology of re-use of human excreta such as is practiced in more advanced and systematic form in Japan, China, Korea, Vietnam and India. Re-use of excreta is not discussed in public but it takes place in individual households in various forms such as fertilizer for corn fields or coffee plants, or feeding of pigs.

Planners should develop reliable techniques for studying user behavior.

6. **Behavioral Mapping.** This is a reliable and simple technique for observing and recording specific behavior in relation to specific locations. For example, it can be used to determine relationships between water use and defecation patterns in order to identify possible re-use alternatives for gray water and culturally acceptable locations for bathing, laundry, and latrine facilities. This method can be used by the sanitary engineer and the planner in discussing with the users alternatives that combine bathing areas and excreta disposal.

7. **Pictorial Analysis and Sorting.** The director of an extremely successful integrated rural development project with a health component in Colombia found that difficulties between the villagers and the planners were solved by the relatively simple technique of photographic sorting. Selected villagers were asked to sort photographs of the community into categories of needs and then to prioritize these. Although the villagers each categorized the needs and problems somewhat differently, there was considerable agreement in the priority listing. When this same task was assigned to the planners, they sorted things in very different categories and, most significantly, their understanding of the priority needs of the village proved to be very different from those of the villagers. Comparing the two interpretations can give the planners greater understanding of the community's priorities, perhaps illuminating the reasons for lack of interest in a water and sanitation progam and pointing out the need for a community education effort.

8. **Oral History.** This method involves recording answers to open-ended questions on a single topic or specific topics. With good rapport and sufficient time, material collected in this manner has high validity and allows maximum freedom to the person responding. Historical material, including political implications and system failures, on past programs can be secured in this way. This technique is particularly useful with the elderly to gain valuable insight into local institutions.

9. **Informal Listening.** Informal listening can add new insights. Listening to women washing at the river, for example, may indicate that group laundering is not a preferred activity, as many assume. Listening to statements that are not answers to structured questions can help solve the problem of not knowing the right questions to ask to gain the most useful information.

Gathering information, whatever techniques are used, is only part of the process of stimulating dialogue to identify community needs and assess alternative solutions in a problem-solving approach. Equally important is continuing consultation with the community, through group discussions, task forces, community meetings and within homes, to get everyone involved with the new facilities. This type of consultation will also make clear to the planners whether or not community education is needed and, if so, in what specific areas and what techniques might be most successful.

A Model Strategy for Community Participation

As noted earlier, an integral part of an environmental health program plan is a well-defined community participation strategy that includes the specifics of who, what, when and how for community involvement. This strategy should be developed carefully to meet the needs of the country in which it will be used. The model strategy presented here is incomplete in the sense that it focuses primarily on the "what," "when," and "how" aspects of the strategy which are aspects that should vary less from country to country than the "who." The model is presented in two parts. First, there are specific suggestions regarding the points in the program development and implementation process at which the community should be involved and the form that involvement should take ("when" and "what"). Second, a methodology is presented for introducing and reaching agreement on the technologies to be used ("how").

The community should be an active participant in all phases of the water and sanitation program: planning, design, construction, operation and maintenance, and evaluation. The role of the community in each of these phases should be as follows:

1. **Planning**
   - **Need Determination.** It is essential for the planner to gather information in the community on how the community operates, what it needs, what it believes that it needs, and what it wants.
   - **Need Response.** Projects should be initiated in response to need. Work should be initiated only with the support of the community. This does *not* mean that if the community does not think it needs an improved water supply or sanitation facility, the planner should simply leave and go on to another community. Before a community can make a rational judgment as to what it needs and what kind of system it is willing to use and support, it must have adequate information on and understanding of its problems, their causes, and options for their solution. This will often require a substantial community education effort involving meetings, training sessions, educational materials and other aids to bring the people to the point that they can make intelligent decisions.
   - **Choice of Technology.** After a project has been found to be technically feasible, the community must decide whether it is culturally feasible and will fill its needs. Based on knowledge acquired through demonstrations, slides, visits, talks, and other education efforts, community members must decide how, or if, they can pay for, use, operate and maintain the system under discussion. If there still seems to be a lack of understanding of the technology being considered, it can be introduced on a trial or demonstration basis at one or two sites if this is technically possible.
   - **Rate of Implementation.** Individual communities should have a voice in when the design and construction of the system occur. A project agreement or contract detailing the responsibilities of the community and the national agency, including labor, materials, and money, should be developed. Timing of project implementation should be in accordance with migration patterns, planting, harvesting and climatic cycles, and possible delays should be considered.
   - **Committee Responsibility.** The community should organize a locally selected committee or cooperative to plan and oversee the community's involvement, if such a structure does not already exist. This should be done according to locally accepted procedures. Responsibilities should include: calling and conducting meetings to inform the community about the project status and to elicit the cooperation of community members; organizing the voluntary labor force and maintaining records of individual labor contributions; arranging for community "helpers" to participate in feasibility studies, census-taking, promotion, education, training and evaluation; petitioning the relevant governments for authority to collect maintenance fees; obtaining all legal authorizations needed; selecting community members to be trained in facility maintenance; collecting maintenance fees, maintaining records, and filing periodic reports on these activities; and preparing a contract that details community and agency responsiblilities.
2. **Design**
   - **Level of Service.** The community should decide what level of service it wants and can afford, both currently and in the foreseeable future. This decision should be based on specific designs and attached price tags prepared for the community. Care should be taken that socio-cultural factors related to practices and preferences are taken into account in developing proposed designs.

- **Location of Facility.** The community should decide where water distribution outlets and waste disposal facilities are placed. This is perhaps the most dynamic aspect of community participation. A preliminary map should be drawn and the planner should accompany the villagers through the community placing flags to indicate the eventual positioning of the installations. This could require two or three trips to the community. For installation of household facilities such as patio standpipes or latrines, women should be involved in deciding on the most efficient location to maximize use of the new technology and reuse of waste. Discussion of present uses and practices and behaviorial changes needed for effective home management should be a part of this process.

3. **Construction**
   - **Labor.** If possible, the community should provide the volunteer or paid unskilled labor needed to install the water system and sanitation facilities. A formula should be developed to relate women and children days to "man" days and records of individual household contributions including food, hospitality and housing should be maintained.
   - **Materials.** The project should use locally available construction materials such as rock, sand, wood and gravel gathered by the community. Labor-intensive construction techniques should be employed to lower the cost of outside resources.
   - **Household Installations.** Household installations, such as latrines, are sometimes installed completely by individual families with technical assistance available as needed. Some communities work together in teams on individual installations.

4. **Operation and Maintenance**
   - **Technology Selection.** Technologies requiring minimal maintenance that can be provided by the community itself should be given priority. Training, supervision and evaluation should be a continuing process.
   - **Maintenance Responsibility.** At least two individuals should be identified by the committee as responsible for maintenance of the facilities. This prevents a monopoly by one person on the responsibility for maintenance and thus control of the system. Training in operation and maintenance of the facilities should be provided initially and as needed thereafter.
   - **Care of Facilities.** Households, especially the women in them, should be trained in daily care of their own new facilities, including discussion of household water storage problems and maintenance of sanitary facilities.

Village women should play a key role in deciding where to locate a facility.

Community residents should provide labor, and the skills of women and children should be used when possible.

- **Maintenance Costs.** An appropriate maintenance fee should be charged on a monthly basis for water supply and sanitation facilities. The maintenance fund should remain in the community's treasury. Fees should be collected by a designated member of the committee who has been trained in simple accounting. Maintenance records should be reviewed regularly by program staff or by the facilitator assigned to the local health center.
- **Project History.** A useful technique is a "village book" describing the planning and execution of the project with photographs and narrative written by the planner and the members in the committee. It should remain in the community and be used for additional promotion. It serves as a constant reminder of past contributions and future commitments.

5. **Evaluation**
   - **Project Review.** The evaluation criteria and schedule should be discussed with the community and their contributions included in the evaluation plan. Community members should participate in reviews and evaluations of the success or failure of the project and make suggestions for changes and improvements.

Once the "when" and "what" of community participation have been decided, the strategy should define *how* this participation is to occur. There are infinite possibilities for combinations in the "how" area, just as there are in "when" and "what." The model sequence of project implementation described here is one way in which the order of business of community participation might proceed. It should be revised as local conditions warrant, making use of whichever techniques described earlier seem most likely to be effective. A procedure of this type should be the backbone of the community participation strategy and should be followed by everyone working with communities on water and sanitation projects. Figure 13 shows the model sequence graphically. Each step is numbered in accordance with the steps in Figure 13.

1. The "contact" with communities may occur in the field when facilitators discuss water supply and sanitation with health promoters and/or with leaders in the communities. Or, the contact may occur in the national agency's branch office when community leaders and health promoters inquire about water and sanitation improvement possibilities. They may be aware of the existence of the program office from radio announcements, word of mouth communication, or from having seen or heard about projects completed by the office.

2. Whether the contact is made in the community or in the branch program office, and whether the community members or agency personnel initiate the discussion, there is still a need for investigating the extent of perceived need for water and sanitation improvements on a community-wide basis. The investigation should ideally be carried out with the participation of both community leaders and agency personnel. Facilitators under the guidance of the program team's community organization specialist would be expected to have a primary role. They are most aware of available external resources and can be expected to be most familiar with the community's social and geologic conditions, as well as with previous community experiences in community organization and development projects.

3. The "Joint Baseline Study" (JBS) of perceived and observed community needs and resources should be planned with community leaders and involve their contribution of time in interviewing and having discussions with other community members. This dialogue or problem-solving approach is essential for the success of the project to identify needs, problems and possible solutions.

4. Structured surveys developed by the program team can be used to collect information on existing water sources, health conditions, available local materials and geologic conditions. Information on previous community participation experience in projects such as school building, road construction, and health clinic establishment are examples of information valuable for interpreting the community's potential for participation in a water or sanitation project. Information on attitudes, beliefs and preferences must involve open-ended interviewing with a significant portion of heads of household (at least 15 percent), midwives, pharmacists, school teachers, religious leaders, and health promoters.

5. Analysis of the results of the joint investigation by agency personnel and community leaders should be carried out in an informal gathering, preferably in the community, where community leaders will feel more comfortable in contributing to the discussion with original and personal insights.

6. Expected outputs of the analysis are information which will be important for agency evaluation of alternative technologies and of community capacity and willingness to participate; community insights into the environmental sanitation situation and health implications, as well as increased confidence in the intentions of program personnel; and quantitative data for later evaluation of the program's implementation and project impact.

7. The findings should be presented to the community by leaders in a meeting of all community members. Program personnel (planner, community organization specialist and facilitator) should be present. The presence of the program engineer is not crucial, but it will provide legitimacy to the results and allow better answers to the questions of community members about technical components and alternatives. Suggestions of community members could also provide information to the engineer for altering design options.

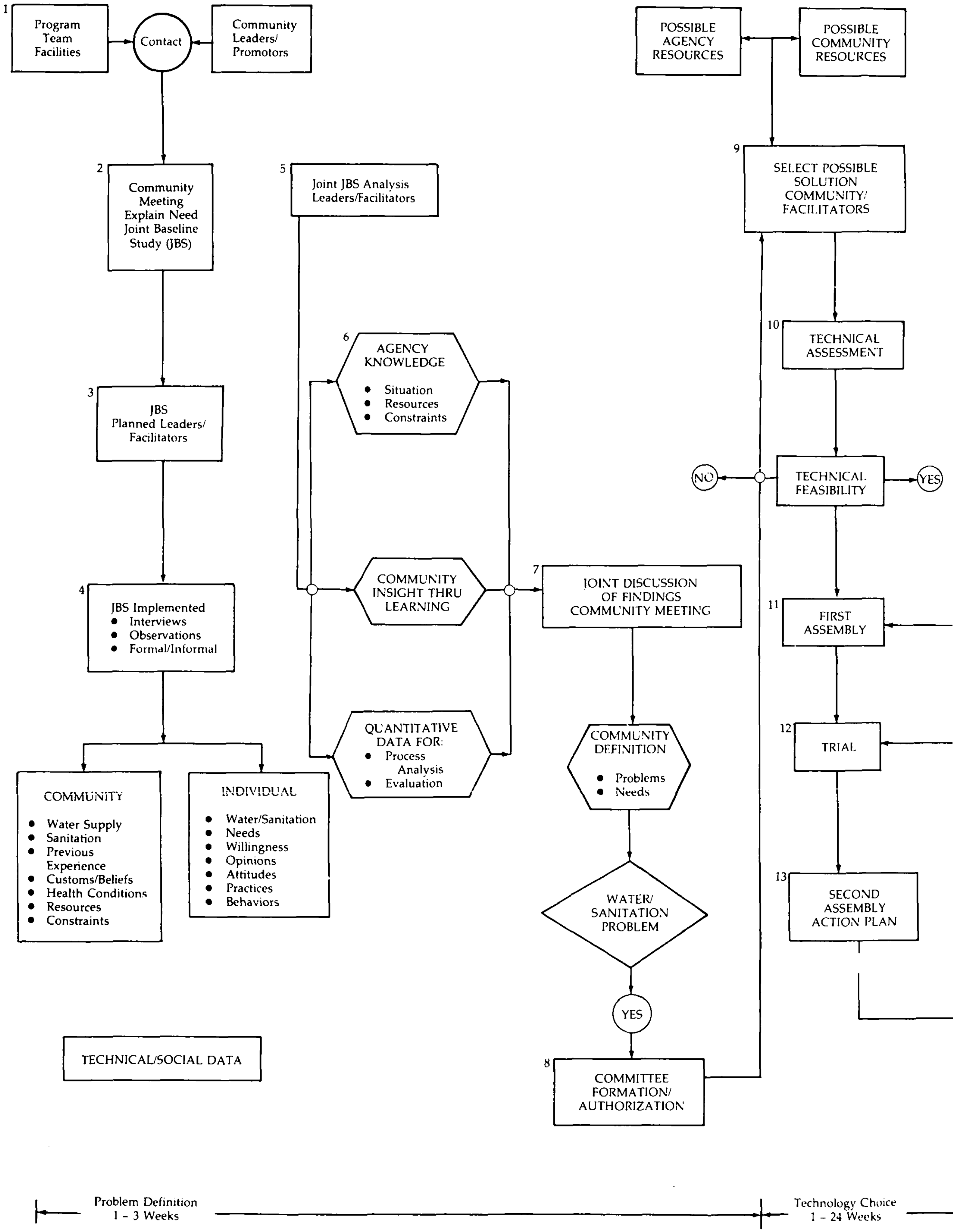
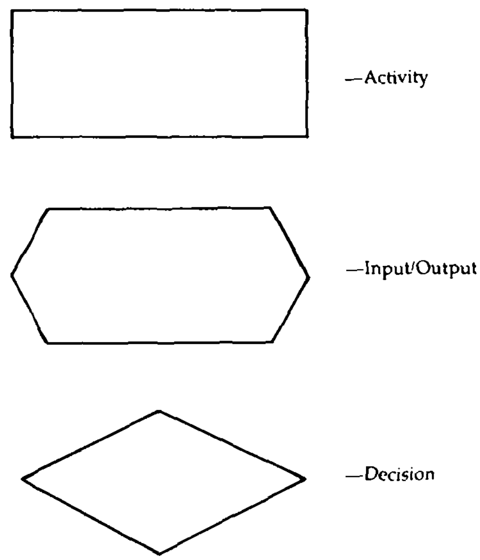
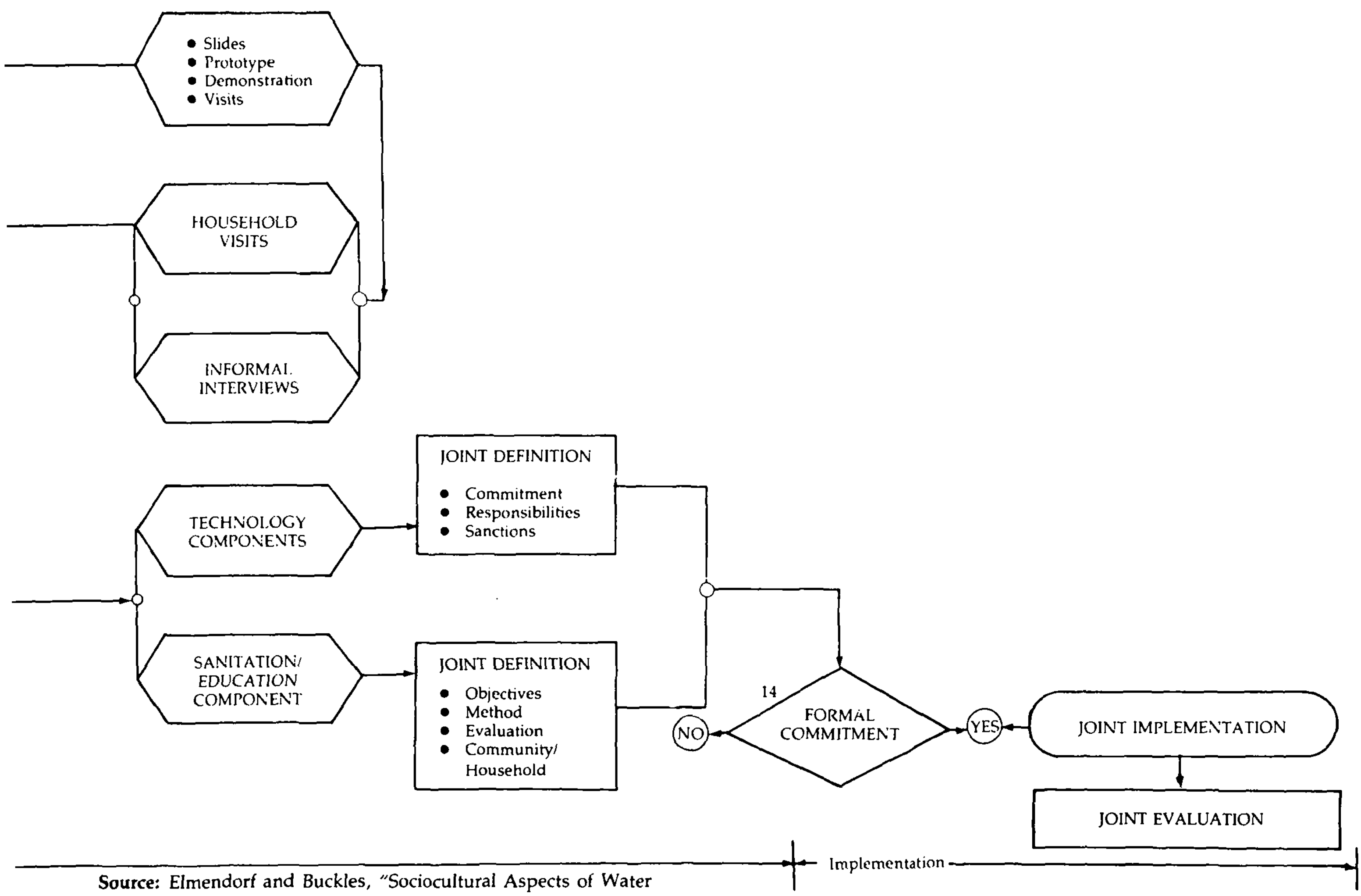

1
Program Team Facilities
Contact
Community Leaders/ Promotors
2
Community Meeting Explain Need Joint Baseline Study (JBS)
3
JBS Planned Leaders/ Facilitators
4
JBS Implemented
• Interviews
• Observations
• Formal/Informal
COMMUNITY
• Water Supply
• Sanitation
• Previous Experience
• Customs/Beliefs
• Health Conditions
• Resources
• Constraints
INDIVIDUAL
• Water/Sanitation
• Needs
• Willingness
• Opinions
• Attitudes
• Practices
• Behaviors
TECHNICAL/SOCIAL DATA
5
Joint JBS Analysis Leaders/Facilitators
6
AGENCY KNOWLEDGE
• Situation
• Resources
• Constraints
COMMUNITY INSIGHT THRU LEARNING
QUANTITATIVE DATA FOR:
• Process Analysis
• Evaluation
7
JOINT DISCUSSION OF FINDINGS COMMUNITY MEETING
COMMUNITY DEFINITION
• Problems
• Needs
WATER/ SANITATION PROBLEM
YES
8
COMMITTEE FORMATION/ AUTHORIZATION
POSSIBLE AGENCY RESOURCES
POSSIBLE COMMUNITY RESOURCES
9
SELECT POSSIBLE SOLUTION COMMUNITY/ FACILITATORS
10
TECHNICAL ASSESSMENT
NO
TECHNICAL FEASIBILITY
YES
11
FIRST ASSEMBLY
12
TRIAL
13
SECOND ASSEMBLY ACTION PLAN
Problem Definition 1 - 3 Weeks
Technology Choice 1 - 24 Weeks

Figure 13. Methodology for Introduction and Adoption of Water Supply and Sanitation Technologies





Source: Elmendorf and Buckles, "Sociocultural Aspects of Water Supply and Excreta Disposal."

8. Once water and sanitation are defined as problems, the community as a whole should select a committee (if one does not exist already) by whatever means tradition and custom dictate tc organize activities and call meetings for discussion of the project.

9. A few days after the general meeting, when informal discussions among individuals will have had time to allow any misconceptions or doubts to be articulated, a meeting between the facilitator and the community leaders to discuss options should be held. This will allow for planning a visit by the technical component of the program team to assess the feasibility of the option selected (wells, gravity systems, public or private water tap connections, composting latrines, or conventional pit latrines, private and/or public facilities) by the community. Visits by community leaders to projects in process or completed may provide tangible visual aids for explaining different options.

10. A visit by technically skilled program personnel to determine the technical feasibility of the option selected by the community should be thorough and accurate. The delineation of expected community costs is of primary importance. A positive response on feasibility and the inclusion of costs will be interpreted by community members as a commitment on the part of the agency to provide resources for project implementation. The agency should not commit itself unless implementation can begin almost immediately or within a reasonably acceptable time period agreed upon with community leaders.

11. At the first assembly, the entire community should be present for viewing of slides, a prototype demonstration, or guest appearances by leaders from communities who have already participated in the program. The meeting should include a thorough discussion and repetition of expected community contributions and agency contributions.

12. If the community is unsure or unfamiliar with the technology, a prototype should first be constructed in the school, the health center, or in a central gathering place, or in the home of a community leader for use on a trial basis. If the technology is already understood by the community members, this is not necessary.

13. The second assembly of the entire community provides a forum for discussing the technology and its extension throughout the community. Members of the program's technical and social team should be present. A plan should be developed for organizing community contributions and participation in health education as well as construction activities. The plan should include an estimate of expected time, money, and material contributions (already agreed upon) and expected timetable for completion.

14. A formal commitment to the agreed-upon plan should be submitted in writing to the agency with indication of agreement by a significant majority of the community (80 percent is suggested).

15. Implementation should only proceed after the formal agreement has been submitted to the agency's branch office.

Prototypes of unfamiliar technologies may be first tested at public places such as the local school.

Community meetings should be held to discuss the project and its implementation.

Case Studies in Community Participation

Two case studies will be described here of how new technologies were introduced to rural communities in two different parts of the world. Neither of the case studies conforms precisely to the model community participation strategy just presented, but in both instances community involvement played a critical role. The case studies are intended to give some reality to the concepts of community participation that have been the subject of this chapter.

San Pedro La Laguna, Solola, Guatemala

A pilot project for the introduction of anaerobic biogas was begun in the town of San Pedro La Laguna in 1977 with the assistance of the Guatemalan private voluntary organization CEMAT (Centro de Estudios Mesoamericanos Sobre Tecnologia Apropiada). San Pedro is a traditional Mayan community in the Central Western Highlands of Guatemala. Sharing a common language, Tzutujil, and a common cultural tradition, the population is principally agrarian but is rapidly undergoing modernization.

Situated at 1,564 meters above sea level on the shore of a volcanic lake, the community is located 160km by road (five hours by automobile) from the capital city. Forty kilometers of the road are nearly impassable during the rainy season from May to September. Average annual rainfall is 150-300mm and temperatures range from 4°C to 26°C depending on the hours of sunlight and the winds blowing from Lake Atitlan.

The population in 1976 was 4,872, with an annual growth rate of 2.4 percent. The crude birth rate is 33 per 1,000 women of child-bearing age, while the infant mortality rate is 116 per 1,000. Among the chief causes of death are gastro-intestinal diseases related to contamination of the water supply and poor environmental and personal hygiene.

Population density is high, with 603.6 persons per km^2. The majority of the houses are concentrated in a small area in the town center. They are made of mud and stone and are traditionally built with only two rooms—one for cooking and the other for sleeping. The crowded conditions permit little space for latrines, and the rocky soil further discourages excavation of pit privies.

Commercial crops produced locally are coffee, onions, and avocados. Most farms are small and do not allow farmers to earn even a subsistence living. Half of the productive male population is employed seasonally on large plantations near the Pacific Coast where coffee or cotton is picked for a wage of US$.90 - US$1.10 per day. The annual family income is approximately US$250.

Existing Water and Sanitation Practices and Technologies

The first improved water supply was introduced by the national government in 1952. A second source was tapped in 1970 as a result of local initiative. In the sample of the population interviewed, 35 percent reported having access to a private tap connection; the remainder use public taps and the lake. Even though laboratory tests have demonstrated high levels of contamination of the water sources by pathogenic organisms, most of the sample population interviewed believed water quality to be good if the water looks clean. Cleanliness of the water is not perceived to be a problem except when bathing and washing clothes in the lake.

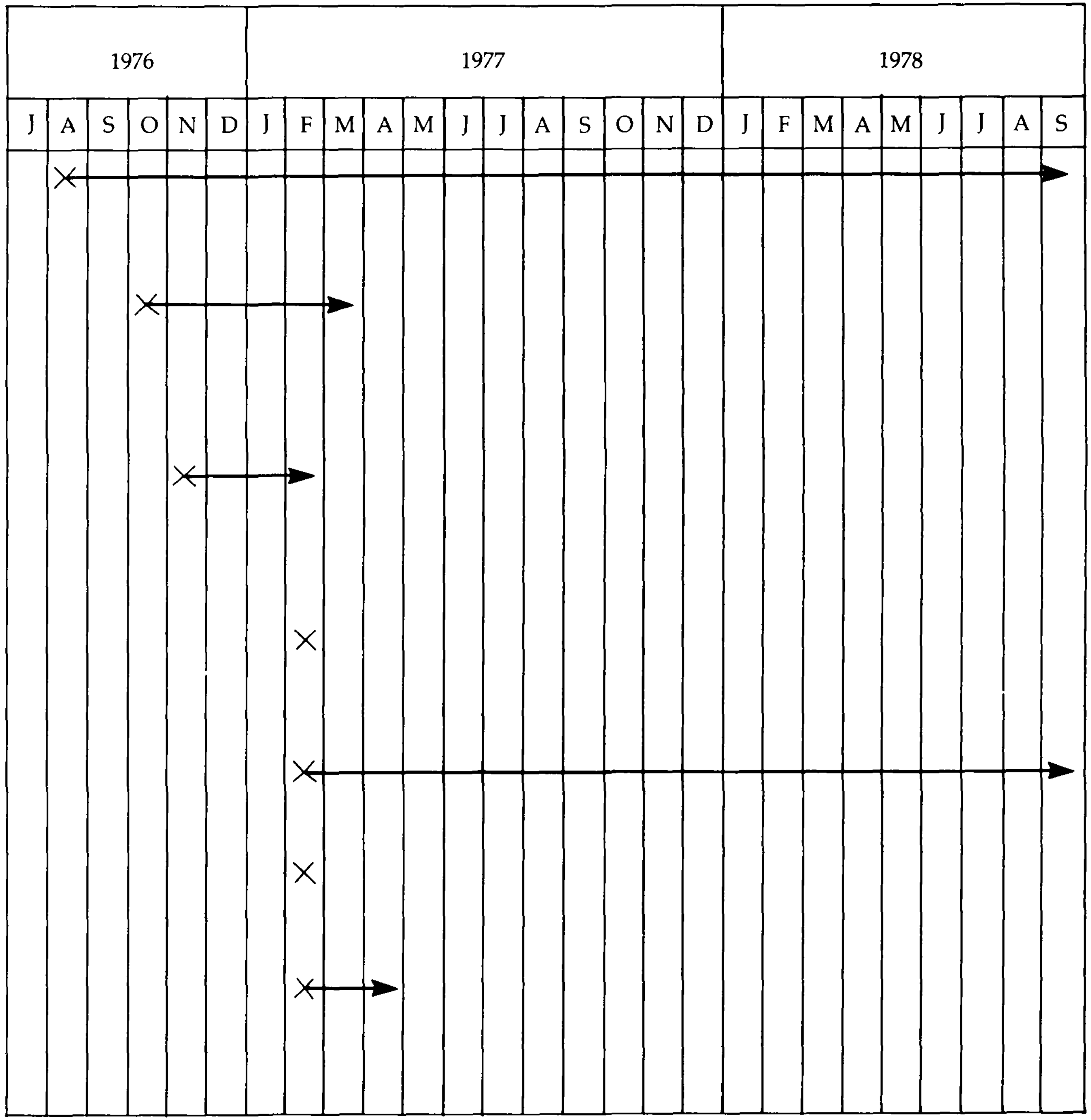
Families are currently paying US$.30 per month for their water, and most do not believe this is too much. Proximity and abundance are the most important perceived advantages of the present water sources. The time and effort expended carrying water is considered to be little and the majority of those interviewed reported no problems obtaining water from the piped system or the lake. However, over half of those interviewed are willing to spend a small amount of money and contribute labor to obtain a better quality or closer source of water.

An average of four to seven water carrying trips are made per day using jugs with an average capacity of 12 liters to carry from 37 to 72 liters of water per family. The water is stored in earthenware jars in the home and is drawn for use with bowls. While the socializing associated with the water carrying task is given a positive value, 37.5 percent of those interviewed reported problems related to sharing the public tap, which results in crowding, loss of time, and quarrels with neighbors. Also, the majority of the women (72.5 percent) prefer washing clothes alone even though the current practice is to wash clothes in the company of other women at the lake.

Currently, 11.2 percent of the population has access to latrines; the rest of the population continues to defecate on the ground in the fields or among the coffee plants. The first program promoting latrines was carried out between 1930 and 1944 when the national government made latrine installation compulsory. Little cooperation was obtained, however, and in 1958 a second promotion was attempted with the support of local leaders. The second program was more successful due to the use of demonstration models in the homes of community leaders. Between 50 and 60 latrines were built at a cost to beneficiaries of US$8-10 each. However, results were only achieved as long as both human and material resources were available and promoters were engaged in promoting latrine installation. Involvement of the promoters in literacy and cooperative extension projects led to eventual abandonment of the latrine installation program. Many of the pit latrines constructed at that time were not relocated due to space limitations and the difficulty of excavating the rocky soil. A third attempt to introduce pit latrines in 1974 provided materials but no promotion. It failed completely.

In the sample population interviewed, latrines were cited as a priority need as often as fertilizer and second only to money. Most would like individual latrines,

Figure 14. Chronology of Introduction of Compost Latrines into San Pedro



1. Advisory Assistance provided by the Behrhorst Clinic to the Health Committee of San Pedro.
2. Formation of a Work Team comprised of a Physician (in residence), a Receptionist, a Health and Nutrition Promotor, a Midwife, an Accountant, a Coordinator/Animator, and a Rural Health Technician.
3. Request by the Project Coordinator named by the committee to present the compost latrines proposed by CEMAT in a meeting for discussion and evaluation of excreta disposal alternatives for San Pedro.
4. Based upon an articulated demand of the community detected by a survey conducted by the Committee, different excreta disposal alternatives are presented and discussed before the Health Committee, the Project Work Team, and their respective advisors.
5. Information exchanged between CEMAT and the Behrhorst Clinic about project evaluation systems and appropriate technology.
6. Formation of an Integrated Development and Health Committee comprised of representatives of different groups in the town.
7. Decision of the Integrated Development and Health Committee and the Work Team to construct two compost latrine prototypes—one for collective use, and the other for family use. The collaboration of the town government and the school would be requested in order to determine the most adequate site.

8. A small digester using an oil drum is designed, constructed, and experimented with to permit the community to see that it is possible to produce combustible gas from agricultural and animal wastes.

9. The town government puts aside an appropriate piece of land for construction of the latrine to be used collectively. The site is situated in the center of town and two conventional pit latrines used by members of the town government are located on it.

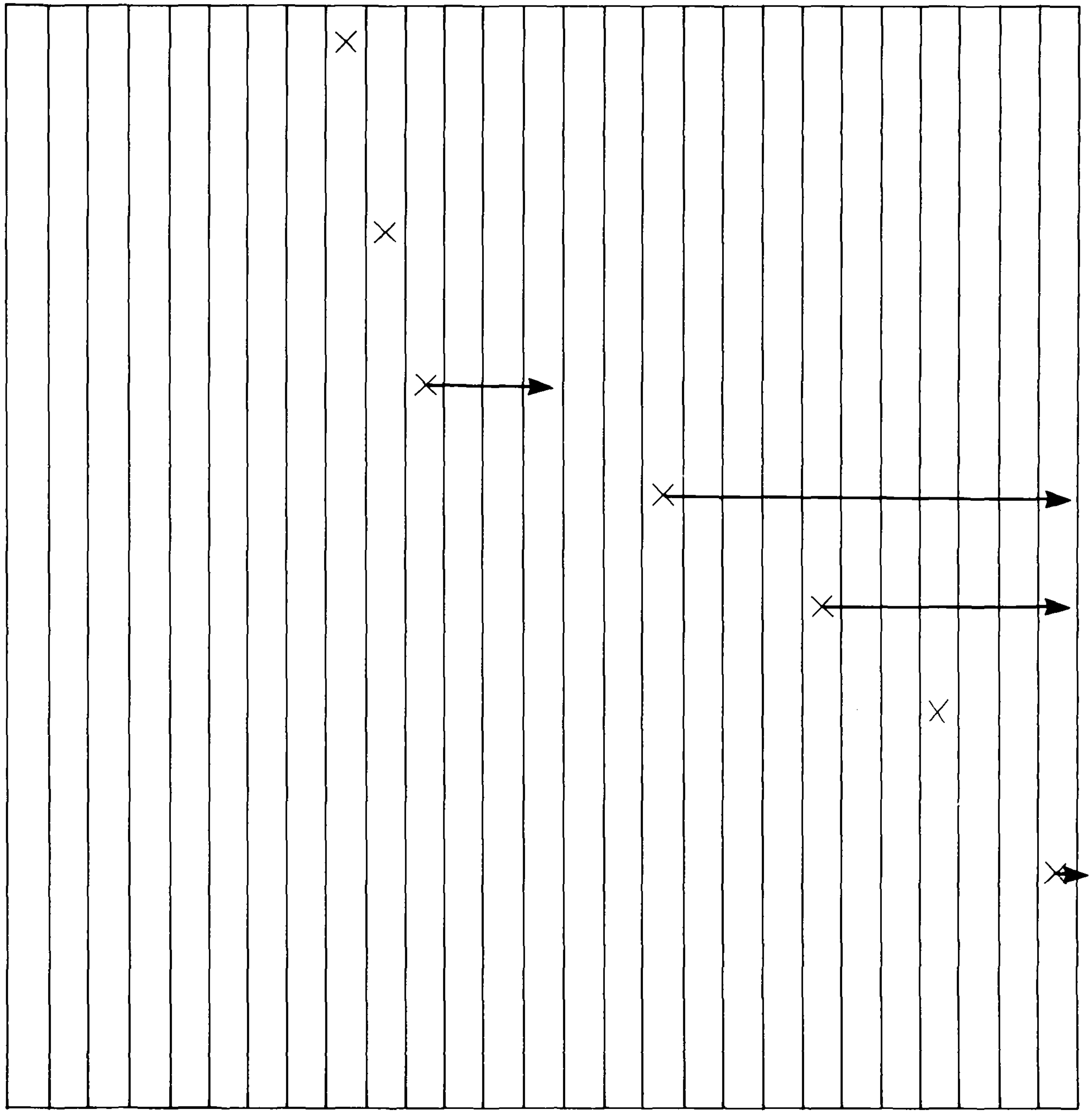
10. Two fertilizer producing latrines are constructed using local materials and labor.

11. The digester latrine for collective use is put into operation. An average of 30 persons per day use it.

12. Sanitation control is begun for the purpose of measuring the number of pathogens existing in the effluents of the digesting latrine.

13. A system for the production of compost activated by the effluents is designed and developed.

14. A campaign is prepared to provide information about the complete, collectively used compost latrine. Small pamphlets using simple drawings, radio programs, and meetings are used to disseminate information. This campaign is only developed when the products of the latrine have provided a minimum demonstration effect.



Source: Elmendorf and Buckles, "Sociocultural Aspects of Water Supply and Excreta Disposal."

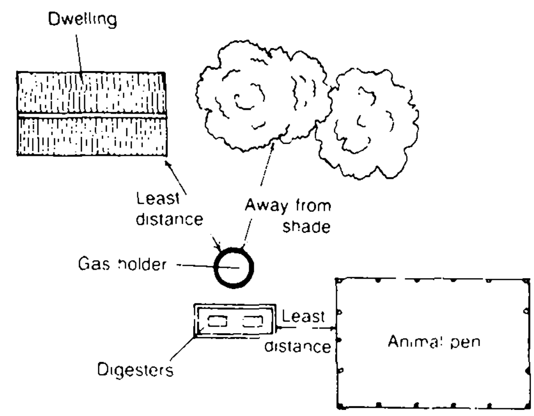
but 32.5 percent are willing to use a public or shared facility. Reasons cited by one third of the respondents for not having already solved the sanitation problems are lack of skills or initiative on the part of the community itself; another third of the respondents cited lack of cooperation among the people themselves; and some respondents cited a lack of space.

The Introduction of an Innovative Sanitation Technology

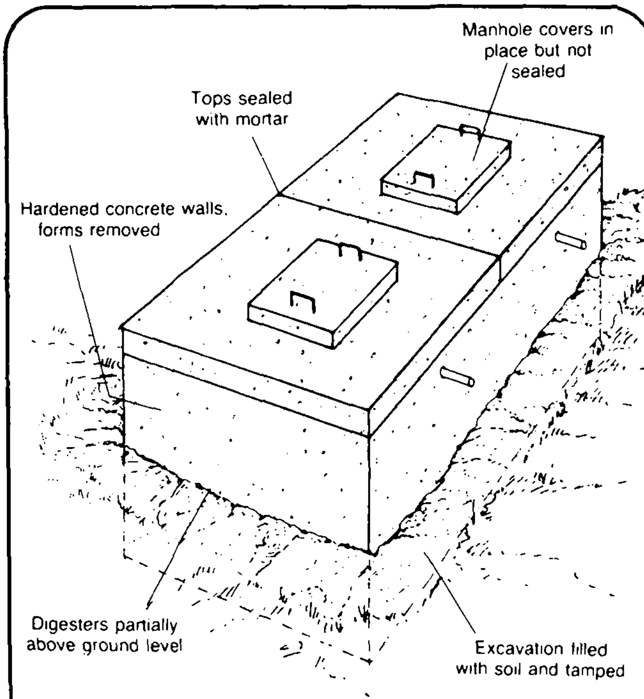
CEMAT's work in biogas latrines began with an inquiry into the basic needs of the rural and marginal urban populations in areas affected by the February 1976 earthquake in Guatemala. As reconstruction programs were developed, the need for constructing low cost kitchen and sanitation facilities in addition to minimum shelters was recognized. In an analysis of failures in latrine construction programs, CEMAT found that conventional privies are unproductive, they conflict with implicit fertilizer reuse practices of defecating in the fields, they contaminate the surrounding areas in some sites, and they cost considerable time and energy with no visible rewards. After investigation of available materials and needs, it was determined that the objective should be to develop a technology which would save energy while producing agriculturally useful by-products.

Since composting is becoming increasingly common in Guatemala and academic institutions are experimenting with anaerobic and aerobic processes, CEMAT determined that development of a fertilizer-producing privy would be the most useful facility for excreta disposal in rural areas. A study of different models though discussion with CETA (Centro de Experimentacion en Tecnologia Apropiada) and with the Low Cost Housing Group of McGill University suggested a prototype eventually used with modifications in San Pedro. A prototype anaerobic biogas latrine was built in the town park of San Pedro under the auspices of the community leaders. Figure 14 lists the chronological order of events as the project developed. Materials cost US$600, skilled labor cost US$300, and construction was completed in approximately four months. Two young boys maintain the facility, and 30 persons per day use it at a cost of US$.03 per person.

A major technical disappointment was the small amount of biogas produced, due either to a crack in the structure or the relatively low ambient temperature of the site. This had some effect on the population and on the San Pedro community's committee, who did not believe it possible that biogas could be produced from agricultural waste and human and animal excreta. For instructive and experimental purposes, a small digester was built of barrels and filled with animal dung and agricultural waste. It produced biogas after a month and played a useful part in convincing the inhabitants of San Pedro of the potential energy source available to them. The construction of this experimental prototype was considered crucial for its demonstration effect.



Location Map of Biogas System



Design of Digesters for Biogas System

Conclusions

It is too early to say whether the CEMAT program is effective or not. It can be noted, however, that the request for technical assistance came from the people of San Pedro. In responding, CEMAT made a conscious effort to involve the people through their leaders in designing and implementing the program. Demonstrations and learning by doing were the key techniques, as local masons and carpenters built the prototypes with indigenous materials. Failures such as the leaky tank were seen as part of the learning process. An important consideration when evaluating the community participation strategy used is the fact that people had to see the innovation in operation before they would believe that it was capable of producing fertilizer or biogas.

Ekali I, Cameroon

This case illustrates the principle that in community development one frequently reaps results where another has sown. Ekali I had been the site of intensive work by Canadian missionaries for nearly four years. This work, aimed at resolving the long-standing estrangement of the older and younger generations that had led to a sizeable out-migration of youth, had contributed to unity of purpose, a wide degree of participation across age and sex categories, and a vigorous cadre of leaders.

Counting a number of dependent hamlets, Ekali I numbers about 1500 inhabitants, the central hamlet having just over 400. This village gave a very positive response to the educational and community organization efforts of a community development project. Not only did the health committee organize easily, but soon took the initiative for planning successive local projects: three springboxes in the central hamlet, one each in two of the peripheral hamlets, over sixty households with well-constructed, well-used latrines, and a functioning village pharmacy for simple drugs and supplies.

By 1978, two years after the end of the project, the committee was planning the construction of a water tower with a pump and gravity distribution to a central standpipe. Additional springboxes in peripheral hamlets were also in the plans. Clearly, the health committee had taken on a life of its own and was functioning as a community planning mechanism.

SOURCES
CHAPTER SEVEN

Sources used for this chapter include three volumes of *Appropriate Technologies for Water Supply and Sanitation*, Washington: World Bank, 1980: "Volume 2. A Planner's Guide" by John M. Kalbermatten, DeAnne S. Julius, Charles G. Gunnerson, and D. Duncan Mara, "Volume 5. Sociocultural Aspects of Water Supply and Excreta Disposal," by Mary Elmendorf and Patricia Buckles, and "Volume 8. Seven Case Studies of Rural and Urban Fringe Areas in Latin America," Mary Elmendorf, Editor. Also helpful were two articles by Anne Whyte: "Guidelines for Field Studies in Environmental Perception," MAB Technical Notes, UNESCO, Paris, France, 1977, and "Extension and Community Participation in Water and Sanitation in Developing Countries," Institute for Environmental Studies, September 1979. Other sources include Gilbert F. White and Anne U. White, "Behavioral Factors in Selection of Technologies: Appropriate Technology in Water Supply and Waste Disposal," American Society of Civil Engineers National Convention, Chicago, Illinois, October 1978; "UNICEF/WHO Joint Study on Water Supply and Sanitation Components of Primary Health," UNICEF/WHO Joint Committee on Health Policy, January 1979; and Margarita Cardenas, "Community Participation and Sanitation Education in Water Supply and Sanitation Programmes in Rural Areas of Paraguay," UNICEF/WHO Joint Committee on Health Policy, June 1978.

RELATED TECHNICAL NOTES
CHAPTER SEVEN

HR.2.M.	Methods of Initiating Community Participation in Water Supply and Sanitation Programs
HR.2.P	Community Participation in Planning Water Supply and Sanitation Programs
HR.2.I	Community Participation in Implementing Water Supply and Sanitation Programs

CHAPTER EIGHT
DEVELOPING HUMAN RESOURCES

SUMMARY

Of all the resources needed to implement water supply and sanitation programs, human resources (people) are probably the most important. Without the proper mix of human resources, the program will fail. Human resource development is a critical part of any water supply and sanitation program and requires assessing human resource needs, designing a training program and implementing a training program.

The type of human resources needed will vary from country to country and program to program. A detailed listing of the people needed and the training required to produce them must be developed. Decisions must be made about the specific tasks which trainees must perform and a training program designed so that they are able to carry out these tasks on the job at the conclusion of training.

There are several options for types of training methods to be used. The selection of a training method depends on the education and experience of the trainers, the capabilities of the trainees, the tasks for which they must be trained, and the resources that are available to devote to training. A method that depends on task analysis as the basic training approach is the most likely to be successful. Training should be carefully designed to transfer the precise information and skills that the trainees need in the most effective possible manner. This means that trainers must be carefully selected and may themselves need training before the training program is undertaken. Training programs require effective training leadership and supervision.

Human resources are essential to water supply and sanitation development projects.

CHAPTER EIGHT
DEVELOPING HUMAN RESOURCES

Human resource development in water supply and sanitation is the process of determining how best to produce, assign, and use people in the right numbers, right places, and with the right knowledge and skills to fulfill required functions. The Interagency Task Force on Human Resources Development for the International Drinking Water Supply and Sanitation Decade recently adopted broad definitions of human resources and human resource development as follows:

> The term "human resources" is intended to include youth as well as adults, women as well as men, providers of services as well as consumers, paid employees as well as volunteers. It includes decision makers and managers, planners, technicians, scientists, researchers, clerical and accounting staff, skilled and unskilled labourers. It includes not only those who help to create facilities, but those who operate and maintain them and those who support, monitor and control the quality of the services. It includes a variety of types of educators and trainers. It includes people working in other programmes which support the water supply and sanitation sector.
>
> The term "human resources development" (HRD) means more than the education and training of people. It includes their employment, supervision, continuing education and training, and occupational welfare. The Decade HRD process should embrace planning, skill development and training, and human resource management, with all three harmoniously geared to the achievement of specified goals.

When one considers all the types of resources needed to carry out a water supply and sanitation program—funds, equipment, supplies and people for management, planning, design, construction, operation, maintenance, and consumption—it is obvious that no matter how much money, equipment and materials there are, nothing will succeed without the proper mix of human resources. Even though human resources are critically important, all too frequently little attention is paid to them in water supply and sanitation programs. Unlike other resources, human beings cannot be stored and pulled from a warehouse on demand. People must be trained and motivated to implement programs at the proper time and place. Human resource development must be an integral part of water supply and sanitation program planning and operations. This will help ensure that an adequate quantity and quality of people will be available to support and implement water supply and sanitation programs and projects.

Human resource development includes supervision on the job as well as training.

The major goals of overall water supply and sanitation human resource development are to:

1. **Promote the development of educational and training delivery systems to provide the proper mix of people needed for planning, design, construction, operation and maintenance.** This means maximizing the use of existing in-country educational and training institutions, supplementing them with other efforts as described below.

2. **Make human resource planning a basic component of every water supply and sanitation program and project.** This means that human resource planning begins at the same time as planning for financing and selection of alternative approaches and designs as described in Chapter 6. Institutional development will only be as effective as human resource development is.

3. **Tap the resources of similar training activities at the international, national, regional and local levels** in order to produce an effort that is as cost effective as possible and is coordinated with other human resource development work.

4. **Develop training that is practical and effective based on the performance of the trainee on the job.** Competency training will serve two major groups of people: new hires coming into the organization and existing personnel needing in-service training. It will include all personnel in the system such as managers, supervisors, skilled and unskilled workers.

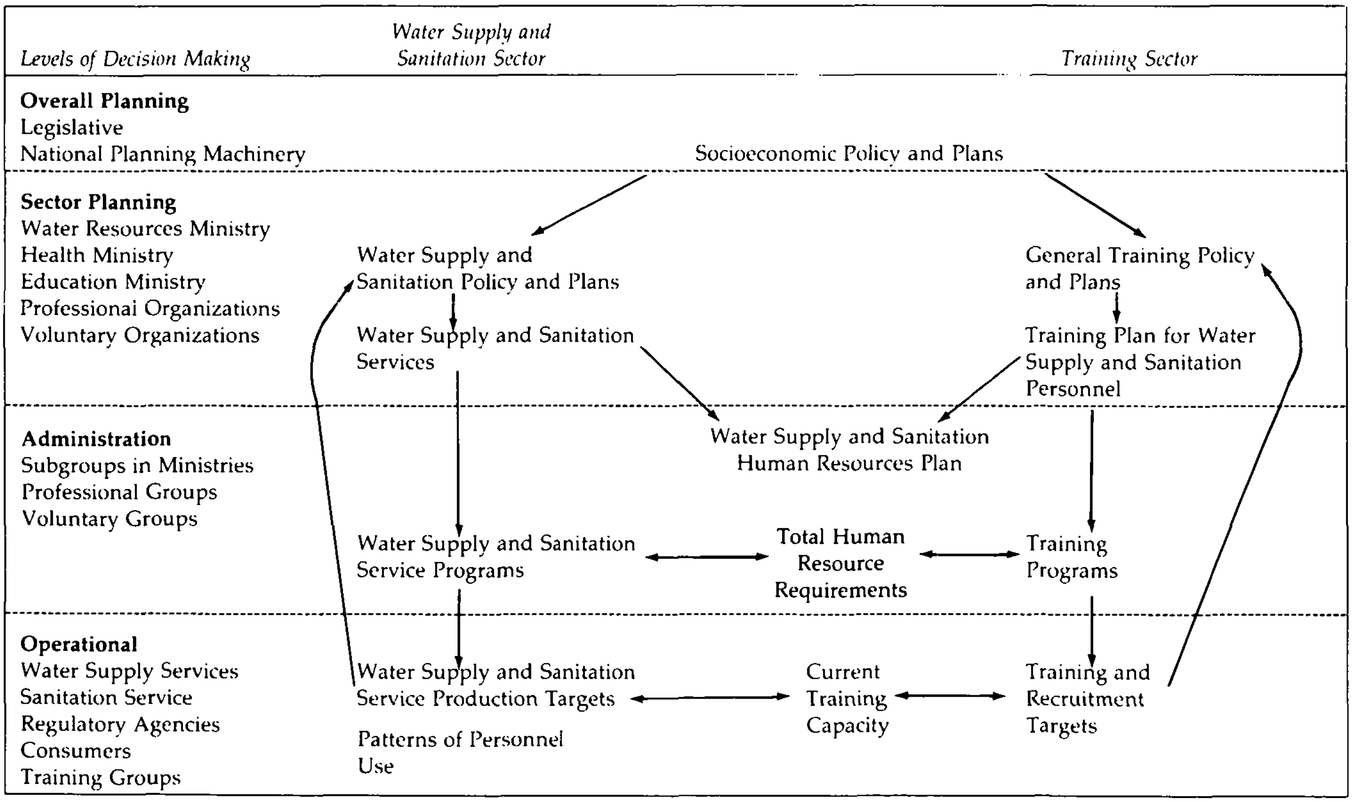
The human resources system is a sub-system of water supply and sanitation development. It is comprised of the institutions and organizations involved in planning for, recruiting, training and managing the people needed in water supply and sanitation programs. It converts policies and resources into personnel capable of planning, designing, constructing, operating, maintaining and managing water supply and sanitation projects.

For this subsystem to function, there must be a constant flow of information, resources and decisions between governmental entities, educational and training organizations, service and professional organizations, voluntary groups and the users of these human resources. The flow between these groups is the lifeblood of the water supply and sanitation human resource development process. Figure 15 diagrams these flows between the water supply and sanitation sector and the training sector at four levels of decision-making. Table 20 indicates the scope of the human resource development process with respect to planning, training and use.

Conceptualization, design, construction, operation and maintenance of water supply and sanitation facilities vary considerably from country to country, from ministry to ministry, and from organization to organization within a country depending on whether a national, regional, district, town, village or individual household effort is planned. It is not possible to devise a single human resource development system to provide personnel specific to the needs of all these cases. However, the same general approach to human resource development can be useful regardless of the specific circumstances under which a program is being carried out.

The process of human resource development can be divided into three stages: assessing human resource needs, designing training programs, and implementing training programs. Each of these stages will be discussed in turn.

Figure 15. Water Supply and Sanitation Human Resource Development Process



Source: Adapted from T.L. Hall and A. Mejia, *Health Manpower Planning*, World Health Organization, Geneva, 1978.

Table 20. Scope of The Water Supply and Sanitation Human Resource Development Process

Overall aim to ensure that the human resources needed for water supply and sanitation programs are available through:

	Planning	*Production (Training)*	*Management (Use)*
Goal	To provide the framework within which the water supply and sanitation human resource development process takes place.	To provide the human resources needed.	To make the best use of water supply and sanitation human resources.
Objective	To specify the number of installations and/or teams and their composition needed to improve the level of water water supply and sanitation up to a proposed level.	To produce X people of Y types.	To determine human resource distribution and productivity standards, patterns of use and non-labor inputs.
Strategy	Regional, district and local water planning programming. Supply and sanitation human resource project formulation.	Educational/training planning and programming, performance objectives and training delivery systems definition.	Reorganization: — regionalization, — integration of operation and maintenance of systems, — rural water supply and sanitation programming, — human resource project management.
Activities	Planning and programming Coordination Monitoring and evaluation Research and development	Recruitment, new entry definition, development and operation of training delivery systems, evaluation of process and products.	Establishment and implementation of: — supervision system, — continuing training, — recruitment and selection procedures, — career development schemes, — assignment of personnel, — development of staffing patterns.
Targets	X teams or services or facilities of Y composition in operation by time T.	X trained personnel of Y type by time T.	X units of service of specified quality delivered to a particular population.

Source: Adapted from T.L. Hall, and A. Mejia, *Health Manpower Planning*, World Health Organization, Geneva, 1978.

Assessing Human Resource Needs

The reason for doing a human resource needs assessment for a water supply and sanitation program at every level—national to village—is to clearly determine the minimum basic tasks that must be performed to ensure the success of the program and to see that the right number of people with the necessary knowledge, skill and motivation can be provided. The principal elements of such an assessment are (1) a clear and specific description of the proposed or existing program defining its scope, strategies, activities and targets; (2) a listing of the specific projects that compose the program by sequential timeframe stages; (3) a list of all the tasks and functions that must be performed broken down by position in order to define the number and type of people that the projects will require during each of their stages; (4) a set of job descriptions to set down the knowledge, skills and motivations that each of those people must have in order to perform effectively; (5) an analysis of where in the labor force of the country and each community affected by the program either already trained skilled people can be found or where suitable candidates for training can be recruited; (6) an educational and training plan for the country, or each operational unit of the program, that will most cost-effectively provide the needed training on a continuing basis.

In recent years much attention has been given to assessing human resource needs as the foundation stage in effective human resource development for the health sector. Many developing countries have already begun to do this kind of work. A systematic approach should be used. Health sector approaches are usually applicable in water supply and sanitation, and any of these can be consulted. Other approaches have been designed specifically for water supply and sanitation. If none of these are available, labor ministries usually have a methodology that can be adapted to fit water supply and sanitation. A partial list of sources useful for human resource needs assessments can be found on the "Sources" page at the end of this chapter.

Whatever resources may be available for a formal needs assessment and whatever the process of getting it done, it will be useful to keep the following in mind.

The type of human resources needed for water supply and sanitation programs and projects will vary from national down to village levels. Job titles will include personnel in categories such as administration or management, professional, sub-professional, craftsman and laborer who will be assigned a host of technical and non-technical tasks. Persons with the same job title in different organizations or at different levels of the same organization have quite different job descriptions.

Organizational responsibility for rural water supplies and sanitation varies from country to country. In nations with strong governments and well-developed infrastructure, people at the national, provincial, district, city, town, village, and family levels implement different aspects of a water supply and sanitation program. In other countries, it may be left to each province or district to run its own rural water supply and sanitation program and to assist persons at the village and family levels. In some parts of the world, it may be the village leaders' responsibility to develop a village water supply and see to its operation and upkeep. In areas with widely dispersed family units, the head of the family or a group of families usually provides for water and sanitation. Applying new technology to rural water supply or sanitation will require that all persons involved with installation, operation and maintenance acquire the knowledge and skills to keep the system operational. This audience may range from well-trained personnel in a program controlled by a national government to persons with no knowledge or skill in water supply and sanitation.

The size, complexity, and level of sophistication of water supply and sanitation systems in a country will vary widely. The relevant people will have to be educated and trained to quite different levels of knowledge and skill to match the task requirements of the systems. Examination of Table 21 illustrates this point. Here are listed most of the professional or social categories of the people who are the human resources of a nation's water supply and sanitation systems. Categories 1 through 11, for the most part, function at the national and provincial levels with some located in cities and a few reaching to the town level. All of them are medium to high level professionals. They must be both generally and technically well educated people. Some might be adequately educated at secondary schools but most would need college or technical school educations as the foundation on which to perform the tasks which would be in their job descriptions.

Categories 12 through 22 for the most part function at the city level and below, with only a few at national and provincial locations and most at the town and village level. Two categories reach all the way to the family level. The categories from 23 to 30 function at the village and family levels with only two at the town level. The people in categories 23 to 30 would have to be residents of the community in which they play a

Everyone involved, including community members, may need training in using a new water system.

role in providing safe water and waste disposal. Many of them, while "experts" on their communities and the ultimate determiners of success or failure of environmental health activities, would typically be illiterate or have limited primary school or secondary school educations. Everyone in categories 1 to 32, if they had not already received it, would need to have training in addition to whatever education they may have had. For example, engineers in a national water authority need training if they are assigned to rural programs and need the knowledge and skill to train village bicycle repairers on the maintenance of hand pumps. Likewise, if heads of extended families need knowledge or skills relating to their water supplies, then they should become trainees. An assessment of human resources should consider the organizational levels involved and the categories of persons in each level.

In addition to the types of talent needed, the human resources assessment must take into account possible existing sources for the workforce needed. Traditional sources, such as universities, colleges, technical and trade schools and related organizations, should be inventoried. These sources can be expected to provide predetermined numbers of trained people at set times. Establishment of water supply and sanitation programs may not conform to the time at which this workforce will be available. If not, alternative plans must be developed.

One problem that is widespread in developing countries is that, even though the human resource development system may provide sufficient numbers of personnel, the salary structure in government, whether national or local, frequently does not entice adequate numbers of qualified people to accept positions. This is especially true of high level technical positions. Often this means that in-house training and advancement of existing employees are required.

Table 21. Categories of Human Resources Required by Water Supply and Sanitation Programs and the Organization Level at which They May Be Needed

No.	*Category of Person*	*Organizational Level*					
		National	*Provincial*	*City*	*Town*	*Village*	*Family*
1	Administrator	√	√				
2	Engineer	√	√	√			
3	Sanitarian	√	√	√	√	√	
4	Chemist	√	√	√			
5	Bacteriologist	√	√	√			
6	Sample collector	√	√	√			
7	Inspector	√	√	√	√		
8	Public health nurse	√	√	√	√		
9	Supplies officer	√	√	√			
10	Customs official	√					
11	Importation officer	√					
12	Manager			√	√	√	
13	Training officer	√	√	√			
14	Trainer			√	√	√	
15	Contractor		√	√	√	√	
16	Well driller	√	√	√			
17	Well digger				√	√	√
18	Construction laborer	√	√	√	√	√	√
19	Mechanic		√	√	√	√	
20	Mason		√	√	√	√	
21	Plumber		√	√	√	√	
22.	Church official	√	√	√	√		
23	Village chief					√	
24	Village religious leader					√	
25	School teacher				√	√	
26	Health aide				√	√	
27	Landowner					√	
28	Clan head					√	√
29	Family head					√	√
30	Chief of tribe					√	√
31	Medicine man					√	√
32	Community residents					√	√

In any sizeable water supply and sanitation program the assessment of human resources needs should be an ongoing process because many factors that determine the need for people with specific knowledge and skills are constantly changing. At the same time, the sources of people and their educational and experience levels are also changing. Finally, the ways in which people are assigned, used and supervised also need to be watched and adapted to new conditions and new operating experience. It is in these ways that human resource development proceeds and operating programs retain their vitality and improve their ability to meet the needs of the people who are dependent on their service.

Designing Training Programs

A human resources assessment, as discussed above, will indicate the types and numbers of skilled people that will be needed to do all the tasks which are required to plan, build, operate and maintain water supply and sanitation systems. The development and replenishment of this extensive array of qualified people requires both education and training. It has already been noted that there are a number of professional categories (Table 21, Categories 1 to 11) that must be based on extensive college or technical school education. Education in this context is pre-employment education provided in regular sessions of academic type institutions where subjects are taught with broad coverage of history, theory, and the generalizations that are required to deal with any aspect of the material. The method of instruction is usually by lecture and laboratory using textbooks and other instructional materials with the student's achievement measured by grades which normally distribute in a bell-shaped curve ranging from F to A. The application of this education to the performance of the tasks required of employees working in water supply and sanitation systems usually requires additional training.

However, most of the people that are the human resources on which safe water and waste disposal systems depend, particularly those in small towns and rural areas, come from local groups that have very much less or even no formal education (Table 21, Categories 12 to 32). All of these people, if they are to perform effectively, must receive training after they are employed.

The state of development of both education and training relevant to the requirements of water supply and sanitation programs and projects varies widely from country to country in the Third World. Over the past two decades, much progess has been made in developing the needed educational capacity in colleges and engineering schools to deal with the problems of environmental sanitation. This development has frequently been related to the introduction of large modern water and sewage systems that serve at least some of the main cities—although incompletely—in most countries. This educational infrastructure growth is important and should be supported and maintained. However, the focus of this program guide is on small town and rural water supply and sanitation systems. Attention will therefore be directed toward the design of employment-related training systems whose purpose is to directly meet the need for task-related knowledge and skills. Attention will also be given to how such training may be linked to an interact with more formally organized educational processes.

The Need for Training

A series of simple questions should be the focus of planning employment-related training in human resources development: What needs to be done? Who is to do it? When do they need to do it? Where must it be done? What are the consequences if it is not done? Although there are many more logistics questions to settle in implementing such training, satisfactory answers to these questions will assist in defining fundamental training needs.

If these questions are addressed at each step in the process, operating systems should not fail as a result of unqualified or insufficient personnel, and operation and maintenance problems should be attended to more effectively.

Once construction is finished, local people are usually responsible for operating small town and rural systems. These people must be involved in the planning and design phases and share in decision-making on how the system will be operated, maintained, and managed. As the examples in Table 22 indicate, many people affect the community workers' ability to provide safe water in sufficient quantity. Often local people hire, pay, train, or authorize these workers, and they too should be involved in decisions affecting personnel needs, assignment, training and utilization.

Once a rural water supply or excreta disposal system is completed, it often does not take long for one or more of the following problems to occur:

1. Workers fail to use new equipment correctly.
2. Workers perform below the desired performance level.
3. Workers lack the basic performance capablity required to operate and maintain the system.

Construction is only one area in which training is needed.

Table 22. Examples of Planning and Design Decisions Negatively Affecting Operation and Maintenance

Planning or Design Decision	*Along With*	*Resulted In*
Ministry A constructs wells, installs hand pumps, and stores spare parts.	Ministry B maintains hand pumps but has no authorization to requisition spare parts and no training provided for workers.	Hand pumps are not maintained; villagers push off slab and use buckets.
Treatment process requires hypochlorite which has to be shipped in from another country.	No plan to reorder hypochlorite according to shipping schedules; personnel not trained in estimating future needs.	Hypochlorite runs out and water is not adequately treated.
Pumping stations are located far from operator; all stations manually restart.	Frequent power outages; operator has only limited transportation to reach pumping station to restart pumps; personnel not trained to anticipate transportation needs.	Long periods with no pumping until operator gets to pumping station; occasionally no water and/or negative pressures in distribution system.
Small catchment basins with dams and hypochlorite feeders are located far from users.	Local person hired to clean intake and operate hypochlorite feeder is inadequately paid and does not monitor system.	Frequent periods of no chlorination and one typhoid outbreak.
Process units and equipment of latest technology are obtained from sources in many countries.	Trade agreements vary with each government; lack of foreign currency; varying import restrictions.	Inability to get spare parts or replacement equipment to keep plant running.

4. Workers take too long to do their work.
5. Workers' turnover rate is high.
6. Next higher level in the system is unresponsive to problems at a lower level (no or little supportive supervision).

Problems like this may be avoided if training is incorporated in the program plan. Training should include testing of workers to demonstrate they are capable of carrying out assigned tasks at an acceptable standard of performance within the appropriate time.

All too often, training is just a reaction to a failure in a part of the system. Something or someone fails, so a short lived training effort is instituted to prevent the problem from repeating. This is not a good way to approach training. It must be a systematic process systematically carried out. The training planner should recognize the following possible causes for large or small system failures:

1. Lack of skill or knowledge—the worker does not know how, when, or how well to perform.
2. Management barriers—the worker is prevented from performing by management problems such as lack of spare parts or supplies, no available transportation, or inappropriate management policy.
3. Lack of motivation and incentive—the worker does not want to perform, is not rewarded for performing.

System operation training can help workers with knowledge or skill deficiencies. To deal with management barriers or lack of motivation and incentives, different training units would have to be designed for program or project managers.

Training should increase the skill and knowledge of the workers.

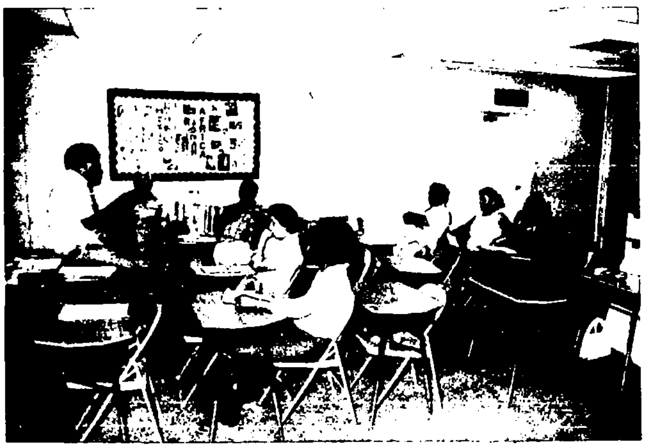
Gathering Information

Before a specific training program can be designed, much information must be collected and decisions relating to the data be made. A detailed exposition of the program or project in which the trainees are to perform must be the starting point. Job titles and descriptions for the project are fundamental since training must be developed so that all trainees can surely perform the tasks outlined in their job descriptions to the level of performance required by the job, not just in the training situation. If job descriptions do not exist, their production should be the first order of business. The location of the trainers or training center is important in planning a program for people in a given geographic area. Information on worker turnover rates may point to problems in management policy and to the needed frequency of training. Information about a new technology or about an existing one being expanded should affect the quantity and quality of the proposed training. Information on the type of trainees (newly hired people or existing employees being upgraded, for example), and their knowledge and skill levels is necessary to define the scope, depth of detail and amount of practice that should be incorporated in the training program. Information on performance deficiencies of other people with similar jobs is useful in designing the training sequence.

Usually, the most cost effective way to design a training system is to make additions or to change an existing system. Most people are willing to accept new ideas and methods that are not too different from those they are already using. When new training units or systems are contemplated, as much use as appropriate should be made of existing educational programs and training systems. This not only reduces costs but enlists a larger number of persons and resources in the training effort. Table 23 suggests possible sources of information on training from within a country which should be investigated.

Many organizations around the world have developed training materials for water supply and sanitation. In many cases, these materials can be translated into other languages, or can serve as a model to develop new materials. Anyone developing a training program should review as many existing materials as possible before developing new ones. Table 24 shows sources of information about such materials. These organizations have a large number of abstracts of training materials and they all are able to provide information about a specific subject.

Table 25 lists publications on several rural water supply and sanitation training programs. Information of this sort can be very useful in planning a new training effort.



Existing educational programs should be used as much as possible in water and sanitation training.

Table 23. Sources of Information on Training Assistance Delivery System Capability Within a Country

Organization to Contact	*Type of Programs*
Ministry (Department) of Education	Vocational Training Centers Vocational Education Program Rural Training Center Radio or TV Training Programs
Ministry (Department) of Health Public Works Environment Natural Resources Rural Development Housing Women's Affairs	Specialized training for rural water supply and sanitation workers
Professional organizations in rural water supply and sanitation field; private volunteer organizations	Specialized training for rural water supply and sanitation workers
International Labor Organization	Specialized training for skills development Specialized programs in management
World Health Organization	Specialized training for rural water supply and sanitation workers

Table 24. Sources of Information About Training Materials

Information Available on	*Available from*
Training materials available in English, French, and Spanish for the water supply field	WHO International Reference Centre for Community Water Supply P.O. Box 140 2260 AC Leidschendam Netherlands
Groundwater training materials	National Water Well Association 500 W. Wilson Bridge Road Worthington, Ohio 43085 U.S.A.
Water supply training materials	American Water Works Association 6666 W. Quincy Avenue Denver, Colorado 80235 U.S.A.
Water quality control training materials	Water Quality Instructional Resources Information System (IRIS) SMEAC Information Reference Center 1200 Chambers Road Columbus, Ohio 43212 U.S.A.
Water supply and sanitation training materials	Secretariat Interagency Task Force on HRD International Drinking Water Supply and Sanitation Decade EHTS/WHO 1211 Geneva 27 Switzerland
General training materials	British Association for Commercial and Industrial Education 16 Park Crescent London, W1N 4AP England
Water supply and sanitation technical notes (see full listing in Appendix B)	Development Information Center Agency for International Development Washington, D.C. 20523 U.S.A.

Table 25. Existing Training Programs and Publications

Organization	*Items Available*
ILO 1211 Geneva 22 Switerzland	— CENTAFOR materials for skills training (task analyses and and training materials) — Modules for employable skills (task analyses and training materials)
EHTS/WHO 1211 Geneva 27 Switzerland	— Modules for training rural water supply workers on how to make task analyses — Training materials (job aids) for rural water supply workers

Possible Training Strategies

There are many strategies by which a training system for water supply and sanitation programs might be put together. Each will most likely differ because of the differences in the situation, as well as the different backgrounds and inclinations of the persons or teams that choose the strategy and plan the training. Among the processes which should be used in formulating a training strategy are:

1. *Evaluate conditions which determine the need for training*, such as: performance problems; introduction of new technology; addition of new personnel; upgrading existing personnel.

2. *Diagnose training needs* by answering such questions as: In what subjects can training improve performance? To what extent can training improve performance? Is it the best way to do so? What should be the aims of training? At what knowledge level should training start? What subject content should training include?

3. *Develop a design for training* based on such questions as: Who needs training? How many people need training? What is their present performance level? What is the desired end of training performance level? Where should the training be carried out? When should the training be carried out? Who should do the training?

4. *Consider the problems of implementing training* including: selecting the training coordinator; selecting and training the instructors; selecting the training facilities; securing training equipment, supplies, aids, instructional and reference materials; orienting and convincing government officials, village officials, family leaders, and others of the need and benefits of the training program (they must understand their place in the training and their obligation to incorporate the trainees into the operation and maintenance of water and sanitation systems); allocating funds, materials, time, and workers to maintain the training program; designating management's responsibility to handle problems encountered in the training program.

5. *Be aware of possible training delivery systems.* There are many training delivery systems that meet the requirements which emerge from looking at questions like those listed above. Table 26 displays key information on the nature and application of the most frequently used systems. They range from traditional, largely classroom, instruction delivered through short-term courses provided at universities or trades training centers, through correspondence courses which may be modeled for content and method on the short courses or use self-paced materials, to systems based on self-paced training materials and on-the-job training. A more detailed discussion of the types of instructional methods that are associated with several of these systems will be useful to allow the training system developer to broaden his or her options in training system design.

Table 26. Possible Training Delivery Systems

Delivery System	*Trainer Needed*	*Materials Needed*	*Application*			
			National	*Provincial*	*Village*	*Family*
Short-term courses at a univeristy	Yes	Books, manuals, audio-visual training aids	√	√		
Short-term courses at a trades training center, national provincial, district	Yes	Manuals, job aids, audio-visual training aids, equipment	√	√	√	
Correspondence course	No	Corresponding instructor work-books, job aids	√	√	√*	√*
Self-paced training materials	No	Self-paced materials, managers or instructors who know how to use such materials	√	√	√*	√*
On-the-job training	Yes No	Job aids Job aids			√ √	√ √

*For limited number of better educated strongly motivated individuals.

Three methods will be described here: self-paced, trainer-assisted self-paced, and on-the-job.

1. **Self-Paced.**

Self-paced materials are developed and field-tested so that workers at a specific level of competence can use the materials individually. After working their way through the materials, most workers will have accomplished the objectives of the training program. Several media types can be used, such as print materials, slides, audio tapes, slide/tapes, video tapes, overhead transparencies, or motion pictures. The choice of media depends on the media equipment capabilities of the delivery system. The choice of the method and the specific materials depends on the level of literacy and education of the trainees. Most types of media will not be suitable because of local equipment limitations. Material can be as simple as a series of printed pictures and an audio tape with instructions for persons who cannot read or as complicated as a complete audio/visual system. The more remote the trainees are from population centers, the more limited the choice of communication methods. When the written word alone is used for self-paced instruction, the material must be self-contained and self-explanatory.

Trainees often have some of the knowledge and skills required but are also missing some. To avoid repeating material already in the trainees' repertoire, diagnostic tests are included to determine the level of competence trainees have and indicate which modules can be skipped or must be worked through. A diagnostic test is often accompanied by a test "prescription" which relates a module and its learning objective to each test item. If trainees do not meet an objective, they can go back and restudy the material pertaining to the knowledge or skill deficiency.

Self-paced modules can be adapted for use under a variety of conditions. A training program based on self-paced materials saves time and provides flexibility to both trainees and supervisors. Training materials in the self-paced format permit adaptation to many ways of training delivery. The degree of sophistication can be changed to suit various levels of workers.

The creation of self-paced materials and systems is far from simple or cheap. This fine method of instruction is usable in most situations only if completely developed and tested materials covering exactly the learning unit required for the specific system have already been developed at someone else's cost, and can be acquired in the needed quantity at a price the training budget will allow.

2. **Trainer-Assisted Self-Paced.**

This type of self-paced learning uses trainers who are the focus of information transfer. They control the time, place, content, and methods used in training. Many decisions are based on the trainer rather than the trainees. The selection of trainers is very important because this type of training can become rigid and inhibit the use of other effective learning techniques.

In trainer-assisted self-paced learning, the trainer serves as manager of the process. The training materials are the same as those used in a self-paced program. The trainee in a self-paced program works alone and must repeat units or seek outside help on a troublesome point. The trainee in a trainer-assisted self-paced program works in the presence of a trainer and can get almost immediate assistance. One advantage of this method over traditional training methods, where the same material is presented by different trainers, is that the subject matter is uniformly presented to all trainees. This ensures that all graduates will fully master the knowledge and skills.

In programs of this type, a learning method is used which is economically and methodologically most efficient for the training intended. The trainer's role is one of managing the learning process by clarifying, motivating, encouraging, and assisting trainees to extend themselves to other training materials. Trainees who learn quickly can complete more material in a unit of time because they are not in a lock-step set by the trainer or the slower trainee. The slower trainee can take additional time to study the material and not hold up the class. Trainees can interact one-on-one with the trainer and receive assistance immediately, whereas in the conventional classroom they perhaps will not seek help because of shyness or fear of appearing slow. Trainees can share equipment since they may work on modules at different times. Diagnostic tests and prescriptions help stagger the trainees' progress. Trainees who master the required objectives and modules can either go on to more advanced studies or use supplementary materials to strengthen their knowledge and skills.

On-the-job training, as in this latrine construction project, is often very effective.

The trainer-assisted self-paced method is best used when groups of trainees need similar training and when their work tasks use similar supplies and equipment; the training can be given at one location; and trainees need a trainer because of deficiencies in basic education, lack of self-confidence, lack of motivation, and lack of good study habits. A well-prepared trainer who can serve as a model and motivate trainees would be an excellent choice.

The trainee who moves quickly through training may help his peers who need assistance. Trainees acting as peer trainers reinforce their knowledge and skill while working with others. Since they have just finished the training, peer trainers may be able to diagnose trainees' problems more accurately and quicker than the trainer. Also, trainees who need help may not feel as "threatened" by peer trainers and better communication can be established. An example of this approach is given in an article by Austin and Batchelor (see list of sources at end of chapter).

3. **On-the-job.**

On-the-job training is very effective in transferring skills and knowledge. It is most effective with trainees who learn new skills from a more skilled person, such as an experienced craftsman, their fathers or senior tribe members, and are not accustomed to being trained in formal groups or by leaving their home communities. The suitability of this method depends on availability of trainers and on the effectiveness of information transferred per unit of cost. Since on-the-job training is similar to natural learning it is highly recommended for village and family systems.

Training in rural water supply and sanitation, whatever the instruction method, should be coordinated at the national, provincial, village, and family levels. The larger, more organized systems can assist the smaller ones and the smaller systems can provide feedback on their problems and efforts at the village and family level. The choice of training method depends on local training needs and the extent of local resources. If well-developed task analyses are available, it is easier to select appropriate delivery systems.

Task Analysis Approach to Training

Traditionally, persons with professional educational qualifications have prepared workers for jobs in rural water supply and sanitation fields. Usually they select subjects relevant, but not specific, to the work being done and cover these areas completely, including history, theory, design, economics, and operations. Often, the operation and maintenance material is general and is particularly weak in teaching diagnosis and decision-making. Many rural water supply and sanitation programs have had serious problems because, after training, trainees lack practical skills.

The design and construction of rural water supply and sanitation systems dictate every operational and maintenance task. Efficient and effective operation depends upon the systematic tabulation of each of these tasks so they can all be incorporated into the training program and supervised on the job.

The definition of tasks requires contributions by the people working on design, equipment selection, construction, operation, and maintenance of the system. The contributions of all these people are best coordinated by someone knowledgeable in doing task analyses and relating them to job performance. This talent is more likely to be found in national or provinicial organizations but rural water supply and sanitation workers can be trained in these skills. It is especially important that the people responsible for operation and maintenance contribute to the task analyses. This way, they are a part of the training system developmental process and the material used for training and operation is their own.

The tasks performed in rural water supply and sanitation operations are about the same regardless of whether the system is national, provincial, village, or family. Once task analyses and training are developed for a system, they can be used anywhere with modifications to fit the workers to be trained. National and provincial programs should be encouraged to develop task analyses and related training modules and share them with small town village and family systems.

Task analysis based training is carefully designed to assure the trainee acquires the skills and knowledge needed to operate and maintain specific water supply or sanitation systems. Each task is defined and analyzed to ensure it is specific to the system's operation. Extraneous material not directly related to the operation of the system is excluded.

To devise a training system relevant to the trainees' task performance, it is important to decide if the problem is a lack of skill or knowledge and not a management or motivational deficiency. Questions to determine this might include:

1. Is there a problem?
2. Is it a performance problem?
3. What is the performance problem?
4. How will we know when the problem is solved?
5. Should we allocate resources to solve it?
6. What are the possible causes of the problem?
7. What evidence bears on each cause?
8. What is the most probable cause?
9. What general solution is indicated?
10. What are the cost, effects, and development time of each?
11. What are the limitations on implementing each solution?

National or provincial organizations could answer these questions sufficiently to plan a training program. If they have problems, they usually know persons or organizations to help them. However, much assistance may be needed at the community level.

Table 27 contrasts some of the major attributes of

Table 27. Comparison of Typical Education/Training Philosophy and the Task Analysis Approach to Training

Item	*Typical Education/Training Approach*	*Task Analysis Approach*
Content of subject area	Broad coverage of history, theory, facts, and generalizations	Task analysis to determine material essential for competent task performance
Designers and developers	Person with highest degree available (PhD is best)	Subject matter expert, instructional technologist or vocational trainer, and practicing skilled workers
Validation of course of instruction	None or by peers (usually of same degree level)	Practicing skilled workers and trainees who must meet set standards of time, quantity, and quality
Instructional method	Usually lecture, textbooks, at set time and place	Variable, to meet conditions and limitations of trainees, funds and availability of trainers
Trainee achievement standards	Trainees distributed over normal bell shaped curve–F to A	All trainees brought to predetermined mastery level performance

typical education/training programs and the task analysis training program described here. Each of these points should be considered carefully, and technical and management control should be placed in hands that have demonstrated capability in the task analysis approach to training.

It is not easy to find experienced persons to lead task analysis based training. Until each region or country trains the number of people required, it will be necessary to share what talent is available through international agencies and programs and to make wide use of the products of new in-country leadership training efforts.

Some Additional Points to Keep in Mind

1. It is unwise and often disastrous for the designers and implementers of training to leave as soon as training has occurred. Training design and implementation should be carried out by people with a long-term commitment to the program. This means involving community residents and other local people who can be expected to stay in the area. At the village and family level, training will often be carried out by volunteers or people selected by village officials or family heads.

2. When the water supply and sanitation facilities are planned, designed, and constructed, many decisions are made which affect the short- and long-term training needed by those who will operate and maintain them. The people who do the planning, design, and construction of national, provincial, village, or family systems vary tremendously in their knowledge and skill. A national system may have access to trained personnel, but the family system may seek out a neighbor or priest for advice on water supply and sanitation problems. These designers, whatever their level of competence, will select equipment that helps determine the tasks required of the operation and maintenance personnel.

System designers will place equipment in locations that affect operation and maintenance. The equipment may be a combination of domestic and imported items. Imported spare parts and supplies may require long lead times in clearing import requirements and customs and may not be maintained in adequate supply. Local regulations governing water supply and sanitation development may hinder operation and maintenance. The builder may have followed the design drawings religiously, or he may have deviated from them without noting the changes. These kinds of actions will affect the tasks that must be performed to operate and maintain the facilities. Training will have to take account of them.

Community education in using the completed facility is very important.

3. In selecting workers to carry out these tasks, it is necessary to determine how many of them the workers can perform. The more complete the capability of new workers at entry, the less training needed to bring them up to the desired standard. The less skilled the new workers, the more comprehensive and lengthy the training program must be.

As much as possible, careful consideration should be given to defining the entry level requirements of each training program. Several points should be kept in mind when defining entry requirements: The greater knowledge and skills vary among the trainees in a group, the greater the probability of losing or boring some, thus creating a difficult situation for the instructor. Failure and dropout rates increase; motivation is low. The narrower the range within which knowledge and skill vary among the trainees, the greater the probability of motivating them since they all will progress at about the same rate. This helps to ensure that the trainees will reach the desired performance level and also helps the trainer manage the instruction better. The use of remedial training materials to help trainees reach a desired performance level is an excellent way to overcome the effects of variation in capabilities among trainees.

Diagnostic testing often helps establish the knowledge and skill levels of trainees. If diagnostic testing shows a significant number of trainees lacking in one area of knowledge or skill, this material should be included in the training program. If only a few trainees are deficient, individual remedial programs can be used. If there is no way to evaluate the trainees beforehand, the trainer must be alert for skill or knowledge deficiencies and take corrective action as soon as possible.

Elaborate tests are not needed to identify trainee capabilities. Trainers should set goals in the form of tasks that the trainees will be able to perform after training. These goals can then be used to determine trainee competence. A trainee's knowledge and skill can be measured through questions and observations. This is probably the best method to use with small numbers of trainees such as in a family or village program.

Well-trained local workers can undertake even fairly sophisticated projects such as a storage tank.

4. A training program must evaluate trainees during the training process and on the job after training. This assures that the trainee is able to transfer the skills and knowledge obtained in training to the job. It can also help in efforts to improve the training given to subsequent trainees. The following criteria may be used to evaluate a worker's on-the-job performance:

- Better water quality
- More satisfactory laboratory tests
- Longer system operation
- Lower maintenance costs
- Lower supply costs
- Less down-time of equipment
- More frequent meeting of regulatory requirements
- Improved relations with water users
- Improved morale of workers
- Lower worker turnover

Putting a Successful Training Program Together

From the foregoing, it is clear that the planning and organization of any training program, especially one for rural water supply and sanitation, is a complex process requiring a considerable range of knowledge and experience. In the past twenty years, there has been much theoretical and practical study, field observation and analysis directed at determining what factors heavily affect the success of training programs. Success, in this context, is ensuring that trainees acquire the knowledge, master the job-relevant skills, and have the motivation that makes it possible for them to perform the tasks their jobs require invariably (because lives may be at stake), promptly, and to full standards of competence in such a way that the water or sanitation system in which they work delivers the level of service it was designed to provide.

Among the more important factors which heavily affect the success of training, it has been found, are those shown in Table 28. As can be seen, these factors operate, with many variations, across the spectrum of physical facilities, funding, training resources, trainer-trainee qualities and characteristics, relations between work supervisors and training, and trainee motivation aspects of the process. Taken together, these factors emphasize that training programs are social enterprises that happen in a political and organizational environment that includes many interacting parts and relationships.

Table 28. Factors That Affect the Success of Rural Water Supply and Sanitation Training

Major Factor	*Variation*
Location	Geographical location of trainees Accessibility of training site to trainees Accessibility of trainees to instructor
Physical facilities, supplies and equipment available for training	At a central training site At the employment site Needed specialized equipment Needed safety equipment
Funds available	From water supply and sanitation organization From outside the organization Unpaid volunteer support
Training resources available	Instructional materials Audio/visual equipment Supplies Equipment Training at system location Transportation
Instructor quality	Technically competent Effective in communications and use of various media Motivates trainees Uses rote learning, not inspiring
Trainee prerequisites	Must meet prerequisites of training course: a. reading level b. math level c. subject area background d. manual experience and skills Remedial training available if does not meet prerequisites
Attitude of trainees' superior toward training	Encourages and actively seeks training Will support trainee-trainer if he finds opportunity Training OK on an occasional basis (once per year for one week) Will permit training on leave time No interest—training is waste of time Ignores training
Superior's support for trainees' training	Highly supportive—will use organization's funds for training costs and pay trainees during training Will pay training cost—trainee must take time off Will allow trainee to be paid while training, but trainee must pay for course and transportation Trainee may go on leave time and pay all his own costs Trainee must do training on his own time
Rewards available to trainee because of training	Increased pay Increased status: a. more responsibility b. privileges Public recognition

Most of these factors have been discussed at more or less great length already. However, it is worthwhile to emphasize how important the relationships in fact are by recalling the following points.

The location and mobility of trainees is important when deciding whether to take the trainees to the training or the training to the trainees. At the village and family levels, training usually should be taken to the trainees. Even in large programs, training probably should be taken to the trainees because of cost, attitudes of superiors, and other factors.

Prerequisites for instructional programs are influenced by the subject areas to be covered, the learning abilities of the trainees, and the trainees' level of experience. Remedial programs may be needed. The instructional program or method selected for implementation will, in part, depend on how long trainees can spend at the training site, how long the trainer can spend with the trainees at the system site, and how much money is available. Instructor quality and availability is crucial. One of the most important determinants of training quality and success is the attitude of the workers, managers and supervisors in encouraging workers, allowing them to take training, and rewarding them for completing training.

To put all this together and produce a successful training component for water supply and sanitation programs where they are most needed in the Third World countries will continue to require great ability, skill, and dedication from those who are challenged by the complexity and importance of this task.

Implementing Training Programs

A team approach should be used in carrying out any training. It is essential for task-oriented training. The team leader should be an instructional technologist or a vocational trainer who has had experience in the environmental field, if possible, or in a related field requiring similar knowledge and skills. It is difficult to find a water supply and sanitation expert with sufficient background in task analysis and training delivery system organization to head a project. The team leader must be well-versed in task analysis and in training program development. He or she must be able to work well with the many subject-matter experts required to cover the program topics. It is well to have field workers verify the practical usefulness of the content and presentation of the topics which subject-matter experts come up with and make adjustments where necessary. Depending on the nature of the training materials, the team may need the services of writers, graphic artists, artists, draftsmen, audio experts, photographers, proofreaders, typists, printers and other specialized persons.

The team approach is most feasible at a regional, national or international level. This reinforces the need for close cooperation among groups engaging in training system development. Persons working at the provincial, village and family levels must be involved at certain points such as task analysis, field trials of materials, and feedback on system effectiveness. But the overall development must be in the hands of qualified persons with resources available for the developmental process.

Managing a Training Program

The basis of any training program is that the workers trained must be able to provide a safe and potable water supply to the consumers or to provide adequate sanitation services. This means the workers must be able to perform to the standards set by the program under all conditions. Technical and management control of the program must rest with people who have these objectives in mind. Such people are not easy to find in most countries.

The development of a training program will be handled quite differently by people in the traditional educational world and those with a task analysis approach. The same holds true for the group that controls the management of the training delivery system. Table 29 summarizes some of the basic philosophies embraced by various groups that might manage a training system. Usually, the blend of talent, funds, and politics will dictate what management system will be used. Where possible, one should try to maximize the use of the task analysis approach to training.

Training can take place at a central site, on the job, or both.

Table 29. Basic Philosophies of Various Management Approaches to Training Delivery Systems

Management Controlled by	*Basic Philosophy*
Traditional academic education	Coverage of subject matter including history, theory, and general application; fixed time and place for delivery. Delivery by persons with highest academic degrees. Grading by traditional normal distribution.
Management of water supply agency	Training permissible when funds available, but priority is low. Try to get worker to use his time for training. Obtaining academic degrees is of higher priority than skill development. If training authorized, send higher level personnel before lower level personnel.
Task analysis approach to training	Task analyses determine cause of performance deficiencies. Local personnel working with outside consultants analyze, design, develop and implement training delivery system. Subject matter based on results of task analysis. Various delivery mechanisms used to overcome local constraints of time, place, and talent. Training conducted by persons qualified in area of performance deficiency. Training conducted to meet set mastery requirement. Training conducted in most cost-effective manner.

Table 30. Information on Training of Trainers

Contact	*Product*
EHTS/WHO 1211 Geneva 27 Switzerland	Manual on "Training of Trainers": Describes program for water supply agencies to put on their own program; includes instructor guide, trainee materials, visual aids, and suggested implementation procedures.
Caribbean Basin Water Management Project PAHO/WHO P.O. Box 508 Bridgetown, Barbados	Instructor's Manual and Planning Guide for Trainers, 1978; A Guide for Training Manual Developers, 1980.
Environmental Protection Agency Cincinnati, Ohio 45268	Basic Instructional Technology, Participant Reference Manual. EPA-430/1-79-010, November 1979; Basic Instructional Technology, Staff Guide Reference Manual. EPA-430/1-79-009, November 1979; Advanced Instructional Technology, Participant Reference Manual. EPA 430/1-79-012, November, 1979; Advanced Instructional Technology Staff Guide. EPA-430/1-79-011, November, 1979.
Office of Drinking Water, Environmental Protection Agency Washington, D.C. 20460	Instructor Development Workshop, Instructor's Manual; Instructor Development Workshop, Participant's Handbook; Instructor Training Seminars, A Manual for State Training Supervisors. August 1979.
East-West Center 1777 East-West Road Honolulu, Hawaii 96848 USA	Manual on *Helping People Learn: A Module for Trainers.* Includes: Manager's Guide, Text, Exercise Book.
WHO Pulications Center USA 49 Sheridan Avenue Albany, New York 12210	Educational Handbook for Health Personnel, J.J. Guilbert, WHO Offset, Publication Number 35; 1977.

Setting Training Priorities

Priorities for training can only be set after a detailed analysis of a number of factors is made. Many of these factors already have been discussed. They include:

1. What are the performance problems?
2. Which ones are caused by:
   - Skill/knowledge deficiencies?
   - Management deficiencies?
   - Motivation/incentive/attitude?
3. What internal and external resources are available?
   - Funds
   - Personnel
   - Facilities
   - Training programs
4. What support will there be for the efforts?
5. Who must support the effort? Is success in training necessary to justify expenditures?
6. Which efforts will be of greatest benefit in terms of:
   - Improved knowledge and skill
   - Improved management
   - Improved motivation, incentives, and attitudes
7. Which require interaction with other agencies (village, provincial, national, international)?
8. Which require recruiting of new personnel, reassignment of personnel, or upgrading of personnel?
9. Who will, and who will not, support the effort? Can those against the effort be persuaded otherwise?
10. Is a quick, dramatic effort required to impress others?
11. What time is available to carry out the training? In general, priorities must be set based on some combination of:
    - Need for improved performance
    - Resources available
    - Political realities
    - Need for success in training

Recently, a regional project in the Eastern Caribbean went through the above analysis. Training coordinators from ten Eastern Caribbean countries developed a system of worksheets to analyze their priorities, gather information from each country, and work up a master plan for a two-year training effort. This plan included training to be conducted at the water system site, in local trade-training centers, in other Eastern Caribbean countries, and out of the region. This basic approach could be used in setting priorities in any training program.

Selecting and Training the Trainers

In most situations, the personnel selected to do the training will not be full-time trainers. They will most likely be people with technical expertise in the subject area but with little experience in training others. Provisions must be made for an efficient and effective training program to prepare trainers for their duties. The content of this training should be based on a task analysis of what the trainer must do. It should, if at all possible, include supervised practice in training. This is especially true when training involves village and family workers. One member of the worker group from each village or family to be trained should be selected as the trainer. This person should be well-versed in the technical aspects of the system, be acceptable to the rest of his co-workers as a trainer, and have the potential and personality to become a trainer. The following list includes many of the tasks (there may be others) that a trainer must perform. His or her entry capability in each of these areas must be considered in selecting a potential trainer:

1. Communicates at the level of the trainees
2. Uses task analyses
3. Uses training guides, job aids, training aids, and audio-visual equipment (where more sophisticated training materials are available)
4. Motivates trainees
5. Clarifies points and assists trainees
6. Evaluates trainee performance
7. Assists in development of instructional sequences, job aids, and other materials
8. Accepts feedback from trainees and training staff
9. Allocates time for preparation of training, training sessions, and follow-up

The importance of this list, or one like it, will depend on the level (national, provincial, village, or family) to which potential trainers will be assigned. Some of the qualities can be perfected by training and practice, but others are a part of one's own personality. The trainers selected should have the highest ratings and demonstrate the most promise.

In many cases, training of trainer workshops for local personnel generate a more effective training staff because the persons are attuned to local problems and can relate better to their peers, and their peers to them, than can a stranger from outside. In many cases, local, provincial, and national authorities are more inclined to appoint their own people as trainers than to recruit trainers from the outside.

A number of organizations now have programs and materials of demonstrated effectiveness in improving the capability of a country to train its own trainers. Table 30 lists persons to contact for information and materials on these programs. Serious consideration should be given to implementing portions of these programs which apply or can be adapted for the water supply and sanitation field.

In the past, all too often the principal trainers selected, frequently from other countries, for central training systems have been one of the following:

1. Consultants, professors, or government professionals who are looking for a vacation with a little training activity to justify the trip.
2. Several expert consultants. This many times leads to conflicting advice and sets training back instead of moving it ahead.
3. Well-respected, well-qualified experts whose suggestions are too sophisticated for local conditions and limitations.
4. Well-respected, well-qualified experts who are out of touch with the latest training techniques.

If at all possible, try to avoid all of the above.

Monitoring and Evaluating the Training Program

Both internal and external evaluation must be carried out to ensure that the training program is doing its job. These evaluations should involve people not associated with the development and implementation of the training program.

Internal evaluation determines if the training delivery system is providing the trainees with the necessary knowledge and skills to overcome performance deficiencies. Aspects of this evaluation might include:

To what extent was the task analysis approach used?

How much time was required by trainees to complete training?

Were the proper prerequisities prescribed for the training?

Did trainers perform in a manner consistent with the management plan of the training delivery system?

External evaluation determines if the training delivery system is producing trainees who perform at the designed standard. Aspects of this evaluation might include:

How well do trainees believe they are able to perform on the job?

What additional training was needed by trainees after arriving on the job?

How well did the training program prepare them for the job?

What portions of the training program were most relevant to their job?

What tasks cause the most difficulty?

How much improvement do superiors see in the trainees' performance on the job?

How does the superior evaluate the performance of these trainees compared to previous groups of trainees?

In what areas were the trainees still inadequate in the view of the superior?

The results of the internal and external evaluation are used as feedback to improve the training program. Priorities for making changes should be based on cost, time available, personnel available to make changes, benefits to the program if changes are made, and detriments to the program if changes are not made.

Human Resources Development

Human resources development is a fundamental on-going requirement crucial to the basic bio-physical and socio-cultural processes involved in water supply and sanitary waste disposal activities. These activities for human families and communities, seen as living changing social organisms, are like the basic physiological processes which, to live, vertebrate animals—including man—must constantly perform. Just as water is an absolute physiological necessity for individual human life, so, in a larger sense, a water supply system, with ample quantities of safe water, is a survival necessity for every level of human community. Similarly, just as vertebrate animals must excrete the physical and chemical waste products generated by their acquisition and use of energy, so the community must dispose of its expended and frequently dangerous solid and liquid waste materials. Water and sanitation systems are bio-physical because people, who form the cells of the community organism, are living individuals who use physical materials in the biological processes on which their being depends.

Water and sanitation systems are also socio-cultural because, at the social level, man has developed communities with their functioning organization and interacting relationships and with their cultural content of knowledge, literature, art, science, and values. Modern communities are possible because water and sanitation systems have made it feasible for populations to grow and be concentrated and for technology and culture to expand and flourish.

Water, waste, man, and community are tied together in the dynamic flows which weave biological and social life together as necessary interacting parts of both the bio-physical and socio-cultural environments that underlie the total human ecosystem. Man's expanding knowledge and understanding of these processes (hydrological cycle, organic matter cycle, disease transmission, social and political organization, public finance, management and control), together with his actions as designer of systems and performer of specific tasks, make it increasingly possible for him both to manage the processes and understand the limits of his power to manage them.

Education and training are the twin means to prepare the huge number of competent people needed to make it possible for all communities, eventually, to have the benefits of safe water and sanitary waste recycling or disposal.

SOURCES
CHAPTER EIGHT

Among the books that will be most useful to those planning a training program in environmental health are *Guidelines for Health Manpower Planning*, P. Hornby, *et. al.*, Geneva: World Health Organization, 1980; *Health Manpower Planning: Principles, Methods, Issues*, T.L. Hall and A. Mejia, Geneva: World Health Organization, 1978; *Manpower Development and Training for the International Drinking Water Supply and Sanitation Decade*, A. Redekopp, Geneva: World Health Organization, 1980; *Suggested Steps in Development of a National Training Delivery System (Water/Wastewater Sector)—A Checklist and Guide*, Rikswijk, The Netherlands: J.K. Densham and Neil E. Carefoot, WHO International Reference Centre for Community Water Supply, 1978; *Instructor's Manual and Planning Guide for Training of Trainers*, Bridgetown, Barbados: Caribbean Basin Water Management Project, 1978, and *A Guide for Training Manual Developers*, Bridgetown, Barbados: Caribbean Basin Water Management Project, 1980; "Trainee Involvement in The Training Process," John H. Austin and Dale Batchelor, *Journal American Water Works Association*, June 1982, pp. 299-303; *Basic Strategy Document*, Intragency Task Force on Human Resources Development for the International Drinking Water Supply and Sanitation Decade, Geneva: World Health Organization, Environmental Health Technology and Support, 1982.

RELATED TECHNICAL NOTES
CHAPTER EIGHT

HR.3.M.	Methods of Operation and Maintenance Training
HR.3.P.	Planning Operation and Maintenance Training
HR.3.I.1	Implementing Operation and Maintenance Training
HR.3.I.2	Evaluating Operation and Maintenance Training

Also see each technical note in the "O" Series (Operation and Maintenance). These will assist with the task analyses to be carried out.

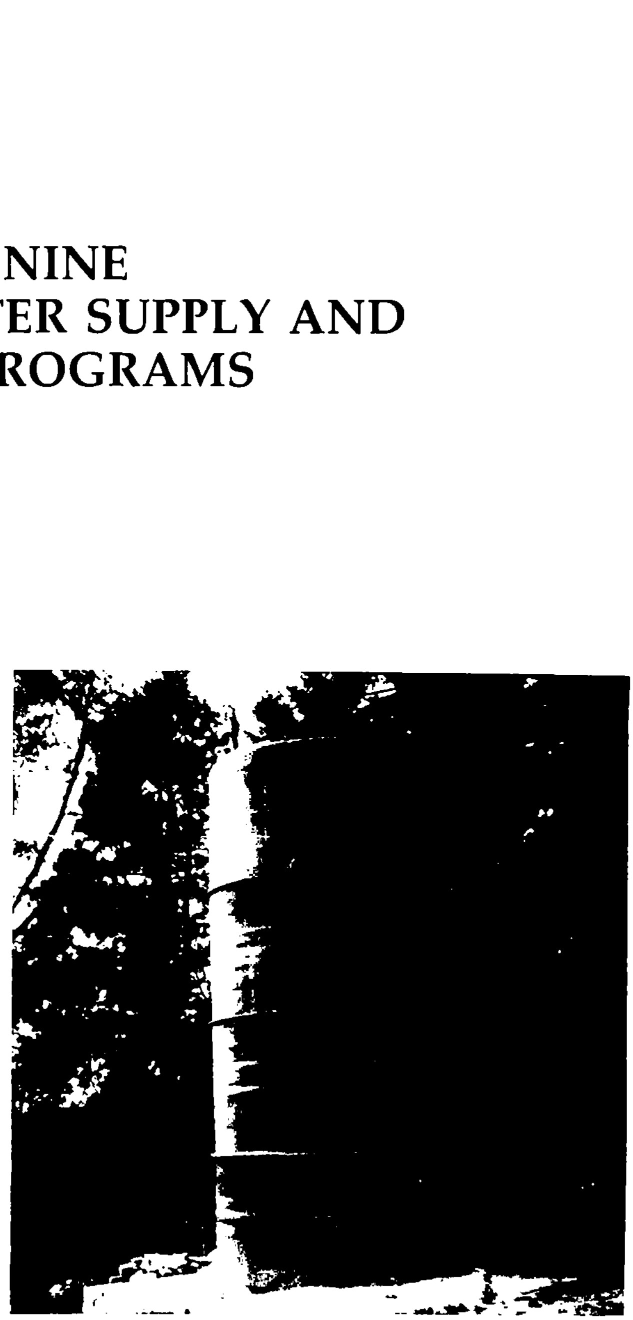
CHAPTER NINE
ECONOMICS OF WATER SUPPLY AND SANITATION PROGRAMS

SUMMARY

The third essential aspect of water supply and sanitation programming is economic and financial. This includes providing for the capital investment of design and construction, of paying for operation and maintenance of the completed system, as well as understanding the basic economic principles which bear on the feasibility and timing of the program.

Funds for capital construction can come from the beneficiary communities themselves, from national government and non-government sources, and from international donor organizations. Planning the economics of water and sanitation programs and projects involves consideration of four basic economic principles: demand, supply, costs, and benefits. Application of these principles will affect the economic character of the water and sanitation program and the individual projects it entails.

Once the system is constructed, the users probably will have to pay for service to defray operation and maintenance costs and perhaps to cover a portion of the capital and interest of the construction costs. It is usually not practical or desirable for the operation of water supply and sanitation systems to be fully subsidized by government. Rate establishment and collec tion are often critical to the on-going success of a system but are sometimes very difficult matters from a social policy viewpoint. The key considerations in rate establishment and collection are adequacy of revenues to meet operation and maintenance costs, fairness to the users, and the ability and willingness of the community to pay the rates.



Capital investment in construction is one important factor in the economics of water supply systems.

CHAPTER NINE
ECONOMICS OF WATER SUPPLY AND SANITATION PROGRAMS

To be successful, a water supply and sanitation program must take into account the economic and financial aspects of program development and implementation in addition to the other factors already discussed. Economic and financial analysis and operations of water supply and sanitation projects, including the establishment and collection of charges for water and sanitation service and the community's acceptance of and willingness to pay for services, requires understanding not only of some basic economic principles but of social considerations. Creative leadership is necessary to make water supply improvements function to the satisfaction of all involved: consumers; local communities; local, regional and national funding and administrative organizations; and participating bilateral and multilateral funding organizations.

Sources of Finance

There are three sources of funds for water supply and sanitation projects: the communities, domestic sources and foreign sources.

Community Sources

A community which wants to improve its water supply and/or sanitation system may decide to finance the whole project through its share of the central or local government budget. This investment may then be recovered through a rate structure of charges for the service or through taxes that are independent of the rate structure but exist within a framework of social objectives.

The initial investment may include a large amount of local labor and materials. Part of the labor may be contributed without charge by local residents. Some of the wealthier residents may pay others to do their share or donate a sum of money directly to the organization that is implementing the project. Materials also may be provided by residents free, under cost, or at cost.

Community financing is most common and most practical in rural areas, including villages and small towns, where it may be possible to create a mutually supportive organization without too much expense. A central organization in charge of water supply may give some resources, including people and equipment, to assist the creation of a community organization to oversee a water supply or sanitation project. These resources do not need to be very great.

Domestic Sources

The primary source of non-community domestic funds is the national budget. Appropriations for water supply and sanitation may be made directly, on a project or program basis, or provided through a central organization responsible for these activities throughout the country. If there are regional organizations, these also may be funded directly from the national budget or through the central organization. In some countries, such as Sri Lanka, water supply is under the Ministry of Local Government and Housing Construction, but sanitation is a function of the Ministry of Health. In Thailand, on the other hand, there are two divisions of the Ministry of Public Works, one of which is in charge of sanitation and the other of rural water supply.

In addition to appropriations, some countries have special revolving loan funds to finance water supply and, in rare cases, sanitation projects. The expectation is that investments will be recovered so that the revolving fund can lend to additional communities. One of the problems such funds often have is default by local governments or other organizations in charge of collecting rates. These groups are sometimes unable to collect enough money to keep the operation solvent. Under conditions of default, loan funds are eventually depleted. If loans are made by a branch or agency of the national government, the amounts owed may be forgiven under the pressure of political leaders from the area where collection has failed.

Grants by central and local governments are also an important source of financing. These grants may be one-time allocations to cover capital costs, or they may continue indefinitely covering part of operation and maintenance.

Foreign Sources

There are two broad categories of international financing sources. The first is donors that provide limited funds and people for studies, research and logistic support but not funds for project implementation. Institutions in this category are the World Health Organization, the Pan American Health Organization and the like. The second type provides funds for both studies and implementation of projects. Institutions in this group include the World Bank, the United Nations Development Program, and various bilateral agencies, such as the U.S. Agency for International Development and other national development organizations.

Within each of these two categories, there are three types of foreign funding sources:

Bilateral national government agencies
Multilateral organizations
Private, nonprofit and other types of private sector institutions

The countries which have bilateral programs and are most interested in providing funds for large, medium and small investments in water supply and sanitaiton are:

Belgium	Netherlands
Canada	Norway
Denmark	Sweden
France	Switzerland
Germany	United Kingdom
Japan	United States of America

Each of these countries has an agency which provides funds, technical assistance, personnel and sometimes commodities for both studies and implementation of projects. Contacts with these agencies are made through the embassies of the respective countries.

The multilateral agencies which provide funding both for studies and implementation of projects are:

The World Bank
United Nations Development Program
United Nations Children's Fund
The Asian Development Bank
The European Development Fund

Among the private, nonprofit and other private sector organizations, the following provide limited resources for study and research purposes:

Rockefeller Foundation
Ford Foundation
Kellogg Foundation
International Development Research Center (Canada)
Water and Sanitation for Health Project (WASH)

The WASH Project was established and funded by the United States Agency for International Development to provide information and technical assistance to developing countries as part of the official U.S. contribution to the United Nations International Drinking Water Supply and Sanitation Decade 1981-1990.

Economic Considerations in Program Planning

There are four economic concepts basic to water supply and sanitation programs: demand, supply, costs and benefits. Costs and benefits are critical to the type of economic analysis that water supply and sanitation programs require. Their application will have great impact on the outcome of economic programming.

Water supply and sanitation projects are "investment" type projects. This means that creating a water supply, sanitation, or solid waste disposal system—whether a series of wells or a group of pit latrines—results in a capital asset that provides benefits over a period of time. A project format for investment decision-making allows costs to be quantified periodically, usually every year. This, in turn, relates the source and destination of funds to the expected benefits and to costs. There are many ways to balance benefits against costs, but for rural water supply and sanitation projects the best way is the least cost or cost effectiveness approach.

There are two kinds of socio-political options that have important economic consequences and should be understood before proceeding with economic analysis of a project: rural versus urban emphasis, and advanced versus appropriate technology. With regard to the rural versus urban consideration, it is important to emphasize the differences that may occur between what political leaders say and what they do. Political leaders may state, sometimes emphatically, that the water supply and sanitation needs of the rural areas are more important, or at least as important, as urban needs. Study of actual budget expenditures may show, even so, that a larger amount of money is spent on urban projects. This is sometimes justified by asserting that since urban areas are more congested and communicable diseases spread more rapidly there, the debilitating effects are felt more acutely in cities and towns. What may also be true, but not stated as often, is that political leaders are more sensitive to large blocs of voters or other types of political power in urban areas. Disaffected masses in cities and towns can make their voices heard more easily in national and international arenas than distant rural communities spread over the countryside.

The economic consequences of the urban versus rural issue lie in the fact that, first, investment resources available to the government are limited and choices for their expenditure must be made. Second, the methods of economic analysis are not very helpful in choosing among similar type of projects in water supply and sanitation. Third, there may be wide differences in the cost per capita, or cost per gallon per capita per day, of water for an urban and a rural dweller.

The situation with regard to sanitation is even more difficult. The tendency is to leave the primary responsibility for installing sanitation facilities in rural areas to households and communities. Often, there is no specific location for excreta disposal in or near the residence. Local and central governments sometimes consider subsidizing the cost of latrines as an incentive for their installation. In urban areas, however, there are usually public authorities that undertake the provision of waste disposal.

Due to such factors, rural areas typically receive fewer resources in water supply and sanitation. Efforts to organize rural communities and pool their resources, such as money, labor and materials, for improvements in water supply and sanitation are often effective. Nevertheless, policies that increase the flow of investment to the rural sector will be needed if rural water and sanitation needs are to be met.

The second socio-political option with important economic consequences is advanced technology versus appropriate technology. In providing water sup-

Appropriate technology using simple systems such as this hand pump is usually a better choice in rural areas than more advanced technology.

ply in rural areas, this question sometimes appears as a choice between a piped water system to each residence and communal hand dug or drilled wells. There are no pat financial or economic formulas to guide this decision. The availability of resources and the specifics of each project will determine the level of technology to be used.

The choice of technology is closely related to the importance given to support programs such as human resource development, community participation, and health education. De-emphasis of support programs, especially in rural areas, accompanied by use of advanced technology, may result in a heavy waste of resources even before a project is completed. The technology used can be effective only if it is accompanied by support programs to operate and maintain water supply or sanitation systems.

With the limitations of economic analysis firmly in mind, economic considerations that are useful in program planning can be described. The four concepts already mentioned—demand, supply, costs and benefits—will be described followed by a discussion of the economic tradeoffs involved in making program planning decisions.

Demand

Demand, in economic terms, can be thought of as a schedule showing how much of a product or service will be used at different prices and at different times. The demand for a service over time may be affected by changes in price, production capabilities and incomes. This introduces the idea of elasticity. Demand for a particular service is said to be elastic of price if the quantity demanded is affected by a change in price. Income elasticity of demand is a measurement of change in the quantity of a service demanded (bought) with changes in income received by the buyer. High income elasticity means that changes in buyer income upward or downward result in corresponding increases or decreases in the quantity of a service demanded.

Demand for water in rural areas is different from that in urban areas. The monetary cost of obtaining water in a rural area may be very low, or even zero, if the time and effort expended to obtain water is not considered. An additional aspect of demand for water in rural areas is the availability of alternate sources at lower monetary cost even though such sources may involve more effort and time. For low-income rural dwellers, if the cash cost of a nearby water supply goes up and there is another lower in price or even free, but farther away or more polluted, the desire to conserve the small cash flow of the family may force family members to travel greater distances to bring water. The demand for water in rural areas is very elastic of price.

Income changes also affect the demand for water in rural areas. At low levels of income, each additional unit of income is important. Although water is also important, there are competing uses for available money. At a given price, it can be expected that more water will be consumed as income rises. At some point of water consumption, the portion going to non-essential uses increases. At higher income levels, there is a higher income elasticity of demand. At high levels of income, the amount of water demanded is more responsive to the price of water than to changes in income because much of the water is going for non-essential uses. If the price is high, the high-income user may curtail some of the non-essential uses. But, if the price is too low, the temptation to excessive use may lead to waste.

The price of water can be used to regulate the demand for water. This is true not only of water for drinking and daily consumption needs but also for agricultural, commercial and industrial uses.

There are two other aspects of demand for water that should be mentioned. These are the ability and willingness of consumers to pay for water. The ability to pay applies to the lowest income groups in rural areas who have many needs competing for the small amount of money available to them. If payment for water is a serious financial burden, families will not be able to afford it.

The willingness to pay for water is a completely different matter and cuts across income groups. Willingness to pay is very much a matter of custom, habit, cultural norms and historical precedence. A strong need for water expressed by a population does not necessarily mean people are willing to pay for it directly. In some societies, people believe that water is a free, natural good or that the government should provide it free. Under such conditions, governments would be well advised to undertake intensive educational campaigns explaining the costs and benefits of water supply to convince the consumers that some payment for water should be made.

If the problem of willingness to pay is not resolved, initial investments may not be recovered and resources needed for operation and maintenance may not be forthcoming from users. Deficit financing in developing countries with high investment requirements for water supply would probably be inflationary and would almost certainly be politically impossible.

The demand for sanitation facilities may be even less than for water. The population may use nearby bodies of water or wooded areas for excreta disposal at no monetary cost. Some communities may have invested in pit or water-seal latrines. Demand is difficult to determine since it is a function of the priority given to it by the family head, the household's recognition of the connection between disease and excreta disposal, the income of the household, community awareness and pressure for improvements, and the availability of monetary and other incentives from the government to undertake improvements.

It is probable that the demand for sanitation in rural areas is quite price and income elastic. As the cost of a pit or water-seal latrine goes up, if income is constant, the demand for latrines will decrease. As incomes increase, given such other factors as awareness, eduation and price stability, the demand for latrines will increase. Other factors causing increased demand are convenience, status, and the desire to be modern.

Supply

Wherever there are human communities, there is some sort of water supply. Since human life is impossible without water, there is never a situation of zero supply. Even in desert or near-desert areas, there is some means of obtaining water at human settlements. In such situations, there is a delicate balance between water supply and consumption which may be seriously upset during periods of drought.

When community water supply needs are studied, often the major requirements are an *increase* in the quantity of presently available water and an *improvement* in the quality of present and future water supplies. The amount of water provided and distributed per capita has a direct effect on the cost per capita and the total amount of investment required. In rural areas of the developing world, consumption may range between 20 and 60 liters per capita per day or less.

There are substantial cost variations in water from surface and from groundwater sources. There are also large cost variations among sources of the same type, depending on the size of the population, the quantity, quality and means of conveyance of the water to the consumer.

While variations in demand result from the price charged for water, variations in supply are determined by the levels of service and their costs. A major consideration in determining which supply should be chosen is the cost of a particular level of service. In addition to considering the least cost alternative for a predetermined quantity and quality of water, determination of service levels requires a choice from the following:

Community wells:	With hand pumps
Individual family wells:	With hand pumps
Piped water with public taps:	Dispersed among neighborhoods in rural and urban areas, along roads or at gathering places such as markets
Piped water with individual house connections:	In-house: single or multiple connections Outside: usually single yard or patio tap

The choice by decision-makers in deciding on a single or a combination of service levels must be influenced by social as well as economic and financial considerations. If only house connections are provided, poor residents who are not able to afford either the connection or the monthly charges may be discriminated against. A subsidized type of payment for the water might provide an equitable solution. However, the subsidy would need to apply to the initial connection charge as well as to the monthly payments.

There is no formula to determine service levels. Chances are that a mixture of service levels using, in some areas, a combination of hand-dug and drilled wells with individual or community tanks, and, in other areas, household connections with plumbing, yard connections, and public community taps, will best meet both cost and service level considerations.

The supply aspects of sanitation in rural areas are even more complex. Difficulties arise in attempting to predict the demand associated with different population groups, different service levels, and the least cost alternatives. For example, the installation of pit and water-seal latrines and septic tanks in a rural area may be the responsibility of individual households. These investments would be household decisions but could involve public subsidies.

On the other hand, a bucket latrine collection system or a piped sewage system falls within the domain of the public sector. If a community has a mixture of wastewater and excreta disposal systems which are to be upgraded, say, from bucket, pit, water-seal latrines and septic tanks to piped sewerage, it is extremely difficult to determine the most economical system to be supplied. Demand forecasts and cost levels will be very different from each other.

If the community has a strong awareness of the different benefits of each service level, the demand for piped sewerage by households with septic tanks may be quite low and sensitive to prices. On the other hand, in areas with bucket latrines, the desire for a piped sewage system may be strong while the demand is low since the initial cost and monthly payments may be too high for low-income residents. Per capita water consumption in a given area is an additional problem. The higher the consumption of water per capita, the greater the justification there may be for a piped sewage system since the wastewater must be handled in some way. Another situation arises in low-income areas where low per capita consumption of water causes disease. These unhealthy conditions would certainly be improved by piped sewerage.

The supply of an appropriate wastewater and excreta disposal system cannot be determined just by cost or service level. It is crucial to estimate, predict and categorize the demand, analyze the prices and costs associated with individual demands, and whenever possible determine elasticity of the demand as aids in choosing the least cost alternative.

Costs

The costs of providing water supply and sanitation services can be divided into primary and secondary. Primary costs are related to land, labor and capital. Depending on the type of system, land may or may not play a significant part in cost calculations. An increase in communal hand-dug wells with hand pumps may use land that has no other productive use. Similarly, a pit or water-seal latrine built behind a residence also may not withdraw land from another use. On the other hand, water diverted from a river, a series of ponds and a treatment plant may require large amounts of land that had other productive uses.

Labor is another primary cost item. In many water supply and sanitation schemes, a substantial amount of community labor is utilized. Regardless of whether the labor is paid or voluntary, its value should be reflected in the economic analysis during project preparation.

Capital consists of the physical items required by the water supply or sanitation system. This includes all the needed materials, supplies and equipment.

Secondary costs are "sunk" costs, taxes and the costs of the debt incurred to finance the project. In many cases, there may be no previous monetary investment in a water supply but substantial sums may have been expended in getting water from a lake or a river. No matter how small and rudimentary the initial investment was, if improvements or extensions to an existing water supply or sanitation system are planned, the initial costs incurred are the "sunk" investment. For example, suppose a community of fifty houses has ten bucket latrines which cost a total of U.S. $200 to build 20 years ago. Now each family is to have a pit latrine in its back yard. In calculating the cost of the pit latrines, the sunk cost which was incurred in the building of the bucket latrines must be included. Taxes are treated as costs in a project financial analysis of a project but as a transfer payment in economic analysis.

The third type of secondary cost is the repayment of capital and interest. In countries where water is considered a free good or as something to be provided by the government free of charge, this is an important and serious cost to society. If the government is unable or unwilling to charge the consumer for water, there eventually may be a lack of resources for operation and maintenance of the system. In some cases, the system may completely deteriorate and be abandoned. As in the case with taxes, the debt cost item is treated differently in economic analysis than in financial analysis. In the former, it is considered a transfer payment and is not included in the economic accounting of true resource allocation. In the latter case, it is treated as a financial cost or outflow of funds.

All costs occur in three stages: pre-project, project, and post-project. During the pre-project stage, common activities are initial planning studies, engineering, economic and social feasibiity studies, and design of the system.

Pre-project costs may range between 2 and 10 percent of total project cost. It is important to note the major determinants of these costs. The first is how carefully and extensively each aspect of the project is analyzed and refined. The second determinant is whether the professional work is done by local professionals or expatriates. The use of expatriates always increases the cost. This is also an important factor in the project stage.

If local institutions are used with little or no expatriate participation, there may be substantial cost savings. The amount of foreign technical expertise used depends on the size and technological complexity of the project, the supply of local experts and local wage levels. Very often, donors who are underwriting part of the cost of a water supply or sanitation system require the use of technical assistance and sometimes supplies, material and equipment, as well, from the donor country.

The project stage involves construction, training, institutional development, community organization and evaluation. While most pre-project costs and some project stage costs are one-time expenditures or expenditures that are not frequently incurred in the post-project stage, the costs of the post-project costs are essentially recurring outlays.

When the water supply or sanitation system has been completed and delivered to the managing organization, the post-project stage begins. During the pre-project stage, a number of critical activities that will occur in the post-project stage should be considered.

Perhaps most important is the financial, administrative and professional capability of the managing organization which will operate the system. There are two cost issues of special concern. The first is the organization's internal structure and its ability to maintain financial accounts. Second is the institution's ability to collect user rate funds for operation and maintenance. If consumers refuse or avoid payment on a wide scale, the only way to keep the system operating may be through subsidies. This will require raising general taxes or it will be highly inflationary when multiplied for many systems over long periods of time.

Benefits

Benefits from water supply and sanitation projects are economic, health and social. Most benefits are obvious but are difficult, if not impossible, to quantify.

1. **Economic Benefits.** There are three aspects of water supply projects for which it is easier to measure cost than direct benefits. A water supply project may improve water quality, increase the quantity available, and make water more accessible.

Direct costs can be assigned to water quality improvement without serious problems. That improvements in water quality contribute to better health is not seriously disputed. It is quantifying the health improvement which creates problems. To place a specific monetary value on longer lives with more healthy days and greater income as compared to shorter lives with more sick days and decreased income is very difficult.

Increased quantities of water present a similar problem. People adjust quickly to using more water for many purposes, especially if previous quantities were low. Improved health may follow more water consumption but the relationship is difficult to prove and even more difficult to assess in money terms. In some situations, increased quantities of water make new or expanded cottage or rural industries possible, thus contributing to income expansion.

The decrease in the time and effort required to fetch water because it is more accessible also requires indirect measurement of benefits. Especially in rural areas, women and children, who are the primary drawers of water, save a substantial amount of time and effort when the water source is made more accessible. This time and effort can then be used for more productive activities.

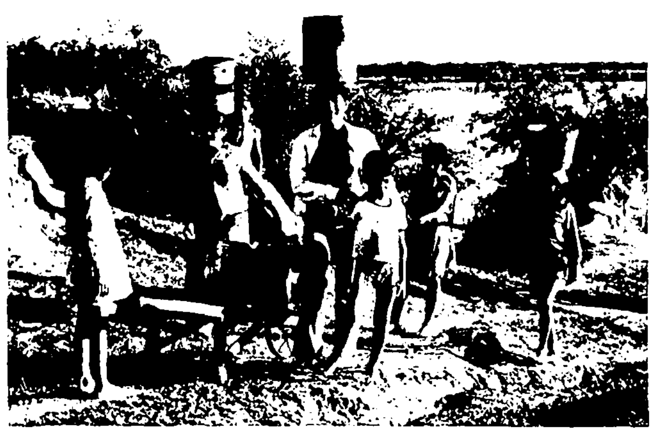
2. **Health Benefits.** There are two major problems in assessing and quantifying health benefits. The first is the low reliability of mortality and morbidity statistics, especially as related to waterborne diseases and to the quantity and quality of drinking water available to a specific population. Changes in health in rural communities are the result of many interrelated factors. Measurements of these changes is always very difficult.

The second problem is related to measuring the health effects of specific water supply and sanitation projects. Resources are not usually available for detailed baseline studies of communities about to receive such projects. Without community-specific data, scant national and regional statistics are usually applied to the project area. There usually are few resources for post-project evaluation and estimates, rather than specific results, are used to assess project impacts. Evaluation of health benefits is possible only where there is a health evaluation plan using extensive data collection and enough people, money and equipment to carry it out.

3. **Social Benefits.** In many developing countries, certain services are available to small portions of the people in rural towns and villages. In rural Paraguay, there are villages where only 10 to 15 percent of the houses, and most of the businesses, have access to electricity. In some Ecuadorian communities, only a few of the houses may have pit latrines or nearby wells. It is not unusual for the highest income families in a rural area to provide themselves with electricity, more and better drinking and home use water, and sanitation facilities. Expansion of an existing water supply system or a new system that replaces or augments existing traditional supplies has two kinds of social benefits.

The first benefit is a more balanced distribution of social justice. Water and sanitation projects should serve the needs of the entire community. A water supply project that provides piped water to a few households, to public standposts, clothes washing areas, and public bath houses but makes no provision for the rest of the population may lead to social friction.

The second type of social benefit, again difficult to measure, is the effect of a water supply or sanitation system on income and asset distribution. Income distribution is affected since a healthier population will be able to work better and more productively over a longer time per day and over a longer life-span than if water supply and sanitation services were not available.



There are health and social benefits of improved water supplies as well as economic ones.

Tradeoffs

The decision-making process for water and sanitation programming requires trading off supply, demand, costs and benefits against each other to reach the best solution. These tradeoffs occur in the planning, design and implementation phases of a project.

1. **Planning.** The urban centers of developing countries usually depend on an existing organization for water supply and sanitation services. Such organizations have a number of options if there is a shortage in supply: (a) suffer the shortage indefinitely, (b) change the supply through expansions of the existing system or through new systems, or (c) introduce measures to decrease consumption.

In rural areas, the effects of both need for and cost of water are felt more urgently by the users. This is especially so if there is no local organization for solving water supply and sanitation problems. There is often no viable alternative to establishing a local organization to identify problems, search for solutions and implement projects with the participation of the beneficiaries. This approach has social, psychological, and economic benefits. Solutions imposed by outsiders will result in wasted resources if the local population rejects the solution as not its own or as one which the community does not want to support. Rural organizations, too, must consider the three options.

The "no action" option is not without costs or benefits. The likely results are worsening health conditions, water shortages and disease epidemics, all of which affect the income, assets and general welfare of the population.

Changing the supply, the second option, most likely will involve changing the existing system in some manner. It can be expanded via new or improved surface or groundwater supplies. The tradeoffs involved are both social and economic. Even if treatment of surface sources is more economical than ground water, an existing preference for ground water might be sufficient reason to choose this alternative. Not doing so may prove to be a waste of resources if the water made available from a source unacceptable to the community goes unused.

Another possible change in an existing system is improving productivity and efficiency of both existing human resources and capital stock. Improvements in the quality of skilled and semi-skilled people requires training and the payment of reasonable and acceptable wages to avoid personnel loss to the private sector or foreign labor markets.

Improving the efficiency of capital stock can improve capacity in a variety of ways. Leakage before and after treatment may lose large quantities of water. It may be much better to increase the capacity of an existing system by minimizing losses from leaks than to search for new surface or groundwater sources. Although leaks in the system prior to treatment are costly, leaks which lose treated water are costlier since resources have been spent on treatment. In smaller systems, there may also be water loss by leaks in piped systems or through improperly maintained hand pumps.

Evaporation of water from surface sources may present a difficult problem. The rate of evaporation is influenced by both air and water temperature which relate to the intensity and length of exposure to solar energy, and to wind and humidity. Although attempts have been made to reduce evaporation through the spread of special films on water surfaces, neither the cost, availability, nor effectiveness of these procedures are such that they are very useful.

Another source of loss of surface water is seepage, especially in unlined earthen irrigation and drainage canals. The combination of high evaporation and seepage in these canals over long distances may lose 50 percent or more of the water leaving the source.

Increasing the water supply through cloud seeding has been tried in a number of developed as well as developing countries. Cloud seeding in Thailand and the Philippines in 1980 gave some positive results. The advantage of this type of weather manipulation is that, especially for large systems, the cost is relatively low and the benefits, if the resulting rain can be controlled, are high. However, unpredictable factors that may produce undesirable results may create serious problems. Flooding and the ensuing damage may more than cancel the benefits.

In the sanitation area, the range of available services includes bucket, pit or water-seal latrines and simple piped systems. The planning alternatives lie in the choice of service levels affected by the water supply system. Bucket and simple pit latrines do not require water for their operation. Water-seal privies need small amounts of water while septic tanks and piped sewage systems require increasingly large amounts of water.

The main problems with the social and economic benefits of sewage treatment are similar to those encountered with industrial pollution affecting air, water supplies and land. Many developing countries seek accelerated economic growth in the short- to medium-term at the expense of serious long-term cumulative pollution. Thus, expensive treatment may not be an attractive alternative to decision-makers although it probably should be.

The following example may help to focus the problem of appropriate planning procedures. In a small residential development on the fringes of Santo Domingo in 1980, the sanitary installations of most of the houses were linked directly to an aquifer under them to avoid the costs of a septic tank or another form of latrine. It is difficult to estimate the social and economic loss from damage to health that could result from connecting the sanitary installations of some 100 houses to the aquifer directly underneath them. Several of the area wells had already become unusable before the last section of the houses was completed.

The regulation of demand for water supply is quite important in developing countries. It may be essential to conserve existing supplies to achieve a rational distribution of resources. Changes in demand can occur through pricing or rationing of water supplies. Pricing is a means of demand intervention. It may be based on metered or non-metered water rates.

The second way to change demand is to restrict the use of the existing supply. This may be effective, but only in the short term. Recent observations in rural areas of Sri Lanka indicate that prolonged periods of restricted use, such as one to two hours a day, is not a socially and politically desirable long-term policy.

2. **Design.** In designing water supply and sanitation projects, the tradeoffs can be classified as follows:

- Technology: Advanced versus Appropriate
- Materials: Local versus Imported
- Labor: Free versus Paid
- Design period: Long versus Short

Despite the vogue begun by "Intermediate Technology" (ITDG) and the "Small Is Beautiful" movement, organizations in charge of water supply and sanitation in developing countries should not automatically reject all advanced technology. For systems in large urban populations centers, the most advanced technology with some modifications may be the best solution. The situation is dramatically different for both concentrated and dispersed rural populations. The best technologies for these populations may already exist. Slight or even major modifications to existing systems often can be made inexpensively without resorting to the advanced technology used in developed nations. The most approporiate technology in a rural area is determined by its sanitary effectiveness, the amount of community acceptance and the capability and willingness of the people to undertake its operation and maintenance. In terms of materials, preference should go to maximum use of local materials. As the level of technology increases, so may the requirement for imported materials and equipment.

Labor is a very important factor in the cost of water supply and sanitation projects. In rural areas with below market wages, labor may not be as costly but if labor costs are at market wage rates, they will be a significant cost component. The length of the design period for a system may be a subject of controversy, depending on the policies adopted by the government and by the institution in charge of water supply and sanitation services. This is usually related to a combination of politics and the availability of resources. Substantial cost savings may result from a short design period which also may be more expedient politically. Long design periods may require a quantity and quality of resources that the development institutions cannot mobilize.

3. **Implementation.** Both water supply and sanitation projects involve some combination of coverage and support programs. Coverage programs involve the expansion of water and sanitation facilities, while support programs include development of institutional and human resources needed to operate and maintain the facilities. Appropriate timing in implementing these programs is critical if resources are not to be wasted. An emphasis on one type of program at the expense of the other may endanger the entire effort.

4. **Service Levels.** There are four areas in which alternatives should be considered:

- Quantity of water, including the classification of beneficiary groups.
- Quality of water, including safety and physical and chemical characteristics, with attention to taste preferences of users.
- Availability of water on a continuous basis throughout the year.
- Accessibility in terms of time, distance, and effort involved in fetching water.

As far as quantity is concerned, it is possible to classify the users in any specific area according to the level of service planned. This means that houses with piped connections would have higher levels of water consumption, while houses served with public taps or hand pumps have lower levels per capita.

There are few generally accepted tradeoffs in water quality. Cost and water quality are very much related but international organizations tend to emphasize water quality standards, especially coliform bacteria counts, often overlooking the cost of meeting them. Many developing countries consider the quality levels established by the World Health Organization to be too rigorous because the cost of meeting them is too high. Such attitudes need to be very carefully examined if the health of people is to be given high value. Availability and accessibility of water involve definite tradeoffs in costs and benefits which were discussed in earlier sections.

Establishing and Collecting Water Rates

The process of establishing rates for water and sanitation services involves a number of complex financial, economic, social and political problems. What may be economically viable in the long run may not be politically expedient in the short term. While raising water rates may be a requirement for financial soundness, the political costs of such increases may be so high they are impossible to implement. There are two policy decisions that must be made before rates can be established. First, is the system to be self-supporting or subsidized and, second, are rates to be a flat amount or variable.

Water Subsidies

In many developing countries, especially those in which water traditionally has been considered a free good, governments have been obliged to heavily subsidize water supplies. Over the past decade, institutions involved in operating water systems have attempted to increase the awareness of political leaders about a number of critical problems arising from subsidization. The first and most important difficulty is that developing nations that depend on foreign financing for water supply development find that foreign funding agencies are definitely in favor of a self-supporting alternative. Donors do not necessarily object to a lifeline (low quantity) supply to low-income consumers over the short run, as long as the system generates enough revenues to service the initial investment and has sufficient resources remaining to operate, maintain and expand the system.

The second important problem is the inflationary pressures of heavily subsidized systems on the economy. If long-term subsidization of the low-income population is adopted as a pricing policy, then a decision must be made as to whether the subsidy will be fully or partially recovered from higher income users or whether general taxes will be used to fund the subsidy. Care should be taken in setting rates for higher income consumers to lessen resistance to a policy with income redistribution consequences. If there are no subsidies, low-income users may have to spend a disproportionate amount of their disposable income on water.

Water Rates

The first issue in considering pricing policies is whether or not to install meters. It is not enough to show that meters will provide enough revenue to cover the cost of meter installation and, more important, will make the system a financially viable operation. The meters also have to be acceptable to the users. They must be made aware that meters allow each household to pay only for water consumed. Otherwise consumers may disconnect or otherwise disrupt the functioning of the meters, or even disregard them completely and refuse to pay.

Water from public standposts can be metered just as house connections are. However, this metering would be for purposes of measuring total demand since standpost users would be charged a flat rate, probably subsidized. In some cases, when public standposts, with or without meters, are completed, a grace period of no charge or a very low charge is followed by slowly increasing the rate per family, thereby decreasing subsidies. People must know in advance that this is going to happen.

In rural areas, especially those with low population densities, piping water to houses from central sources is costly and so must carry high rates. Although difficult to justify from economic and financial standpoints, piped water may fulfill critical social and health needs. One solution to the financial dilemmas involved in such rural systems is the close involvement of the community in project development. Labor and materials provided by the community will reduce the need for outside resources and so hold rates down.

If variable rates are to be used, there are six possible kinds of pricing structures:

1. **Incremental Block Pricing.** This alternative is useful where water conservation is a critical factor. As the quantity of water used increases, so do the rates. They can increase either in accordance with the proportional increase in water used or can go even higher, depending on how important conservation is and whether some sort of rationing is intended for users of very high quantities. A low price can be established for a lifeline (low quantity) supply. Incremental block pricing is the opposite of declining block pricing.

2. **Declining Block Pricing.** Under this pricing alternative, a rate is established for a minimum amount of water. As the quantity of water used increases, the rate charged for each additional block decreases. This is similar to the pricing of electricity in some countries where large users of power, such as industries, pay a much lower price per kilowatt used than small users, such as residences. In areas where system expansion is likely to be a serious problem because of constraints on surface and groundwater supplies, declining block rates should be avoided. On the other hand, this alternative could be considered in areas with extremely low current water use and no serious constraints on system expansion or where supply is abundant and there is a desire to stimulate economic development by encouraging small industries with high water uses.

3. **Constant Rate Pricing.** Under this pricing alternative, the rate charged for every unit of water used is constant. Although this has been popular in many urban areas of developing countries, it is not appropriate for areas where wide variations in income are the norm.

4. **Flat Rate Pricing.** This is one of the alternatives to metering. In the absence of meters, a flat charge may be established regardless of the quantity used. Or, the quantity of water made available to consumers may be rationed to restrict consumption to the maximum extent.

5. **Property Assessment Tax Pricing.** This also is an alternative to metering. Water rates are established as an additional tax on property and collected as part of property taxes. By passing on the responsibility of payment to the property owner rather than the water user, there may be some income redistribution effects which disappear, however, as these costs are passed on to the water users. On the other hand, unless the tax rates vary widely taking into consideration the value of the property and the consumption capacity of the users,this may not be a fair system.

6. **Differential Seasonal Rates.** In countries where substantial variations in water supply occur at different seasons of the year, it may be necessary to influence demand for water during water-short seasons. This is accomplished by increasing the rates for a set period and then returning to regular rates at the end of the period. It is important that the consumers are informed a long time in advance as to why and how this pricing system is to operate.

Sanitation Rates

It is difficult to establish pricing policies for improvements in excreta disposal services other than for sewer systems for large urban areas. In a recent study in Sri Lanka, improvements in excreta disposal were calculated to cost about US $131 per family. Funding was estimated to be 12 percent through subsidies by the central government, 40.5 percent through contributions in labor and materials by residents and 47.5 percent from international donors. Improvements in excreta disposal through simple methods such as pit and water-seal latrines are not suitable for traditional economic analysis. Not only is quantifying benefits difficult, but the determination of options and the prices associated with each option is difficult to establish. This is especially true for communities that suffer from a high disease rate due to fecal contamination but do not attribute it to a lack of excreta disposal facilities.

The initial investment in simple excreta disposal facilities is high compared to the cost of operation and maintenance. Assuming that a bucket latrine is not a desirable option, the next two alternatives, pit and water-seal latrines, have relatively low operating cost. This may be borne by the family, except in the case of public latrines where maintenance is paid for by public funds.

For sanitation improvements, the important aspect is not establishing a rate or price for the improvement, but allocating the necessary contributions in an equitable fashion. The community and the individuals have to generate the resources for the operation, maintenance and eventual replacement of these facilities.

Rate Collection

It is not sufficient to establish rates—they have to be collected. In many developed countries, this is not a problem. There may be resistance to high rates by particular groups in a society. Certain industry groups or even homeowners may disagree with what they perceive to be unjustifiable high water or sewerage rates and work toward lowering them. However, once a consensus is reached, the rates are usually paid.

In developing countries, water is often considered a free good or an aspect of tribal or communal rights that do not extend beyond a traditional boundary. The sharing of water with outsiders and the idea of having to pay for it, even in cleaner form or nearer people's homes, may require a substantial effort in educating the users about the purpose of the payments.

The type of rate established may not have any connection with the users' willingness to pay. In Sri Lanka, for example, where water rates consist of a tax levied on property, difficulties arise not only from resistance to paying the taxes but also from extremely low assessments of the properties taxed. Further, the assessments and the taxes do not consider inflation, even though the costs incurred by the water supply authority spiral as a direct result of inflation. Since rate collection is ineffective, the authority and other organizations involved in water supply have all become dependent on some form of local or central government subsidy.

Installation of meters, unless undertaken with the agreement and acceptance of potential consumers, is no guarantee that the rates established will be collected. If the meters installed are not properly serviced and repaired when broken and read at regular intervals, non-payment will be encouraged.

In the final analysis, one of the most critical decisions is whether or not to cut service for non-payment of bills. This applies both to metered and non-metered situations. If the government does not enforce rate colection when it is being resisted by a community, it must consider an educational campaign if it is truly interested in an efficient allocation of resources and in recouping the investment. Otherwise, the government will be involved in a vicious circle of subsidies.

Analysis of rate collection procedures has to consider whether the sale of water, for example, will be on an individual or communal basis. In rural areas, water can be sold wholesale to a community which, in turn, sells it on a retail basis to individual households and other institutions according to one of the rates discussed.

One action which might assist in the collection of established rates is the dissemination of information about the process by which the rates were determined. If subsidies or cross-subsidies are involved, informing the consumers may reinforce their sense of obligation to pay for water used. If social fairness and income distribution effects are built into the rate structure, public awareness of the issues involved might help overcome the opposition of high-income groups which may be disadvantaged by these policies.

Connection fees for water supply and for sanitation systems are often too high for low-income people to pay. A cross-subsidization scheme can be considered either among different income groups in the same location or between two separate communities in the same country. Connection fees are usually a one-time payment but they can be covered by slight increases in the monthly charges for water supply and/or sanitation.

The most appropriate approach to collecting rates begins with a series of questions to determine how important the new facilities are to the users. Once the priority level is established, a survey can be used to find out how much the local community would be willing to pay for the service. The survey might include a series of real and hypothetical methods of obtaining more and cleaner water, each associated with costs and methods of rate collection. Prior to the survey, an information campaign to explain the different ways of establishing rates may be needed.

The financial and economic feasibility of water supply and sanitation facilities is closely tied to social factors such as acceptability. The feeling that the service to be received is important and worth paying for, and that the amount of money being charged for it is fair, makes it much easier to collect fees. In the absence of these circumstances, collection is difficult in any type of rate system.

The economics of water supply and sanitation services are complex and important. Those who bear leadership responsibilities for the health and well-being of their communities have an obligation to be well-informed on these matters and to be persistent and creative in applying that knowledge to the practical problems of their communities.

SOURCES
CHAPTER NINE

This chapter was written entirely from materials prepared especially for the AID Knowledge Synthesis Project.

APPENDIX ONE
GLOSSARY

ACIDITY—The degree of presence of chemical compounds that buffer a water against a rise in pH.

AERATION—The process in which water is brought into contact with air in order to improve the water's physical and chemical characteristics; used in both water and wastewater treatment.

AEROBIC—Occurring only where free oxygen is present.

AESTHETIC—Having to do with water characteristics related to the human senses but not directly related to health, such as odor, color or taste.

ALGAE—Tiny green plants suspended in surface water.

ALKALINITY—The degree of presence of chemical compounds that buffer a water against a drop in pH.

ANAEROBIC—Occurring where no free oxygen is present.

AQUIFER—A water-saturated geologic zone in which water moves or is stored.

BACTERIA—One-celled microorganisms, some of which are harmless and some of which cause disease.

BAFFLE—A wall or screen which redirects water flow in a tank or basin.

BIODEGRADABLE—Readily decomposed by bacterial action.

CATCHMENT—A surface from which rainfall runoff is collected; common catchments are roofs and especially prepared ground areas.

CHLORINATION—A water treatment process in which bacteria are destroyed by the addition of the chemical chlorine.

CHLORINE DEMAND—The amount of chlorine required in the disinfection process to disinfect water.

CHLORINE RESIDUAL—The amount of chlorine left over in water after the chlorine demand has been met.

CLARIFICATION—The process of removing suspended matter and other forms of turbidity from water.

COAGULATION—The process of chemically combining small particles suspended in water; used in water and wastewater treatment.

COLIFORM BACTERIA—Bacteria found in the intestines of man and animals; a coliform count is often used as an indicator of fecal contamination in water supplies.

CONSTITUENT—A part or component.

CONTAMINATION—The presence of chemical or infectious impurities, such as bacteria, that may be harmful to health.

DIGESTION—Decomposition of organic matter by bacteria.

DISINFECTION—The process of killing bacteria, viruses and parasites in water.

E. COLI—A type of coliform bacteria present in the intestines of man and animals, the presence of which in water in sufficient quantity indicates fecal contamination.

EFFLUENT—Settled sewage.

ENDEMIC—Present in an area all of the time.

ENTERIC VIRUS—A virus that is found in the intestines and can cause illness in humans.

EPIDEMIC—Attacking many people in an area at the same time.

ESTUARY—A lowland area where river waters meet tidal waters from the sea.

EUTROPHICATION—The process by which bodies of water become richer in aquatic plants such as algae because of increases in dissolved nutrients.

EVAPORATION—Loss of surface water to the air as the surface water is heated by the sun and rises to the atmosphere as vapor.

EVAPOTRANSPIRATION—The amount of water transferred from the soil to the atmosphere by evaporation and transpiration.

EXCRETA—Liquid and solid human body wastes.

FECAL—Having to do with solid human or animal wastes discharged through the bowels.

FECAL-ORAL CYCLE—The process by which fecal material gets into the mouth, usually through lack of adequate personal hygienic practices and sanitation.

FECES—Solid human or animal wastes discharged through the bowels.

FILTRATION—A water treatment process that removes suspended matter and bacteria by running the water through soil, fine sand or an artificial filter.

FLOCCULATION—The process by which very small particles in sewage or water are brought together through chemical, physical or biological action.

FLUORIDE—A compound that contains the chemical element fluorine.

FUNGICIDE—Any substance (usually chemical) used to kill fungi.

GROUND WATER—Water that is stored or moves below the ground's surface.

HEAD—Water pressure expressed in terms of the depth of water necessary to create the pressure.

HERBICIDE—Any chemical used to destroy plants, especially weeds.

IMPERVIOUS—Not allowing liquid to pass through.

INDICATOR ORGANISMS—Organisms whose presence in a water supply is used to assess the degree of fecal contamination; *E. coli* is the most commonly used indicator organism.

INFECTIOUS DISEASE—An illness caused by microorganisms which are transmitted from one person to another by some means.

INFILTRATION—The process of water passing from the surface, through the soil and into groundwater reserves, losing its impurities as it flows.

INSECTICIDE—Any substance (usually chemical) used to kill insects.

INTAKE—The point where water enters a water supply or treatment system.

ION EXCHANGE—The chemical process in which ions (electrically charged atoms) are transferred between a solid and a liquid; widely used in water softening and wastewater treatment where metals are present.

LEACHATE—A liquid solution formed when water passes through solid wastes or soil and extracts soluble or suspended substances.

METABOLIC—Having to do with the process in organisms of breaking food down into simpler substances or waste matter.

METHANE—A colorless, odorless, flammable gas.

METHEMOGLOBINEMIA—A condition caused by nitrates in water which produces a blood disorder in babies causing them to turn blue.

MICROBE—A microorganism.

MICROBIOLOGICAL—Having to do with microorganisms.

MICROORGANISM—An organism so tiny that it can only be seen with a microscope.

MORBIDITY—Having to do with illness or disease, especially the rate at which people become sick.

MORTALITY—Having to do with death, especially the rate at which people die.

NITRATE—A very stable oxidized form of the chemical element nitrogen.

NITRITE—One of the forms in which the chemical element nitrogen occurs; it is less stable than nitrate but more stable than ammonia.

NITROGEN—A chemical element occurring naturally in the environment in many different forms; its most stable form is nitrate, its least stable is ammonia.

PANDEMIC—Epidemic over a very large area.

PATHOGEN—An organism or substance that can cause disease.

PERMEABLE—Allowing liquid to soak in or move through.

PESTICIDE—Any chemical used to kill weeds, insects, and other pests.

pH—A measure of how acid or alkaline a liquid is; solution below 7 is acid, above 7 is alkaline.

PHOTOSYNTHESIS—The formation in green plants of substances, chiefly sugars, from carbon dioxide and water caused by the action of light on the chlorophyll in the plants.

POROSITY—A soil's ability to store water.

PRECIPITATION—A water treatment process that separates a suspended substance from the water by changing it into a solid form. Also, condensed water vapor that falls from the air, such as rain, or is deposited on the ground, such as dew.

PUTRESCIBLE—Capable of rotting.

RECHARGE—A natural process by which water is added to a source to form a balance between inflow and outflow of water.

RUNOFF—The part of precipitation that flows along the ground into surface water or through the ground into ground water.

SCHMUTZEDECKE—A thin slime which forms on the top of the sand in slow sand filters; it contains forms of microscopic life that filter out and kill most pathogenic organisms in water.

SEWAGE—All washwater, excreta, and water used to flush excreta that flows from a building or buildings through a sewer pipe and into a septic tank, cesspool, stabilization pond, or sewage treatment plant.

SEWERAGE—A system of sewer pipes and the associated treatment processes that moves washwater, excreta, and water through pipes and into a septic tank, cesspool, stabilization pond, or sewage treatment plant.

SLUDGE—Material that accumulates at the bottom of a settling or sedimentation basin; it is semi-solid but still very liquid.

SPRING—Water flowing naturally from the ground onto the surface of the land or into a body of surface water.

SURFACE WATER—Water that collects or flows on the surface of the earth, such as rivers, ponds and lakes.

TOPOGRAPHY—The surface features of a land area, such as hills, rivers and roads.

TRANSPIRATION—Similar to evaporation except that the water loss comes from stored water in plants; vapor leaves plants through small pores in the leaves.

TURBIDITY—Cloudiness in water caused by very small particles of suspended matter.

VECTOR—A carrier, especially an animal or insect, that transfers an infectious disease from one person to another.

VIRUS—A very small infective agent that causes disease in man.

WATERSHED—The area of ground over which rainfall flows into bodies of surface water.

APPENDIX TWO
"WATER FOR THE WORLD" TECHNICAL NOTES

Human Resources

Rural Water Supply

Operation and Maintenance

RWS.1.O.1	Maintaining Structures for Springs
RWS.1.O.2	Maintaining Intakes
RWS.1.O.5	Maintaining Small Dams
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RWS.2.C.2	Constructing Driven Wells
RWS.2.C.3	Constructing Jetted Wells
RWS.2.C.4	Constructing Bored or Augered Wells
RWS.2.C.5	Constructing Cable Tool Wells
RWS.2.C.6	Maintaining Well Logs
RWS.2.C.7	Testing the Yield of Wells
RWS.2.C.8	Finishing Wells
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SAN.2.P.2	Estimating Sewage or Washwater Flows
SAN.2.P.3	Determining Soil Suitability

Design

SAN.2.D.1	Designing Subsurface Absorption Systems
SAN.2.D.2	Designing Cesspools
SAN.2.D.3	Designing Septic Tanks
SAN.2.D.4	Designing Sewer Systems
SAN.2.D.5	Designing Stabilization Ponds
SAN.2.D.6	Designing a System of Two or Three Stabilization Ponds
SAN.2.D.7	Designing Mechanically Aerated Lagoons
SAN.2.D.8	Designing Non-Conventional Absorption Systems

Construction

SAN.2.C.1	Constructing, Operating and Maintaining Subsurface Absorption Systems
SAN.2.C.2	Constructing, Operating and Maintaining Cesspools
SAN.2.C.3	Constructing Septic Tanks
SAN.2.C.4	Constructing Sewer Systems
SAN.2.C.5	Constructing Stabilization Ponds
SAN.2.C.7	Constructing Mechanically Aerated Lagoons
SAN.2.C.8	Constructing, Operating and Maintaining Non-Conventional Absorption Systems

Operation and Maintenance

SAN.2.O.3	Operating and Maintaining Septic Tanks
SAN.2.O.4	Operating and Maintaining Sewer Systems
SAN.2.O.5	Operating and Maintaining Stabilization Ponds
SAN.2.O.7	Operating and Maintaining Mechanically Aerated Lagoons

Methods

SAN.3.M	Methods of Solid Waste Management

Planning

SAN.3.P	Planning Solid Waste Management Systems

Design

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SAN.3.D.2	Designing a Composting System
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Construction

SAN.3.C.4	Constructing a Biogas System

Operation and Maintenance

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SAN.3.O.2	Operating and Maintaining a Composting System

SAN.3.O.3 Operating a Solid Waste Collection System

SAN.3.O.4 Operating and Maintaining a Biogas System

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DIS.1.P Planning Disease Control Programs

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DIS.2.M.2 Methods of Controlling African Trypanosomiasis

DIS.2.M.3 Methods of Controlling South American Trypanosomiasis

DIS.2.M.4 Methods of Controlling Enteric Diseases

DIS.2.M.5 Methods of Controlling Onchocerciasis

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