IRCWD Report No.08/90

USE OF HUMAN WASTES IN AGRICULTURE AND AQUACULTURE

UTILIZATION PRACTICES AND HEALTH PERSPECTIVES

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[1]Each country chapter is preceded by a detailed list of contents specific to that case

FOREWORD

WHO (Geneva) and IRCWD jointly initiated a project in 1982 whose aim was to assess the health implications of excreta and sludge use in agriculture and aquaculture. This work should complement the activities on resource recovery by the UNDP/World Bank which initiated at about the same time a similar project on wastewater reuse. Both WHO and UNDP/World Bank are faced with increasing demands by authorities in arid and semiarid countries for guidance on the health aspects of waste reuse. These demands originate from the widespread need of many different areas to introduce or to expand and improve the practice of faecal waste use. The immediate rationale for the WHO/IRCWD group, which joined forces with the London School of Hygiene and Tropical Medicine (LSHTM), and the UNDP/World Bank group, was thus to arrive at modern guidelines on the hygienically safe use of faecal wastes. Behind this rationale, there was, however, a far-reaching, overriding objective: wastewater and excreta use should become integral parts of water resources and waste management planning. The reuse of faecal wastes, whether liquid or semi-liquid, as valuable resources should be promoted to the extent dictated by the climatic, socioeconomic and cultural conditions of each specific country or locality.

IRCWD/LSHTM first prepared state-of-the-knowledge reviews on the cultural (Part I), microbiological (Part II) and epidemiological (Part III) aspects of excreta use. Summaries of these reviews are presented in Section 0.3. The epidemiological review revealed very clearly that only a very limited number of reliable epidemiological studies existed at the time, on the basis of which firm guidelines could be formulated, and confirmed the findings by the group of Shuval et al. commissioned by the UNDP/World Bank. An increase in the number of methodologically sound epidemiological studies were deemed desirable and necessary. At the same time, IRCWD/LSHTM considered an in-depth knowledge of the actual reuse practices to be an important prerequisite for the formulation of new guidelines. These two **objectives:** initiating new **epidemiological studies** and **observing and understanding reuse practices and problems,** formed the rationale for the observation and contact missions which Ursula J. Blumenthal of LSHTM and Martin Strauss of IRCWD jointly undertook in 1985. This document "tells the story" of their observations, their deliberations with numerous persons involved in reuse and the study of relevant documents. Some of their information was later complemented and updated through comments and further documentation provided by persons they contacted during their visits.

On one hand, the document is a compilation of case studies which stand on their own, on the other, the authors have spun a "red thread" which allows it to be used as an armchair-guide on excreta and wastewater use. In each case, there is an in-depth discussion on the health implications of the particular use practice, leading to suggestions on how to improve, if necessary, public health protection. It contains comparative observations and deliberations in discussion chapters as well as synoptical views.

WHO and WHO/UNEP published new guideline documents in 1989 (see Section 0.4). They constitute the indirect result of joint project meetings held in 1985 and 1987 in Switzerland among individuals and institutions[1] involved in the applied research and programme management of human waste use.

One important message in those new guideline documents is that **health protection** may be achieved not only by waste treatment, but by a **combination of measures**, including crop restriction, choice of the irrigation or application method, exposure control and waste treatment. This concurs with the observations made in a number of places by Ursula Blumenthal and Martin Strauss. It also takes into consideration the **economic situation** of the less-industrialized countries which precludes, in many instances, the full treatment of all wastes prior to their use.

With this case-study document, IRCWD concludes the series of publications on the health impacts of faecal waste use. It will, however, continue to actively participate in providing advice, disseminate newly acquired knowledge on the subject and promote the new guidelines.

IRCWD is grateful to all the institutions and persons who were involved in this multi-stage project for their fruitful collaboration and support. They include, among many others: Somnuek Unakul, Ivanildo Hespanhol and Gunnar Schultzberg (WHO); Richard Feachem and Sandy Cairncross (LSHTM); Hillel Shuval and Carl Bartone (UNDP/WB); Alex Redekopp and Don Sharp (IDRC); Warren Pescod, Duncan Mara and Piers Cross.

Last but not least, I should like to thank Martin Strauss for his perseverance and diligence in managing the project and in preparing this detailed report, and Ursula Blumenthal for her contributions to the project from the epidemiological perspective, i.e. for providing the health "thread" in a very competent manner.

Duebendorf, September 1990

Roland Schertenleib
Director IRCWD

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[1] WHO, UNEP, World Bank, UNDP, FAO, IDRC, LSHTM and IRCWD

Acknowledgements

We are thankful to a great number of persons who, as individuals or in their official function within particular institutions, have supported the work of this document. At the beginning, many hosted us on our observation and contact tours to the various countries. Our hosts went to great trouble to show us around, bringing us into contact with farmers and farm workers, officials, researchers, and other resource personnel. In many places, we were also given useful and mostly unpublished documents, which complemented our own observations and outcomes of many discussions. Much of it has been included in this document.

The project on health aspects of human excreta use was jointly initiated by WHO and IRCWD in 1982. Over all these years, the collaboration between WHO and IRCWD has been excellent. IRCWD has received valuable support from the WHO staff in the Community Water Supply (CWS) Section, Division of Environmental Health (DEH) as well as from the staff in the WHO Regional Offices in Alexandria and New Delhi, PAHO (Washington, D.C.), CEPIS (Lima) and PEPAS (Kuala Lumpur). The WHO offices helped to establish many of the contacts and provided logistic support to our missions. We wish to thank in particular Dr Ivanildo Hespanhol and Mr Gunnar Schultzberg (DEH/CWS at WHO Headquarters), Ing. Alberto Flórez M. (Director CEPIS), Dr Carl Bartone (formerly at CEPIS), and Dr Somnuek Unakul (former Director, PEPAS). In India, our visits were coordinated by Mr A.K. Roy, former Director of the UNDP/World Bank Technical Advisory Group unit in New Delhi.

Drafts of the case studies were sent for review to the resource persons in the various countries with whom we were in contact during our observation missions. Many of them have spent substantial time and effort in reviewing the drafts, and some also sent us additional documentation. This helped to further complement and update the information contained in this report. The reviewers, to whom we are greatly indebted, are listed below in the sequence of presentation of the case studies in this report.

MEXICO

- Dr Enrique Cifuentes, Inst. Nac. de la Nutrición, Mexico, D.F.

CHILE

- Ing. Julio C. Monreal Min. of Health, Santiago
- Dr Catterine Ferreccio Min. of Health, Santiago
- Prof. Jorge Castillo G. Dept. of Civil Engineering, Univ. of Chile, Santiago
- Dr Oscar Brunser, Univ. of Chile, Inst. for Nutrition and Food Technology (INTA), Santiago

INDIA

- Dr G.B. Shende, Min. of Environment and Forests New Delhi
- Mr M.L. Gupta WHO/SEARO, New Delhi
- Mr K.N. Gupta TAG Interregional Project INT/81/047, New Delhi
- Dr K.P. Krishnamoorti Nat. Environm. Engineering Research Institute, Nagpur
- Mr S.R. Kshirsagar Nat. Environm. Engineering Research Institute, Nagpur
- Dr S.C. Pal, Nat. Institute of Cholera & Enteric Diseases Calcutta
- Prof. B.N. Ghosh, Director All India Institue of Hygiene & Public Health, Calcutta

PERU

- Ing. Alberto Flórez M. Director CEPIS, Lima
- Dr Carl Bartone Infrastructure & Urban Development Dept., The World Bank, Washington
- Blga. Carmen Villanueva R. National University, Ica
- Dr Humberto Guerra, Director, Inst. of Tropical Medicine, Universidad Peruana Cayetano Heredia

ARGENTINA

- Ing. Graciela Fasciolo de Bagini, INCYTH-CELA Mendoza
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SAUDI ARABIA

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- Mrs Ana María Xet Mull
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  Guatemala-City

SOUTH KOREA

- Mr Lee Yoo-won, Nat. Inst. of
  Environmental Research, Seoul

INDONESIA

- Dr Bakir Abisudjak
  Inst. of Ecology, Bandung
- Sri (Ms) Soewasti Soesanto
  Health Ecology Research
  Centre, Jakarta
- Mrs Julie Sulianti, Jakarta
- Eng. Albert Kartahardja, Bandung

The final draft version was reviewed by a selected number of persons to whom we are thankful. They are: Dr Ivanildo Hespanhol (WHO), Dr Sandy Cairncross (London School of Hygiene and Tropical Medicine), Prof. D. Duncan Mara (University of Leeds), Roland Schertenleib and Martin Wegelin (IRCWD).

We thank Prof. M.B. Pescod, reuse specialist and able editor, for taking on the task of preparing the Executive Summary of this voluminous document.

We express our great appreciation to Sylvie Peter for her linguistic revisements of the contributions by Martin Strauss whose English is unavoidably affected by his Swiss mother tongue.
Special thanks go to Brigitte Hauser whose task of processing repetitive drafts of the case studies hardly ever ended, and who very carefully and ably edited the whole document.

Finally, we are very grateful to Roland Schertenleib, who all along provided encouragement and guidance in the preparation of this document. He had, at times, the non-enviable task of helping us get our minds and objectives clear, not "lose the sight of the wood for trees", and get the document out before the end of the 1980-90 Decade. We alone bear the responsibility for having met this last objective at "five to twelve", only.

0. INTRODUCTION

0.1 Scope of the Document[1]

- Objective

The rationale for this document is to familiarize the reader with present practices and patterns of excreta and wastewater use in agriculture and aquaculture. The report reflects the team's observations and impressions of these practices in Latin America, Northern Africa, Western and South-East Asia in the various countries visited between July and December 1985. The observations and impressions were complemented by information retrieved from relevant unpublished and published documents which specifically deal with the subject in the particular countries or areas. The volume is to provide an overview of the range of reuse practices. However, since many of the visits were only quick location "stops", the authors do not claim comprehensive nor exhaustive coverage of the subject. The **aim** of the document is to create a **"picture book"** which, through its illustrative character and the deliberations on health protection, may well provide an "armchair guide" to the various aspects of human waste use. It may thus complement the guideline documents recently published by WHO (1989) and Mara and Cairncross (1989) for UNEP/WHO.

The authors have compiled information on the various use practices and present it in such a way as to enable the reader to find answers to all or almost all of the following **questions** for each of the cases reported about:

Historical Aspects

- What is the rationale for the use of excreta or wastewater?
- How did the practice evolve? Is it based on tradition or has it only just recently been introduced?

Use Pattern

- What is the technical and organizational pattern of excreta or wastewater use (users, mode of collection, distribution and application of the wastes, crops or fish grown)?

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[1] See also the Foreword for a brief history of the Project on health aspects of human waste use.

Health Aspects

- What is the situation regarding excreta-related diseases (type of infection, prevalence, hygiene situation), and what is the potential health impact of excreta or wastewater use?

- Which health protection measures are in operation and which ones could be introduced to reduce adverse health effects of the reuse practice?

Institutions and Regulations

- Who are the authorities and institutions in charge of the various aspects of excreta or wastewater use (collection and distribution of wastes, formulation and enforcement of regulations)?

- What regulations govern the use of excreta or wastewater?

• The Readers

This document will be of interest to all persons concerned with the subject of excreta or wastewater use. These may include officials of government agencies responsible for public health and water resources planning, construction and operation of waste management infrastructure and agriculture. The report might be of interest to persons working in international, bilateral and non-government development organizations as well as in research institutions involved in the development and extension of the use of human wastes, and in the assessment of the health impact of the various practices. The document is also addressed to persons working in the field of environmental protection.

• Structure

The document contains the information obtained and the observations made during visits to excreta or wastewater reuse sites in the following 10 countries:

in Latin America

- Argentina
- Chile
- Guatemala
- Mexico
- Peru

in Northern Africa

- **Tunisia**

in Western Asia

- Saudi Arabia

in South-East Asia

- India
- Indonesia
- South Korea

The selection of countries visited was based mainly on institutional links established through the WHO Headquarters and Regional Offices and on suggestions from persons actively involved in the subject of human waste reuse. With a few exceptions, the report focuses on the situation and needs in less-industrialized countries and areas. Therefore, practices in industrialized countries were not considered for inclusion in the field visits and in this document, although they represent interesting examples of wastewater reuse (e.g. U.S.A., Portugal, Germany, Israel).

The **health perspective** of the varied reuse practices forms one of the "red threads" of the report. This is being emphasized by reflections about health protection measures at the end of each country report. Some of the reflections are informal speculations about the effect of current and the feasibility of additional health protection measures proposed by the authors.

Important and illustrative examples of the use of excreta or wastewater can be found in the countries listed above. In some of them, traditional reuse practices are deeply rooted in the local culture for already many centuries (excreta disposal in fish ponds in Indonesia, e.g.). In others, practices or schemes have been introduced only quite recently (e.g. reuse of treated wastewater in Saudi Arabia). The reader should note that the document is not an exhaustive review of human waste utilization practices but rather a selection of examples. The amount of information available or acquired both through own observations and through documents varies for each country visited. Each of the case studies stands for itself and should be seen intrinsically linked with the local cultural, economic and climatic environment. The pattern of reuse practice is often typical of a particular location and might differ substanially or even be non-existent elsewhere in the country. There are many other countries where human wastes are utilized, however, these have not been included in this document. It was not a purposeful "omission" but was governed by the course of the project and by temporal and financial limitations. Yet, the authors believe that the examples presented in this document do cover a sufficient range of use practices to allow the reader to obtain an overview of the various types of practices and of their dependencies on the local cultural, economic and climatic conditions.

With one exception: in an overview of human waste reuse practices, the reader would certainly expect a case study of **excreta utilization in China**. There, use of the human waste has been made for millenias and is still more widely practised than in other countries. Reportedly, a large proportion (as much as 70% ?) of the excreta produced in rural and urban areas is used as a soil conditioner and fertilizer in agriculture and aquaculture. While, previously, the excreta were applied to the fields untreated, the practice of storing them prior to use has now been widely accepted. Co-composting of excreta with animal manure and crop residues is also practised.

Unfortunately, a case study on excreta use in China could not be included although a comprehensive description of the technical, agricultural, health and cultural aspects of excreta use in this country would doubtlessly be very instructive and enlightening. The reason behind this omission is that the authors did not have the chance of visiting the country in the course of their orientation and contact tours. Also, we were unable to retrieve publications or documents which could compensate for own observations and provide the reader an informative insight into the excreta use practice in China.

The presentation of the descriptive case "histories", forming the main part of this document (Parts A-D), is structured according to the type of waste used and the kind of application, viz:

- **Wastewater use in agriculture**
- **Excreta use in agriculture**
- **Wastewater use in aquaculture**
- **Excreta use in aquaculture.**

Within each part there are examples from different countries showing a variety of practices and a range of health protection measures adopted. It is hoped that readers will compare and contrast the situations in different countries and not just concentrate on examples from a particular region.

The main parts conclude with discussion sections in which the authors have tried to make a qualitative assessment of, among other things, the rationale, the health protection measures and possible health effects, as well as the impact on the local economy and agriculture of the particular use practice, always viewed under the specific local conditions.

Chapter 1, **Introduction**, contains sections in which the resource aspects (Sect. 1.1) and the relevant health issues (Sect. 1.2) are addressed along with the available health protection measures (Sect. 1.3). The latter comprise the microbiological aspects of waste recycling and deal with the risks posed by excreta-related infections.[1] Information is presented regarding excreta-related diseases, the behaviour of excreted pathogens in the environment, i.e. outside the human host, and epidemiological aspects

[1] In this document, the health risks associated with chemically polluted wastewater, i.e. with heavy metals or refractory organic substances have not been taken into consideration. These aspects have been excluded from the project since (i) most municipal wastewaters in developing countries usually do not contain these compounds in significant amounts, and (ii) since a detailed handling of this subject would have been beyond the project's scope. It is, however, dealt with and covered by other specialists and documents.

of human waste use. Also included are the microbiological quality guidelines which have recently been recommended for the reduction of health risks. The "tool-box" of measures available to protect the health of agricultural workers and consumers while making optimal use of excreta and wastewater, is presented and discussed. Most of these measures are already being practised in one place or another.

In the concluding chapters (Part E, Chpts. 16 and 17), the authors have attempted to draw general conclusions about the various reuse aspects from the examples presented in the document. Also, the authors presented their views and suggestions regarding strategies for suitable health protection measures.

- Reference Literature

At the end of each country chapter the authors have listed the documents pertaining to that particular chapter. Many of them are unpublished reports. They were written by persons affiliated with the institutions visited by the authors.

Readers wishing to enter deeper into the subject of human waste reuse with a particular emphasis on practices in less industrialized countries and with a view on health aspects, are referred to the following published documents:

- Mara, D.D., Cairncross, S. (1989). *Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture: Measures for Public Health Protection.*. UNEP/WHO.
  (Obtainable through: WHO, Community Water Supply, CH-1211 Geneva, Switzerland.)

- WHO (1989). *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture.* Report of a Scientific Group. Technical Report Series No. 778.
  (Obtainable through WHO country offices or headquarter.)

- IRCWD (1988). Human Wastes: Health Aspects of their Use in Agriculture and Aquaculture. *IRCWD News* **24/25**, May.
  (Obtainable from IRCWD)

- Shuval, H.I., Adir, A., Fattal, B., Rawitz, E., Yekutiel, P. (1986). *Wastewater Irrigation in Developing Countries: Health Effects and Technical Solutions*. Technical Paper No. 51, The World Bank. (Obtainable from the World Bank, Publications, 1818 H Street, N.W., Washington, D.C. 20433, U.S.A.)

- Cross, P. (1985). *Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part I: Existing Practices and Beliefs in the Utilization of Human Excreta.* IRCWD Report No. 04/85.
  (Obtainable from IRCWD)

- Strauss, M. (1985). *Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part II: Pathogen Survival.* IRCWD Report No. 04/85.
  (Obtainable from IRCWD)

- Blum, D., Feachem, R.G. (1985). *Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part III: An Epidemiological Perspective*. IRCWD Report No. 05/85.
  (Obtainable from IRCWD)

- Edwards, P. (1985). *Aquaculture: A Component of Low Cost Sanitation Technology*. World Bank Technical Paper No. 36.
  (Obtainable from The World Bank)

- Cointreau, J. S. (1987). *Aquaculture with Treated Wastewater: A Status Report on Studies Conducted in Lima, Peru*. Applied Research and Technology, Technical Note No. 3, The World Bank.

- Pescod, M.B., Arar,A.(eds.)(1989). Treatment and Use of Sewage Effluent for Irrigation. *Proceedings of the FAO Regional Seminar on the Treatment and Use of Sewage Effluent for Irrigation*, 7-9 October, 1985, Nicosia, Cyprus. Butterworths.

- Feachem, R.G., Bradley, D.J., Garelick, H. and Mara, D.D. (1983). Sanitation and Disease - Health Aspects of Excreta and Wastewater *Management*. John Wiley & Sons, Chichester/New York.

0.2 Country Background

The world map (Fig. 0.1) below shows the countries which were visited by the authors, and on which case study reports were written and included in this document.

Data on important health and social indicators from these countries have been collected to provide comparative background information about aspects which closely relate to the issue of human waste reuse and its health implications (Table 0.1). The figures on the various indicators and countries are mostly based on official statistics compiled and produced by the respective health authorities. Methods of reporting, accuracy and comprehensiveness of health and disease data vary from country to country. Individual figures should therefore not be taken as absolutely "true", but rather as indicative of the respective indicator. For certain countries and indicators, either the reviewed documents do not contain the respective information or relevant documents could not be traced. In Table 0.1, information from two industrialized countries, Switzerland and U.K., have been included for comparison purposes.

Fig. 0.1 Countries Where Wastewater or Excreta Use is Practised and Which were Visited by the Autors

(This map is based on the Peters Projection. It shows the countries and oceans according to their actual areas).

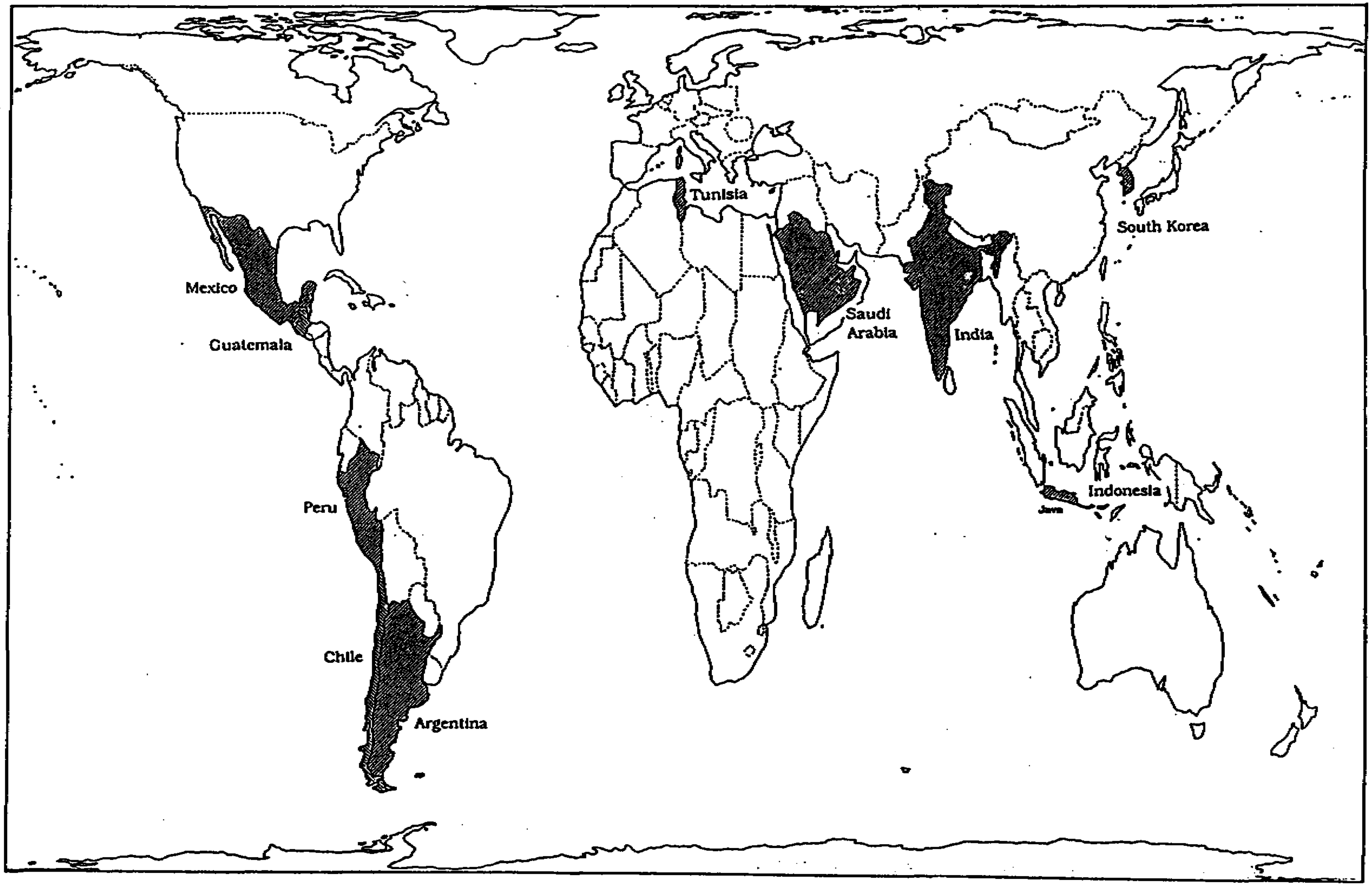


Table 0.1 DATA ON MAJOR HEALTH AND SOCIAL INDICATORS FOR SELECTED COUNTRIES[1]

	Per capita GNP ($, 1986)	Life expectancy at birth (1986)	Infant mortality per 1000 live births	% Infants >2500 g	Probability of death before age 5 per 1000	Doctors per 1000 population	Health expenditure as % of total gov't. expenditure (1986)	Chances per 1000 of dying from:[2] Infectious and parasitic diseases (01-07)	Malignant neoplasms (cancers) (08-14)	Diseases of circulation system ( )	Heart diseases (251, 27, 28)	Diseases of respiratory system (31, 32)	Traffic accidents ( )	% Safe water supply (1983) total	urban	rural	% Sanitary excreta disposal (1983) total	urban	rural
								(letter for year applies to all 6 disease categories)											
Mexico	1960	68	35.2[f]	85.0[a]	77	n.a.	1.4	77.0[f]	86.8	239.5	161.7	114.8	31.2	74	90	40	56	93	12
Chile	1320	71	19.1[i]	93.2[f]	28	8.0[g]	6.0	30.7[i]	171.1	303.8	170.1	123.5	9.1	85	100	18	83	100	10
India	290	57	114.0[c]	70.0[g]	167	3.9[g]	2.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	54	80	47	8	30	10
Peru	1090	60	90.8[h]	91.0[e]	143	9.5[g]	6.1	110.0[e]	103.9	253.4	141.8	182.4	n.a.	52	73	18	35	57	2
Argentina	2350	70	27.5[f]	n.a.	42	27.0[g]	1.3	26.3[h]	179.1	494.8	336.3	64.7	10.6	67	72	19	84	93	37
Tunisia	1140	63	60.0[h]	93.0[g]	121	4.6[i]	7.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	89	98	79	46	66	29
S.Arabia	6950	63	85.0[e]	94.0[g]	120	14.0[i]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	93	100	68	86	100	33
Guatemala	930	61	56.0[h]	90.0[c]	118	4.7[g]	9.5	164.9[g]	54.1	164.8	120.2	161.2	1.3	51	90	26	36	53	28
Korea	2370	69	34.2[f]	90.8[d]	39	8.6[i]	1.5	34.7[h]	142.1	331.3	81.6	47.5	16.8	83	n.a.	n.a.	86	100	33
Indonesia	490	57	98.0[c]	86.0c	235	1.0[f]	1.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	33	40	32	30	30	30
Switzerland[3]	17680	77	6.9[h]	94.8[f]	10	14.6[h]	13.1	8.3[j]	280.8	443.1	311.4	66.7	17.3	99	n.a.	n.a.	85	n.a.	n.a.
U.K.[3]	8870	75	9.4[h]	93.3[f]	12	16.4[h]	12.6	4.0[j]	254.1	479.0	342.6	115.1	9.8	100	-	-	100	-	-

[1]Sources: WHO (1986, 1987, 1988). World Health Statistics. Geneva. The World Bank (1988). World Development Report. Oxford Univ. Press.
[2]Numbers in parentheses for the disease columns refer to the International Classification of Disease (ID9)
[3]Included for comparison purposes n.a. = not available
a - 1978 b - 1979 c - 1980 d - 1981 e - 1982 f - 1983 g - 1984 h - 1985 i - 1986 j - 1987

0.3 Summaries of the Previous Documents in this Series[1]

Cross P. (1985).
Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part I: Existing Practices and Beliefs in the Utilization of Human Excreta, IRCWD Report No. 04/85.

This report highlights cultural differences in excreta management practices, discusses beliefs and habits, and suggests ways to strengthen the role of sociocultural perspectives in programmes dealing with excreta disposal and hygiene-related problems.

Table 0.2 provides an overview of the range of human excreta use practices and indicates the social units which are responsible for this use.

Table 0.2 Range and Examples of Human Excreta Use Practices

Practice	Social Unit	Examples
1. Soil fertilization with untreated or treated stored nightsoil	family or community	China, Korea, Taiwan, Japan, Thailand, India
2. Nightsoil collected and composted for use in agriculture	community or local	China, India
3. Nightsoil fed to animals	family	Melanesia, Africa
4. Use of "composting" or mouldering latrines	family	Vietnam, Tanzania, Guatemala
5. Biogas production	family or community	China, India, Korea
6. Fishpond fertilization with treated or untreated nightsoil	family or community	Taiwan, Korea, China, Malaysia, Indonesia
7. Fish farming in stabilization ponds	family (illegal) or commercial farmer	India (Calcutta), Israel
8. Aquatic weed production in ponds	family, community or local authority	Vietnam, S.E. Asia
9. Agricultural application of treated or untreated wastewater	local authority or commercial farmer	India, Saudi Arabia, Kuwait, Jordan, Tunisia, South Africa, Mexico, Peru, Chile, Argentina, California
10. Irrigation with stabilization pond effluents	local authority or commercial farmer	Jordan, Israel, India, Peru, California
11. Algae production in stabilization ponds	local authority	Mexico, Japan

[1] All three publications are state-of-the-knowledge documents and were prepared on the basis of reviews of published literature.

Three case studies are used to illustrate the cultural variations in excreta utilization and non-utilization practices. These are:

An area in which excreta utilization is an ancient and well-accepted custom (China); an area in which use of excreta is abhorred (certain cultures of Islamic religion); an area in which excreta utilization is little practised but where there are no overriding religious convictions prohibiting its usage either (Subsaharan Africa).

The Chinese case study is perhaps the most remarkable in nutrient reuse, both in the extent of the practice of excreta use and in the pragmatic government policies adopted. The mass programmes to promote sanitation and nutrient reuse are undoubted reflections of a commitment to improving the rural environment and rural production. At the same time, they are consistent with Chinese traditions of frugality, and they propose practices within an ancient framework of ideas regarding excreta disposal and usage. While practices have been made more efficient and appear less injurious to health, the indigenous cultural understanding of relations between man, his bodily products, the fertility of the soil and food production has not changed. Similarly, a reason for the development of double-vault composting latrines in Vietnam is undoubtedly largely attributed to a prior cultural acceptance of the use of human excreta in agriculture.

In contrast to the Chinese tradition, in **Islamic cultures,** Muslims profess the avoidance of all contact with human excreta. Excreta and urine, along with semen, corpses and other specified substances are regarded as spiritual pollutants by Koranic edict, and Islamic custom demands that Muslims minimize contact with these substances. Muslim principles of personal hygiene include: ablution with water after elimination; using only the left hand for contact with the anal area and using the right hand for human contact and when eating; and forbidding contact with (or the consumption of) dogs, pigs or other animals which eat carrion or waste matter. Despite the power, influence and clarity of Islamic law with regard to contact with human wastes, in practice, resource constraints, and religious, ideological and cultural variations lead to different practices. For instance the direct application of nightsoil to fish culture in West Java, Indonesia, is an ancient cultural practice which has altered little under Islamic rule. In other places, the use of wastewater for restricted irrigation has been declared compatible with Islamic precepts provided specific requirements regarding treatment and use are adhered to. As an example, reuse of municipal wastewater is widely practised in Tunisia and in Saudi Arabia, as well as in other Gulf countries.

Subsaharan Africa is shown as an area in which excreta utilization is little practised but where there are no overriding religious convictions prohibiting its usage either. The African continent contains a great diversity of cultures, however, the cultural traits which bind the continent are not subordinate to an embracing system of thoughts as in the Islamic world or in China. Reports from a great many African societies show that a disaffection for contact with human excreta is a custom common to most, if not all African cultures. Human excreta are commonly regarded as defiling, and those who touch them are distanced from the main body of society. As excrements are considered a measure of protection by the body against pollution, in African cities where nightsoil is collected, the municipal workers responsible for bucket collection are often regarded as being of inferior status. Notwithstanding these generalizations, there are several examples of instances of excreta utilization in Africa. Within Africa's sprawling peri-urban populations, there are reports of ingenious informal sector uses for a variety of waste products. Fishing (often illegally) in waste stabilization ponds is reported from several cities (for example the Kenyan city of Kisumu). Fish farming in sewage ponds is also formally endorsed by several local authorities (for example in Lusaka). The formal sale of sewage sludge by local authorities has long been established in many cities, most notably South Africa where there is an extensive public health legislation controlling the use and sale of sludge.

Based on his literature review, the author draws the following **conclusions** and **recommendations**:

Social and cultural problems severely constrain the implementation of several technologies utilizing human excreta that might otherwise contribute to ease resource constraints in poor countries.

The most prominent sociocultural question asked when considering use of human excreta is: is excreta usage culturally acceptable? This is an important question, however, its importance relative to other sociocultural and programme-management questions may have been overstated. Excreta utilization technologies of real benefit to a populace, affordable and not entailing unacceptable social costs, may well gain acceptance even where there are religious or cultural taboos to the concept of using human excreta. It is moreover not a question which can always be simply answered. Firstly, because cultures are rarely homogeneous and frequently contain a complexity of subcultures with quite different orientations. Secondly, because cultures are not fixed entities; values, beliefs and customs change and can be made to change. Thirdly, because the most appropriate study methodology for gathering data on this culturally sensitive area, principally social anthropological field work, has rarely been employed.

Strauss, M. (1985).
Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part II: Pathogen Survival. IRCWD Report No. 04/85

This Report presents compiled information on the survival of excreted pathogens in excreta and faecal sludges prior to utilization (i.e. during storage and treatment), and deals with the fate of these pathogens in the soil, on crops and in nightsoil-enriched fish ponds. The document is partly a complementation of the publication *Sanitation and Disease - Health Aspects of Excreta and Wastewater Management* by Feachem et al. (1983) which is based on literature published prior to 1980. The publication by Strauss considers additional literature published between 1980 and 1983 as well as unpublished reference material.

Pathogen survival outside human hosts depends on the die-off rate of pathogens. This rate is exponential in most instances. It is influenced by the pathogen characteristics (resistance to adverse environmental effects, life cycle) and environmental impacts (e.g. macro and microclimate, type of soil). The die-off rate increases the higher the temperature. Survival times increase in ascending order from protozoa (e.g. *Entamoeba*) to viruses and bacteria, and to helminth eggs (e.g. the roundworm *Ascaris*). During storage and decomposition of excreta in latrines and septic tanks, a certain percentage of pathogens are inactivated. Inactivation varies with each type of pathogen and depends on the period of excreta storage or treatment. Under real-life conditions, faecal contents of typical installations and end products of different types of treatment systems will, in many instances, contain viable excreted pathogens.

In contrast to this, as is illustrated in Table 0.3, the faecal products from disposal systems such as double-vault latrines with urine separation, pour-flush latrines with twin leaching pits or waste stabilization ponds, will under ideal-life conditions be free of viable pathogens with the possible exception of the survival of *Ascaris* eggs in low concentrations.

Table 0.3 Survival of Excreted Pathogens During Pre-Application Storage and Treatment in Warm Climates IDEAL-World Situation (To be aimed at!)

Storage/Treatment System	Ideal-World System Characteristics Relevant for Pathogen Die-off/Survival	Survival of Pathogens			
		Helminths/eggs	Viruses	Bacteria	Protozoa
• Pit-Type Latrines:					
- Pit Latrines w. 1 Pit	Latrine abandoned when pit is full; contents let to rest for t ≥ 1 year	◑[3]	○	○	○
- Pit Latrines w. 2 Pits	t ≥ 1 year	◑[3]	○	○	○
- Double-vault ("Vietnamese"-type) Latrine;	t = 10-12 months; urine separation, dry conditions; use of ash	◑[3]	○	○	○
- Pour-Flush L. w 1 Pit	(Handling of fresh excreta when emptying pit)	●	●	●	●
- Pour-Flush L.w.2 Pits	t ≥ 1 year	◑[3]	○	○	○
• Aqua Privies and Septic Tanks	Continuously operated systems: always contain portions of fresh excreta at times of emptying	●[1]	●[1]	●[1]	●[1]
• Thermophilic Composting	T = 50-70° C, t ≥ 1 day T = 40-45° C, t ≥ 1 week for all parts of waste piles	○	○	○	○
• Biogas Digesters	t ≥ 60 days, T = 30-35° C; effluent draw-off from bulk slurry not from settled sludge	●	◑	◑	○
• Waste Stabilization Pond	t ≥ 20-30 days; min. 3 cells in series; no short-circuiting	○[2]	○[2]	○[2]	○[2]

○ - zero or near-zero survival
◑ - survival in low concentrations
● - survival in substantial "
t - excreta retention time
T - temperature

[1]Survival in the septage
[2]In the treated wastewater (pathogens accumulate in the sludge)

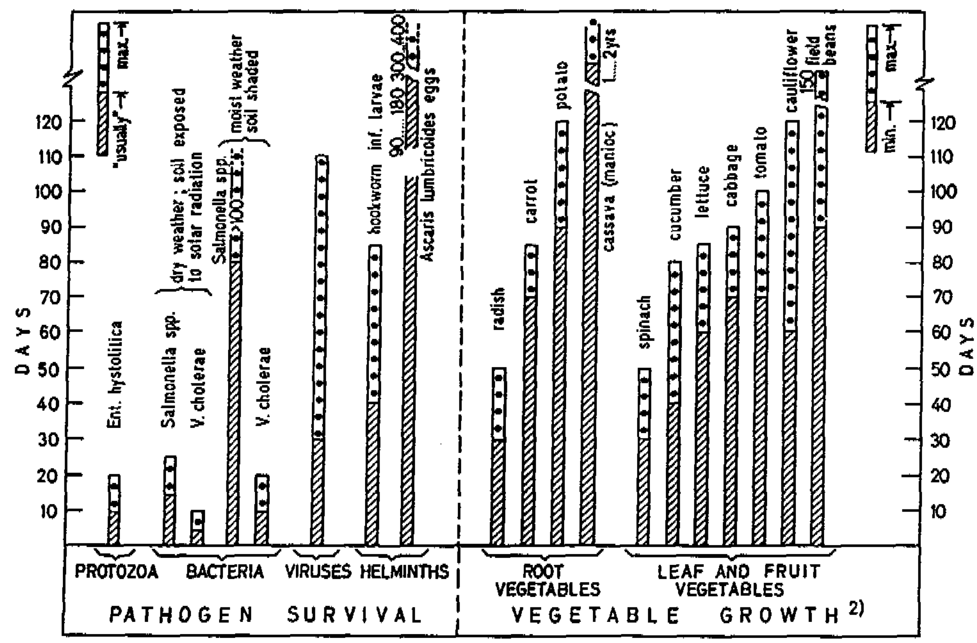
[3]Possible survival of *Ascaris* eggs

The excreted pathogens are subjected to further adverse effects when the stored or pretreated nightsoil is applied to fields. Typical survival periods of freshly excreted pathogens in soil and on crops in warm climates are given in Table 0.4

Table 0.4 Survival Times of Excreted Pathogens in Soil and on Crops in Warm Climates

Type of Pathogen	Survival in Days			
	in Soil		on Crops	
	average	max.	average	max.
Protozoa	10	20	3	10
Bacteria (Salmonellae)	80	>100	25	50
Viruses	30	110	25	60
Worm Eggs (Ascaris)	<180	>300	25	60

Pathogen survival periods on leaf and fruit crops tend to be shorter than the growth periods of most of these plants. In soil, however, survival of viruses, salmonellae and *Ascaris* eggs may exceed the growth period of crops. Viable pathogens are therefore more likely found on root than on leaf crops as is illustrated in Fig. 0.2.



1) Determined under widely varying conditions
2) Maturation period from transplanting or from sowing if not transplanted

Fig. 0.2 PATHOGEN SURVIVAL IN SOIL VS. VEGETABLE GROWTH PERIODS IN WARM CLIMATES[1]

In Table 0.5, recommendations for **excreta storage periods** in warm climates are made based on the current knowledge of pathogen survival in faecal wastes. The minimum storage period which might have to be aimed at in a particular situation would then depend on the local circumstances and on factors such as: type of excreted infections prevalent in the area, local excreta disposal and use patterns, hygiene and dietary habits, as well as socioeconomic considerations.

Table 0.5 Recommendations for Excreta Storage Periods in Warm Climates

Storage Period	Hygienic quality achieved
≥ 2 days	Inactivation of *Clonorchis* and *Opisthorchis* eggs
≥ 1 month	Complete inactivation of viruses,bacteria and protozoa (except, possibly, *Salmonella* on moist, shaded soil); inactivation of schistosome eggs
≥ 4 months	Inactivation of nematode (roundworm) eggs such as hookworm and whipworm (*Trichuris*); survival of a substantial percentage of *Ascaris* eggs
≥ 12-18 months (depending of temp.)	Complete inactivation of *Ascaris* eggs

The following was concluded with respect to potential risks of **bacteria and virus transmission through fish:**

- Muscle of fish grown in excreta-fertilized or wastewater ponds might become invaded by bacteria or viruses if respective concentrations are very high in the pond water. On the basis of the literature reviewed, tentative threshold levels might be set as follows:

  - FC (faecal coliforms): 10^4/100 ml
  - *Salmonella*: 10^5/100 ml

  Other fish organs might become invaded at lower pond water concentrations.

- The potential for invasion of muscle tissue appears to increase with the duration of exposure of the fish to contaminated water. This is probably due to the concentrating effect in the digestive tract.

- Pathogen concentrations might be particularly high in the digestive tract and the intraperitoneal fluid of fish.

- Therefore, even if the fish muscles do not become invaded by pathogens, there are two other potential transmission routes for bacteria and viruses through the persons who handle and gut the fish:

  - The flesh can become cross-contaminated during gutting on accout of high levels of pathogens in the digestive tract and in the intraperitoneal fluid. A potential risk of infection therefore exists if the fish is eaten raw or undercooked.

- The person who guts the fish might become a potential transmitter via routes other than fish (e.g. person-to-person contact, contamination of dishes and food) if personal and domestic hygiene is poor.

Fish can also be transmitters of **helminthic infections** such as clonorchiasis, opisthorchiasis and fascioliasis (see also Fig. A1.2 in Appendix 2) where these are endemic. In the water, cysts develop out of the eggs contained in the human excreta. Transmission occurs if fish harbouring the cysts under their scales are eaten uncooked or undercooked.

As a technical measure to reduce the risk of bacteria and virus transmission, nightsoil might be stored e.g. in alternating-pit or vault latrines prior to its use in ponds to allow bacteria and virus die-off. Water supply improvement, particularly in terms of available quantity, may in the long run contribute to improving hygiene and thereby help lowering the potential risk of disease transmission through persons handling and gutting the fish.

The single most effective measure to control fish-transmitted excreted helminth infections would consist in treating the nightsoil or septage prior to its discharge into the fish ponds. Storage at ambient temperature in warm climates for a minimum of **one week** in areas where *Clonorchis, Opisthorchis* or similar trematodes are endemic is a simple and effective method. Where *Fasciolopsis* is endemic, excreta should be stored for about **3-4 weeks** for the eggs to lose infectivity.

Blum, D., Feachem, R.G. (1985).
Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part III: An Epidemiological Perspective. IRCWD Report No. 05/85.

For most excreted pathogens, there are several alternate potential transmission routes. The route via excreta-fertilized soil, crops or fish ponds is but one of them. The important determinants of actual transmission of excreta-related infections are hygiene customs, dietary habits, the custom to eat or not eat uncooked food, vegetable fertilization practice, food marketing patterns, and the host's susceptibility to infection.

The review of epidemiological literature revealed that only a few studies have been published on the epidemiology and on actual - as opposed to potential - health risks of human waste utilization. Most of the reported investigations have methodological shortcomings. Moreover, they almost exclusively focus on helminth (worm) infections and on raw or minimally treated excreta. There is nevertheless reasonably good epidemiological evidence that utilization of **raw** nightsoil or sludge in agriculture may lead to the transmission of hookworm or *Schistosoma* (an occupational risk), and *Ascaris* or *Trichuris* (a risk associated with consumption) in areas where these infections are endemic.

Table 0.6 below summarizes the epidemiological knowledge regarding infectious disease risks from **raw nightsoil or sludge use in agriculture.** The equivalent information for **aquaculture** is contained in Table 0.7

Table 0.6 Current Epidemiological Evidence of Excreted Infection Transmission Risks from the Utilization of Raw Excretra in *Agriculture* (after Blum and Feachem 1986)

Exposure Group	Transmission risks from nightsoil or sludge fertilization of: Crops for humans	Crops for animals	Non-consumable crops
• Persons consuming crops	V △B □P ○N	-	-
• Persons consuming meat or milk	-	△B ○C	-
• Those working on excreta-fertilized fields or sites	V̲ B P ○N ○T	V̲ B P ○N	V̲ B P ○N

V - Viruses
B - Bacteria
P - Protozoa
N - Nematodes
C - Cestodes
T - Trematodes
\- - not applicable

V - *Potential* risk; no epidemiological data
○ - *Actual* risk supported by epidemiological data
△ - Actual risk likely according to the waste water epidemiological data
□ - Actual risk reported but insufficient epidemiological data for confirmation
V̲ - Actual risk inconsistently supported by epidemiological data

Table 0.7 Current Epidemiological Evidence of Excreted Infection Transmission Risks from the Utilization of Raw Excretra in *Aquaculture* (after Blum and Feachem 1986)

Exposure Group	Transmission risks from excreta or nightsoilfertilized ponds		
	Crops[1] for humans	Crops[1] for animals	Non-consumable crops
• Persons consuming crops	V B P C (T)	-	-
• Persons consuming meat or milk	-	B	-
• Those fishing or harvesting in excreta-fertilized ponds	V B P T	V B P T	V B P T

[1] Fish or plants grown in ponds

V - Viruses
B - Bacteria
P - Protozoa
C - Cestodes
T - Trematodes
\- - not applicable

V - *Potential* risk; no epidemiological

◯ - *Actual* risk supported by epidemiological data

0.4 Abbreviations

BOD	Biochemical oxygen demand
DO	Dissolved oxygen
DTC	Digestive tract content
EC	Electrical conductivity
FC	Faecal coliforms
lcd	Litres per capita and day
lps	Litres per second
MM^3	Million cubic meters
MPN	Most probable number
PF	Peritoneal fluid
STP	Sewage treatment plant
TC	Total coliforms
WSP	Waste stabilization pond(s)

1. BACKGROUND

1.1 Human Wastes as a Resource

The document contains examples of how people practise the use of human "wastes", i.e. of excreta or wastewater, in different parts of the world. This extends from the traditional practice of excreta recycling for vegetable cultivation or fish raising, to the reuse of treated wastewater in newly designed, well-managed schemes which have only just recently been implemented. The value of excreta lies both in their organic substance, which helps maintain the soil's humus fraction, and in their content of essential nutrients such as phosphorus, nitrogen and potassium.

Wastewater is used mainly because of its "water value" as it either replaces freshwater which has become scarce (e.g. overpumped groundwater) or because it constitutes the only available and economical water source in a particular area. Besides, wastewater is also a supplier of nutrients and can therefore partly or even fully replace mineral fertilizer. Thus, the term "wastes" is misused in this context, as it designates material or substances which are neither recyclable within the natural cycles of water and elements, nor of further use. Excreta and wastewater, however, when used in agriculture and aquaculture, as illustrated in this document, are components of closed cycles of organic material and water and are therefore true **resources** rather than wastes.

Table 1.1 Nutrient Values of Some Organic Fertilizers

	Nutrient content (% of dry matter)[1]		
	N_{tot}	P_2O_5	K_2O
• Fresh human excreta[2]	10.4-13.1	2.7-5.1	2.1-3.5
• Fresh cattle manure	0.3- 1.9	0.1-0.7	0.3-1.2
• Pig manure	4-6	3-4	2.5-3
• Chicken manure	6	5	2.7
• Plant residues	1-11	0.5-2.8	1.1-11

1 Figures are taken from miscellaneous sources and relate to widely varying conditions
2 Comprises faeces and urine

Excreta are to be valued both because of their **nutrient content** and because of their **soil-conditioning and humus-building potential.** The nutrient content might be used to establish an order-of-magnitude estimate of a family's **fertilizing potential.** Based on a daily excreta production of 110 g/person (dry weight) and on the nutrient contents as indicated in Table 1.1 (Strauss 1985), the estimate for a family of 5 "adult equivalents" can be calculated as indicated in Table 1.2.

Table 1.2 Excreta Fertilizing Potential of a 5-Adult Family in Rice Cultivation

	N	P_2O_5	K_2O
• Nutrient content on dry weight basis (%)	8*	3.5	2.5
	(*assuming that 30-50% of the nitrogen contained in the urine are lost as ammonia gas during anaerobic fermentation)		
• Daily per capita production (g/cap,d)	8.8	3.8	2.7
• Yearly production by 5 adults (kg/yr)	16	6.9	4.9
• Nutrient requirement for rice cultivation (kg/ha,yr)[1]	98	34	80
• **Rice cultivation area fertilizable by the 5-adult family (m^2)**	**1600**	**2000**	**600**

[1] (Ministry of Foreign Affairs, France 1984; figures indicate orders of magnitude only)

These figures indicate that through their excreta, a family of 5 adult equivalents theoretically produces enough nitrogen and phosphorus to cultivate a rice plot ranging between 40 x 40 m and 40 x 50 m in size - indeed a considerable area! For maize, this amount could fertilize 20-30% less surface area, while for soybeans it would be sufficient for 25-50% more land.

Similar reflections can be made with regard to the reuse of **wastewater.** Here, the question raised deals with the amount of hectares which can be cultivated with the effluent of **1000 persons**, e.g.. Table 1.3 contains an estimate based on the following underlying assumptions:

- Crop water requirement:

  - rice : approx. 2000 mm/yr
  - vegetable: " 7-800 mm/yr
  - maize : " 3-400 mm/yr

- Per capita sewage production: 100 l/d

Table 1.3 Fertilization and Watering Potential through the Wastewater of 1000 Inhabitants

	N	P_2O_5	K_2O
• Nutrient concentration (after Mara & Cairncross 1987) mg/l	15	6.9 (3 mg P/l)	29 (20 mg K/l)
• Yearly nutrient load produced by 1000 persons kg/yr	547	252	1058
• Nutrient requirement for maize cultivation kg/ha,yr	114	43	125
• **Maize cultivation area fertilizable on a nutrient supply basis ha**	**4.8**	**5.9**	**8.5**
• **Area irrigable on the basis of crop water demand:**			
- maize	**9.0 ha**		
- vegetable	**4.6 ha**		
- rice	**1.8 ha**		

Thus, if maize is irrigated on the basis of irrigation water requirements, N and P are the limiting factors, and plant nutrient requirements can be satisfied up to about 60% only. In this case, crop yields might be somewhat curtailed. On the other hand, the farmer may want to complement the organic fertilizer with some mineral fertilizer. For the irrigation of soybeans, the situation differs completely: water and nutrients requirements are provided by the wastewater in balanced proportions. In the case of rice cultivation, where water requirements are higher than for other crops, water is the limiting element and a considerable nutrient proportion, particularly nitrogen, might be lost through seepage, as the soil cannot "store" nitrogen compounds.

The above reflections show that excreta and wastewater are indeed precious resources. They not only supply essential nutrients, but contribute through their humus-building capacity - a characteristic not shared by mineral fertilizers - to the restoration or conservation of soil productivity on a long-term basis. The use of excreta and wastewater can therefore help secure the production basis or the subsistence of farmers and enhance the agricultural economy as a whole. Finally, the reuse of wastewater helps to reduce or avoid overutilization of scarce freshwater sources and surface water pollution.

In order to make use of these resources safely, adequate measures need to be taken to provide protection against the transmission of communicable diseases. This is dealt with in Section 1.3 below.

1.2 Disease Aspects

In this Section, the state of current knowldge and ideas on disease aspects of wastewater and excreta use in agriculture and aquaculture and on suitable guidelines and health protection measures will be described. Parts of this have been abstracted from the executive summary of the recent UNEP/WHO guideline publication (UNEP/WHO 1989) and from the new WHO guidelines for wastewater reuse (WHO 1989). The Section provides the foundation on which the assessment of health risks of the particular practices described from different countries is based.

• Health Risks

In developing countries, excreta-related diseases are very common, and excreta and wastewater contain correspondingly high concentrations of excreted pathogens - the bacteria, viruses, protozoa, and the helminths (worms) that cause disease in man. There are approximately thirty excreted infections of public health importance (see Annex 1), and many of these are of specific importance in excreta and wastewater use schemes. However, the agricultural or aquacultural use of excreta and wastewater can only result in an **actual** risk to public health if **all** of the following occur:

(a) that **either** an infective dose of an excreted pathogen reaches the field or pond, **or** the pathogen multiplies in the field or pond to form an infective dose;
(b) that this infective dose reaches a human host;
(c) that this host becomes infected; and
(d) that this infection causes disease or further transmission.

If (d) does not occur, then (a), (b) and (c) can only pose **potential** risks to public health.

The sequence of events required for an actual health risk to be posed is summarized in Fig.1.1, together with the pathogen - host properties and interactions that influence each step in the sequence. If the sequence is broken at any point, then the potential risks cannot combine to constitute an actual risk. This is the rationale behind the various methods of public health protection discussed in Section 1.3.

Excreted Load

↓
- latency
- multiplication
- persistence
- treatment survival

Infective Dose Applied to Land/Water

↓
- persistence
- intermediate host
- type of use practice
- type of human exposure

Infective Dose Reaches Human Host

↓
- human behaviour
- pattern of human immunity

Risks of Infection and Disease

↓
- alternative routes of transmission

Public Health Importance of Excreta and Wastewater Use

Figure 1.1 Pathogen - Host Properties Influencing the Sequence of Events Between the Presence of Pathogens in Excreta or Wastewater and Measurable Human Disease Attributable to Excreta or Wastewater Use (Blum and Feachem 1985)

The actual risks to public health that occur through waste reuse can be divided into three broad categories - those affecting consumers of the crops grown with the waste (**consumer risk**), those affecting the agricultural workers who are exposed to the waste (**worker risk**), and those affecting populations living near to a waste reuse scheme (**nearby population risk**). Where wastewater irrigation is unrestricted, so that all types of edible crops can be grown, then both consumer risk and worker risk are of interest. If irrigation of certain crops, such as vegetables eaten raw, is restricted, then this prevents the risk to consumers; in this situation only the worker risk needs to be considered.

It is now possible to design and implement schemes for human wastes reuse that do not pose any risk to public health, but this requires an understanding of the epidemiology of the excreted infections in relation to wastes reuse. In this way, adequate standards for the microbiological quality of excreta and wastewater intended for reuse can be established, in order that public health can be properly protected.

• The Epidemiological Evidence

The actual public health importance of an excreta or wastewater use practice can only be assessed by an epidemiological study to determine whether or not it results in an incidence or prevalence of disease, or intensity of infection, that is measurably in excess of that which occurs in its absence. Such studies are methodologically difficult, and there have been only a few well-designed epidemiological studies on human wastes reuse.
Most of the available evidence concerns wastewater irrigation, and there is much less information about excreta use in agriculture and about aquacultural use.

Wastewater irrigation. All the available epidemiological studies on crop irrigation with wastewater have been critically reviewed in a recent UNDP/World Bank report (Shuval et al. 1986), and the most important conclusions of this study can be summarised as follows:

- Crop irrigation with **untreated** wastewater causes significant excess infection with intestinal nematodes in both consumers of the irrigated crop and those who work in the irrigated fields. The latter, especially if they work barefoot, are likely to have more intense infections, particularly of hookworms, than those not working in wastewater irrigated fields.

- Crop irrigation with adequately **treated** wastewater does not lead to excess intestinal nematode infection amongst field workers or consumers.

- Cholera, and probably also typhoid, can be effectively transmitted by the irrigation of vegetables with untreated wastewater.

- Cattle grazing on pasture irrigated with raw wastewater may become infected with beaf tapeworm, but there is little evidence for actual risks of human infection.

- There is limited evidence that the health of people living near fields irrigated with raw wastewater may be negatively affected either by direct contact with the soil, or indirectly through contact with farm labourers; in communities with high standards of personal hygiene such negative impacts are usually restricted to an excess incidence of benign gastroenteritis, often of viral aetiology, although there may also be an excess of bacterial infections.

Table 1.4 Relative Health Risks from Use of **Untreated** Excreta and Wastewater in Agriculture and Aquaculture

(Source: "The Engelberg Report", IRCWD 1985)

Class of pathogen	Relative amount of excess frequency of infection or disease
1. Intestinal nematodes: • *Ascaris* • *Trichuris* • *Ancylostoma* • *Necator*	High
2. Bacterial infections: • Bacterial diarrhoeas (e.g. cholera, typhoid)	Lower
3. Viral infections: • viral diarrhoeas • hepatitis A	Least
4. Trematode and cestode infections: • schistosomiasis • chlonorchiasis • teaniasis	From high to nil, depending upon the particular excreta use practice and local circumstances

- Sprinkler irrigation with treated wastewater may promote the aerosolized transmission of excreted viruses, but disease transmission is likely to be rare in practice since most people have high levels of immunity to viral disease endemic in their community.

It is clear from these findings that, when **untreated** wastewater is used to irrigate crops, there are high actual health risks due to intestinal nematodes and bacteria, but little or no risks due to viruses (Table 1.4). It is also clear that wastewater treatment is a very effective method of safeguarding public health.

Excreta Use in Agriculture

The epidemiological evidence on the agricultural use of excreta has been extensively reviewed in a recent report (Blum and Feachem 1985). The conclusions of this study are very similar to those of the UNDP/World Bank study on wastewater irrigation, and can be stated as follows:

- Crop fertilization with **untreated excreta** causes significant excess infection with intestinal nematodes in both consumers and field workers;

- There is evidence that **excreta treatment** can reduce the transmission of nematode infection;

- The excreta fertilization of rice paddies may lead to excess schistosomiasis infection amongst rice farmers; and

- Cattle may become infected with tapeworm, but are unlikely to contract salmonellosis.

Aquaculture use

Blum and Feachem (1985) also reviewed the epidemiological evidence for disease transmission associated with the aquacultural use of excreta and wastewater. The conclusions of this study are less certain than those concerning wastewater and excreta use in agriculture, due to the limited amount and quality of the available data. There is clear epidemiological evidence for the transmission of certain trematode disease, principally *Chlonorchis* (oriental liver fluke) and *Fasciolopsis* (giant intestinal fluke), but none was found for schistosomiasis (bilharzia) transmission, which is nonetheless a major potential risk to those who work in excreta-fertilized ponds. Nor was any conclusive evidence found for disease transmission by passive transference of the pathogens by fish and aquatic vegetables, but this too, remains a potential risk.

- Microbiological Quality Criteria for Wastewater Use

If excreta and excreta-derived products (such as wastewater sludges, compost, septage and latrine contents) are applied to the field prior to the planting of crops, then no quality guidelines are necessary, provided that:

- the wastes are placed in trenches and covered with at least 25 cm of soil;
- farm and sanitation workers are adequately protected during this process;
  and
- root crops are not planted directly over the trenches.

If the waste products are not buried in trenches but are applied as a top soil dressing (as is common with composts, for instance), or if they are regularly applied to the soil after planting has occurred (as is usually the case with liquid nightsoil), then the WHO guidelines for wastewater irrigation should be observed and interpreted as either $\leqslant$ 1 egg per litre or kg (wet weight) and $\leqslant$ 1000 faecal coliforms per 100 ml or 100 g (wet weight), as appropriate. Nightsoil treatment to achieve the helminth standard for restricted use can be achieved by storage for at least one year. Thermophilic composting is an effective way to achieve the standard of $\leqslant$1000 faecal coliforms per 1000 g for unrestricted use.

In the 1960's and 1970's, a microbiological approach to health risks was dominant, concentrating on potential risks and not actual risks, and strict guidelines were set where wastewater was to be used to irrigate crops eaten raw. In California (State Department of Health 1968), this was set at the minimum bacterial (indicator) concentration detectable by routine monitoring ($\leqslant$ 2.2 coliforms/100 ml), and was meant to indicate that the wastewater was pathogen free. A few years later, a WHO Meeting of Experts set guidelines for treatment methods (WHO 1973). For crops eaten raw, the level practically achievable with chlorination after conventional treatment was set, that is, 100 coliforms/100 ml. In the 1980's, this was deemed to be an overly restrictive approach, using a higher safety margin than was necessary and efforts were started to gather and assess the epidemiological evidence of health risks, and to propose more realistic guidelines based on it.

In 1989, a WHO Scientific Group formulated new guidelines for wastewater use in agriculture and aquaculture which are summarized in Table 1.5 (WHO 1989). They are based on preliminary recommendations made by a group of sanitary engineers, epidemiologists and sociologists in Engelberg in 1985 (IRCWD 1985). The main consideration was given to the fact that in many developing countries the **main actual health risks** associated with human waste use, as pointed out above, are associated with **helminthic diseases** and that the safe use of wastewater in agriculture or aquaculture will therefore require a high degree of helminth removal. For agricultural use, these guidelines introduced a new, stricter approach concerning the need to reduce numbers of **helminth eggs** (*Ascaris* and *Trichuris* species and hookworms) in effluents to a level of one or less per litre. This means that some 99.9% of helminth eggs must be removed by appropriate treatment processes in areas where helminthic diseases are endemic and constitute actual health risks (field studies indicate that helminth concentrations are rarely greater than 1000 per litre, even in endemic areas). Stabilization ponds with a retention time of 8-10 days are particularly effective in achieving this but other technologies are also available. While not all helminths and protozoa of public health importance are referred to specifically in the guidelines (for example the protozoa *Amoeba* and *Giardia* species are not mentioned), the intestinal nematodes covered should serve as indicator organisms for all of the large settleable pathogens (including amoebic cysts); other pathogens of interest apparently become non-viable in long-retention pond systems. It is thus implied by the guidelines that all helminth eggs and protozoan cysts will be removed to the same extent.

Based on current epidemiological evidence, a **bacterial guideline** of a geometric mean of **1000 faecal coliforms per 100 ml for unrestricted irrigation** of all crops is recommended. This was considered to be technologically feasible. The Group concluded that no bacterial guideline need be recommended in cases where farm workers are the only exposed population, since there is currently little or no evidence indicating a risk to such workers from bacteria; nevertheless, some degree of reduction in bacterial concentration is desirable in wastewater used for any purpose.

The guideline values given in Table 1.5 must be carefully interpreted and, if necessary, modified in the light of local epidemiological, sociocultural and environmental factors. Greater caution may be justified where there are significant exposed groups that are more susceptible to infection than the population at large, such as people lacking immunity to the local endemic infections. On the other hand, some degree of flexibility may sometimes be justified. For example, where intestinal helminths are not endemic, an egg removal efficiency of 99.9% is not necessary.

The reader is referred to the full report of the Scientific Group for further discussion and interpretation of the suggested guidelines (WHO 1989).

Table 1.5 Recommended Microbiological Quality Guidelines for Wastewater Use in Agriculture (WHO 1989)[1]

Category	Reuse conditions	Exposed group	Intestinal nematodes (arithmetic mean no. of eggs per litre[3])	Faecal coliforms (geometric mean no. per 100 ml[3])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[4]	Workers, consumers, public	$\leqslant 1$	$\leqslant 1000$[4]	A series of stabilization ponds dedesigned to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[5]	Workers	$\leqslant 1$	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

1 In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly

2 *Ascaris* and *Trichuris* species and hookworms

3 During the irrigation period

4 A more stringent guideline ($\leqslant$ 200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.

5 In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

A number of helminth infections are of concern in connection with **waste-fed aquaculture.** Transmission of schistosomiasis can occur when people wade in fish ponds in which infected snails are present, and the larval schistosome penetrates the human skin. Transmission of *Clonorchis* (liver fluke) species can occur when particular species of fish which are infected are eaten raw or undercooked, and the cysts in the fish flesh hatch out in the human gut. With some helminth infections, cysts are formed on edible aquatic plants (for example, *Fasciolopsis* species encyst on water caltrop), and transmission can occur when the fruit of the plant is eaten. Transmission of clonorchiasis and fascioliasis is known to occur only in restricted geographical areas in eastern Asia. Given the cultural preference in some of these areas for eating fish and aquatic vegetables uncooked, transmission can be prevented only by ensuring that no eggs enter the pond or by snail control. The latter is unlikely to be achieved at all times in practice, especially in the small subsistence ponds common in Asia, so that the only feasible means of control is to remove all viable trematode eggs from the wastewater before it enters ponds. **All** eggs must be rendered non-viable because the parasites multiply asexually on an enormous scale within their first intermediate host. Similar considerations apply to the control of schistosomiasis, a disease that is endemic over a much wider geographical area. The appropriate **helminth quality guideline** for all aquacultural use of wastewater is thus the **absence of viable trematode eggs.** This can be achieved by stabilization pond treatment.

Fish grown in excreta-fertilized or wastewater ponds may also become contaminated with bacteria and viruses. These are passively carried on the scales, or in the gills, intraperitoneal fluid, digestive tract or muscle of the fish. If fish are eaten raw or undercooked, transmission of bacterial or viral infections may then occur.

A review of the literature on the survival of pathogens in and on fish (Strauss 1985) showed that:

(1) Invasion of fish muscle by bacteria is likely to occur when the fish are grown in ponds containing concentrations of faecal coliforms and salmonellae greater than 10^4 and 10^5 per 100 ml, respectively, the potential for muscle invasion increasing with the duration of exposure of the fish to contamined water.

(2) Some evidence suggests that there is little accumulation of enteric organisms and pathogens on, or penetration into, edible fish tissue when the faecal coliform concentration in the fishpond water is below 10^3 per 100 ml.

(3) Even at lower contamination levels, high pathogen concentrations may be present in the digestive tract and the intraperitoneal fluid of the fish.

There are, in general, only limited experimental and field data on the health effects of sewage-fertilized aquaculture. Further work is needed, therefore, before a definitive bacteriological quality standard can be established for pisciculture. In the light of this, **a tentative bacterial guideline** of a geometric mean number of faecal coliforms of $\leq 10^3$ per 100 ml has been recommended for fish-pond water (WHO 1989). In view of the dilution of wastewater which occurs in most fish-ponds, this ambient bacterial indicator concentration can normally be achieved by treating the wastewater-fed water to a level of 10^3-10^4 faecal coliforms per 100 ml. The same faecal coliform standard should be applied to pond water in which aquatic vegetables (macrophytes) are grown, because they are eaten raw in some areas.

This bacterial guideline should ensure that invasion of fish muscle is prevented. Pathogens may, however, accumulate in the digestive tract and intraperitoneal fluid of fish and may then pose a risk to consumers through cross-contamination of the fish flesh or other edible parts if standards of hygiene in fish preparation are inadequate. A further necessary public health measure, therefore, is to ensure that high standards of hygiene are maintained during fish handling and especially gutting. Cooking of fish, which is a common practice in most areas where waste-fed aquaculture exists, is an important safeguard.

1.3 Health Protection Measures

It is necessary, as well as possible, to consider ways for the protection of human health other than waste treatment, especially where economic constraints are felt. **Four options** for health protection should be considered. These are:

- waste treatment
- restriction of the crops grown
- choice of methods of application of the wastes to the crops
- control of human exposure to the wastes.

The points at which these four health protection measures can interrupt the potential transmission routes of excreted pathogens are shown in Fig.1.2. While full treatment stops excreted pathogens from even reaching the field or fishpond to which the wastes are applied, crop restriction and human exposure control act later in the pathway, preventing excreted pathogens from reaching the persons concerned, i.e. the crop consumers and the agricultural workers.

It will often be desirable to apply a combination of several methods. The technical factors affecting each option are discussed below, although the administrative and financial factors are equally important (Mara and Cairncross 1989). With reference to the new microbiological quality guidelines for wastewater use listed in Table 1.5 (WHO 1989), waste treatment is considered for the use category A, waste treatment and crop restriction for category B and choice of application measures and human exposure control for category C.

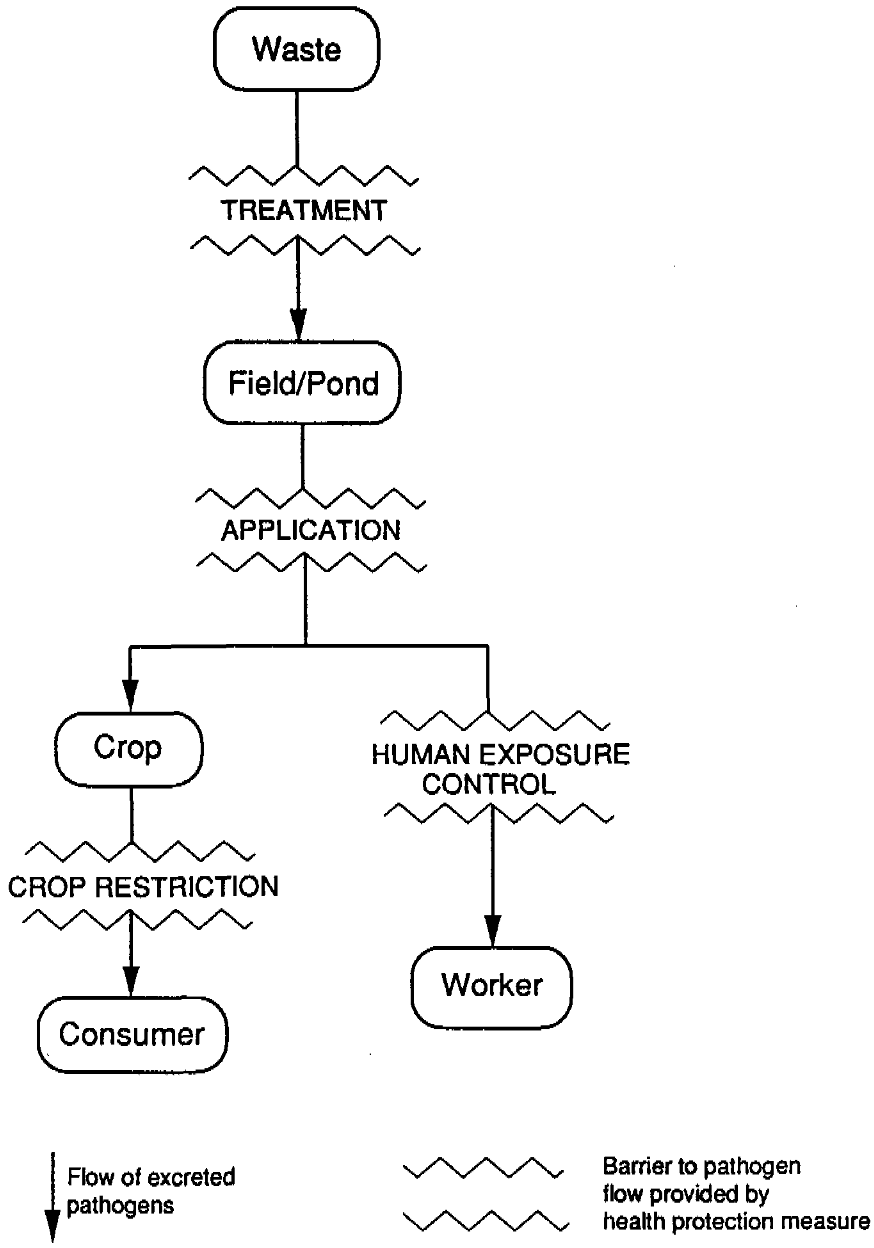


Fig. 1.2 Flow Diagram to Show the Potential Transmission of Excreted Pathogens and Points at which Different Health Protection Measures Can Interrupt the Pathogen Flow.
(Mara and Cairncross 1989)

WASTE TREATMENT

The degree of removal of pathogens or indicator organisms by a waste treatment process is best expressed in terms of $\log_{10}$ units. To achieve the WHO Guideline quality for unrestricted irrigation (category A), a bacterial reduction of at least 4 log units, and a helminth egg removal of 3 log units are required. Helminth removal alone will be sufficient to protect field workers. A lesser degree of removal can be considered if other health protection measures are envisaged, or if the quality will be further improved after treatment. This can occur by dilution in naturally occurring water, by prolonged storage, or by transport over long distances in a river or canal.

Conventional processes (plain sedimentation, activated sludge, biofiltration, aerated lagoons, and oxidation ditches) are not able, unless supplemented by disinfection, to produce an effluent which complies with the WHO bacterial guideline for unrestricted irrigation. Moreover, conventional mechanical and biological wastewater treatment systems are only partly effective for helminth egg removal.

Waste stabilization ponds are usually the method of wastewater treatment of choice in warm climates wherever land is available at reasonable cost. A series of ponds with a total retention time of about 11 days can be designed to achieve adequate helminth removal, while about twice that time, depending on temperature, would usually be required to reach the bacterial guideline. The high degree of confidence with which pond series can meet WHO Guidelines is only one of the many advantages of pond systems. Others are low cost and simple operation. The only disadvantage of pond systems is the relatively large area of land that they require.

Disinfection - usually chlorination - of raw sewage has never been achieved in practice with full success. It can be used to reduce the numbers of excreted bacteria in the effluent from a conventional mechanical/-biological treatment plant if the plant is operating well. However, it is extremely difficult to maintain a high, uniform and predictable level of disinfecting efficiency. In any case, chlorination will leave most helminth eggs totally unharmed.

Other problems are the cost of chlorine and the formation of chlorinated organic compounds which are toxic and cancerogenic. A more appropriate tertiary treatment option is to add one or more ponds in series to a conventional treatment plant. The addition of **polishing ponds** is a suitable measure to upgrade an existing wastewater treatment plant.

Excreta storage or treatment. No treatment is required for excreta if they are placed in trenches prior to the start of the growing season. The handling of untreated excreta, however, carries the risk of disease transmission if the necessary precautions are not taken. To achieve the guideline for helminthic quality, the excreta must be stored for a period of at least 12-18 months, depending on the ambient temperatures. An alternative is the direct treatment of nightsoil and septage in waste stabilization ponds.

Thermophilic co-composting of excreta with other organic material such as cattle manure, plant residues or organic municipal waste, may be used to reduce storage periods required to achieve a hygienically safe product. With temperatures rising to 55-70°C, hygienization may be achieved in about one month.

CROP RESTRICTION

Agriculture

If the WHO quality guideline is not fully met, it may still be possible to grow selected crops without risk to the consumer. Crops can be grouped into three broad categories with regard to the degree to which health protection measures are required:

Category A - Treatment to WHO guidelines for "unrestricted" irrigation is essential: This covers fresh vegetables, spray-irrigated fruits, parks, lawns and golf courses.

Category B - Protection needed only for field workers: This includes industrial crops such as cotton, sisal, grains, and forestry, as well as food crops for canning, fodder crops, pastures and trees.

Category C - Localized (drip or bubbler) irrigation preventing the exposure of workers and consumers: Health protection measures are not required but pretreatment is necessary to facilitate the operation of the irrigation installations.

Irrigation which is limited to certain crops and conditions, such as Category B, is commonly referred to as **restricted** irrigation.

Crop restriction is a strategy to provide protection to the consuming public. However, it does not provide protection to farmworkers and their families. Crop restriction is therefore not adequate on its own; it should be complemented by other measures, such as partial waste treatment, controlled application of the wastes, or human exposure control. Partial treatment to meet the helminth standard of the quality guideline would be sufficient to protect field workers in most settings, and be cheaper than full treatment.

Crop restriction is feasible and is facilitated in several circumstances, including the following cases:

(i) Where a law-abiding society or strong law enforcement exists.

(ii) Where a public body controls allocation of the wastes.

(iii) Where an irrigation project has strong central management.

(iv) Where there is adequate demand for the crops allowed under crop restriction, and where they fetch a reasonable price.

(v) Where there is little market pressure in favour of excluded crops (such as those excluded in Category C).

Aquaculture

Health risk minimization through crop restriction is not as straightforward in the case of aquaculture as it is for agricultural use. Most cultured aquatic macrophytes and some fish are sometimes eaten raw so that the agricultural option of not using excreta or wastewater for food crops is often not feasible, especially in small scale subsistence aquaculture.

METHODS OF APPLICATION OF WASTEWATER AND EXCRETA

Wastewater in agriculture

Irrigation water, including treated wastewater, can be applied to the land in the five following general ways:

- By flooding (border irrigation), thus wetting almost all the land surface.
- By furrows, thus wetting only part of the ground surface.
- By sprinklers, in which the soil is wetted in much the same way as by rain.
- By subsurface irrigation, in which the surface is wetted little, but the subsoil is saturated.
- By localized (trickle, drip or bubbler) irrigation, in which water is applied at each individual plant at an adjustable rate.

Flooding involves the least investment, but probably involves the greatest risk to field workers.

If the water is not of WHO bacterial quality, but if it is desired to use it on fruit trees and vegetables eaten pealed or cooked, sprinkler irrigation should not be used. Also in this case, border irrigation should not be used for vegetables.

Subsurface or localised irrigation can give the greatest degree of health protection as well as using water more efficiently and often producing higher yields. However, it is expensive to install, and a high degree of reliable treatment is required, to prevent clogging of the small holes (emittors) through which water is slowly released into the soil. Subsurface irrigation may lead to increased salinization in arid climates. Bubbler irrigation, a technique developed for localised irrigation of tree crops, avoids the need for small emitter apertures to regulate the flow to each tree.

Excreta in agriculture

Untreated or insufficiently treated excreta should only be applied to land by placing it in covered trenches prior to the start of the growing season. Nightsoil, if treated only to the helminthic quality guideline, may pose a greater risk to fieldworkers than restricted irrigation with wastewater. It can only be minimized by exposure control measures.

Aquaculture

Keeping fish in clean water for at least 2 to 3 weeks prior to harvest will remove any residual objectionable odours and reduce the degree of contamination with faecal microorganisms. However, such depuration does not guarantee complete removal of pathogens from fish tissues and digestive tracts, unless the contamination is very slight.

HUMAN EXPOSURE CONTROL

Agriculture

Four groups of people can be identified as being at potential risk from the agricultural use of wastewater and excreta. These are:

- agricultural fieldworkers and their families
- crop handlers
- consumers (of crops, meat and milk)
- those living near the affected fields.

Direct measures to protect workers include the wearing of protective closing (to prevent contact with pathogens), increased levels of hygiene (to remove any pathogens present), avoidance of contact with pathogens by behaviour modification, and possibly immunization or chemotherapeutic control of selected infections.

Agricultural fieldworkers' exposure to hookworm infection can be reduced by the continuous in-field use of appropriate footwear, but this may be more difficult to achieve than it might at first appear.

Immunization is not feasible against helminthic infections, nor against most diarrhoeal diseases, but immunization of highly exposed groups against typhoid and hepatitis A may be worth considering. Additional protection may be provided by the provision of adequate medical facilities to treat diarrhoeal disease, and by regular chemotherapeutic control of intense nematode infections in children and control of anaemia. Chemotherapy and immunization cannot be considered as an adequate strategy, but could be beneficial as a temporary palliative measure.

Risks to consumers can be reduced by thorough cooking and by high standards of hygiene. Food hygiene is a theme to be included in health education campaigns, although their efficiency may often be quite low. Tapeworm transmission can be controlled by meat inspection.

Local residents should be kept fully informed about the location of all fields where human wastes are used, so that they may avoid entering them and also prevent their children from doing so. There is no evidence that those living near wastewater-irrigated fields are at significant risk from sprinkler irrigation schemes. However, sprinklers should not be used within 50-100 m of houses or roads.

Aquaculture

Schistosomiasis is best controlled by treatment and snail control. Regular chemotherapy would be beneficial in endemic areas. Local residents should be informed which ponds are fertilised with wastes. Improved water supply and sanitation are also important measures for human exposure control, as they help reducing the need for contact with pond water.

MODEL FOR THE REDUCTION OF HEALTH RISKS THROUGH DIFFERENT CONTROL MEASURES

The model of health protection measures presented and discussed below shows how the four methods outlined in the preceding Section can be used singly or in combination to achieve good health protection.

The five concentric bands in Fig. 1.3 represent steps on the pathway from the waste itself to the human consumer or worker. Pathogens "flow" towards the centre, and the thick black circle represents a barrier beyond which they should not pass if health is to be protected. The level of contamination (of wastewater, field or crop) or the level of risk (to consumer or worker) is shown by the intensity of shading. The white area in the centre indicates a presumed absence of risk to human health and therefore indicates that the strategy leads to the "safe" use of wastewater.

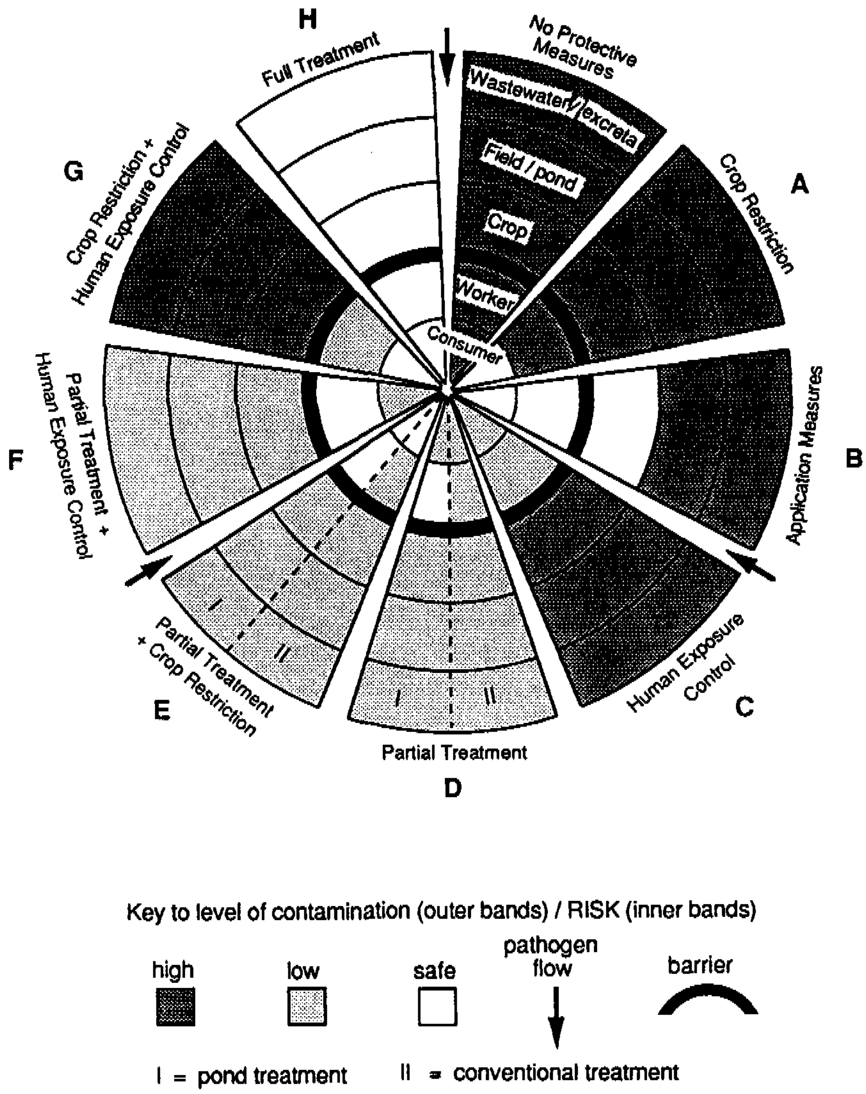


Fig. 1.3 Generalised Model of the Effect of Different Control Measures in Reducing Health Risks from Waste Reuse

If no protective measures are taken, there is a high risk to both workers and consumers; when crop restriction (regime A in Fig. 1.3) is introduced, consumers are "safe" whereas workers are still at high risk. Carefully selected wastewater application measures, such as localized irrigation (regime B), prevent any contamination from reaching the crop or the workers, and the health of both consumers and workers is protected. Human exposure control (regime C) at best prevents some contamination from reaching consumers and workers but, since full compliance with the recommended measures is rarely achieved in practice, a reduced level of risk to both groups remains. Partial treatment of wastes (regime D) reduces the level of contamination but the extent of this reduction varies, depending on the type of treatment used. Treatment in waste stabilization ponds for about

8-10 days (or an equivalent partial treatment) (D-I) removes helminth eggs sufficiently to protect the health of agricultural workers and consumers, but bacterial removal is sufficient only to reduce, not eliminate, the risk to consumers of vegetable crops. Conventional secondary treatment (D-II) does not guarantee sufficient helminth egg removal, and a reduced level of risk remains for both workers and consumers. Full treatment (in accordance with the guideline for Category A in Table 1.5) provides full protection to both consumers and agricultural workers (regime H).

Three examples of combinations of protection measures are shown. When partial treatment is combined with crop restriction, both consumers and workers are "safe" when stabilization pond treatment (E-I) is used, but workers remain at reduced risk when conventional secondary treatment is used (E-II). Human exposure control added to partial treatment (regime F) should protect the health of workers (although neither measure on its own necessarily gives full protection) but is likely to leave consumers at a reduced risk. Where no treatment can be given, crop restriction combined with human exposure control (regime G) can considerably reduce the risk to workers and protect the consumer.

Fig. 1.3 shows three regimes where the health of both workers and consumers is fully protected and several others where health risks are much reduced although complete "safety" has not been achieved. Measures providing partial protection could be used as part of a gradual approach to reducing health risks until it is possible to introduce a regime providing full protection.

In some situations, economic and technical factors may make it impossible to adopt the "blanket" approach of full treatment of all wastes to protect all potential workers and consumers. In such a situation, cultural factors (for example, the type of staple food crops), a strong institutional structure and the availability of the necessary personnel could create good conditions for the enforcement of crop restriction, together with either human exposure control or partial treatment of the wastes. This would be a more "targeted" approach, focusing the resources available on protecting the exposed population.

The most suitable health **protection measures for aquaculture** include wastewater treatment (full or partial), and human exposure control. An alternative to full treatment is the combination of partial wastewater treatment with measures for human exposure control so as to protect both workers and consumers. Human exposure control might include the wearing of protective clothing and increased levels of hygiene for workers, and the thorough cooking of fish and aquatic vegetables to protect consumers. It is not yet clear whether complete health protection is achieved in practice using this approach.

EXAMPLE OF THE APPLICATION OF THE MODEL

The following example from Mexico shows a current reuse practice where treatment of wastes does not occur but where other means of health protection are used. Full health protection of both workers and consumers is not at present achieved. The model can be used to aid decision-making on suitable additional measures to adopt.

Mexico: use of untreated wastewater in agriculture with crop restriction

Part of the wastewater from Mexico City is used in semi-arid areas with low annual rainfall in what constitutes the world's largest wastewater reuse scheme. Food production on a year-round basis is only made possible by the use of wastewater to supplement scarce supplies of fresh water for irrigation. **Crop restrictions** are enforced by staff of the Ministry of Agriculture and Water Resources who run the irrigation system, thereby providing protection to consumers. In one district, wastewater is used to irrigate over 80.000 ha of mainly maize, alfalfa, barley, and oats. Prohibited crops include lettuce, cabbage, beetroot, coriander, radish, carrot, spinach, and parsley, and some tomatoes and chillies are permitted, since they grow above the ground. **No purposeful treatment** is given to the wastewater, although some occurs during its passage through over 60 km of channels, and in one case, further "treatment" occurs in a large storage reservoir. Therefore in some of the areas of reuse, regime (A) applies, involving crop restriction alone, while in other places regime (E) applies, giving partial protection to the health of workers. In some districts, however, it may be necessary to consider the introduction of either partial waste treatment or of human exposure control, to protect the health of the many thousands of agricultural workers involved.

In similar ways, the model can be used in association with each of the case studies presented, to aid evaluation of the extent of health protection achieved, and to identify additional measures that may be needed.

1.4 Evaluation of Impact of Waste Reuse

In the preceding Sections, an overview of the health effects of use of wastes in agriculture and aquaculture and suggestions for health protection measures have been given. There will, however, be local epidemiological, sociocultural and environmental factors which mean that the health effects of a particular practice may be different in one situation than another. For example, the soil-transmitted intestinal helminths are less prevalent in some countries or regions than in others, so that health protection measures targeted at helminth infections may be less important in some areas than in others.

An **accurate evaluation** of the health risks of a specific practice in a specific area is not possible in the absence of an epidemiological study designed to assess the risks. Such studies have not been done in most areas of the world where reuse occurs, making evaluation of the risks difficult. Where specific epidemiological studies are absent, the next best alternative is to make a **judgement** on the possible risks through the consideration of data on the prevalence or incidence of the diseases of interest, data on the microbiological quality of the wastes, and an understanding of the prevailing socio-economic and cultural conditions. Substantial problems are, however, confronted when attempting this approach. The main problem is that data on the prevalence of incidence of intestinal infections are often not available; **many of the diseases** caused are **not notifiable** and so do not appear in routine statistics of causes of morbidity or mortality in a country or district. This is particularly the case for intestinal helminth and protozoal infections. Even if routine data gathered from clinics are available, these often represent an underestimate of the true prevalence found in a community, since many episodes of infection are not reported and because patients often do not report to clinics. Data on non-notifiable disease are only obtainable if specific surveys have been mounted to assess the magnitude of the problem. The results of such surveys are rarely published in the scientific literature and are often difficult to locate. The result is that judgements may need to be made using inadequate data or in the absence of any data on a particular infection.

In the visits the team made to countries where reuse occurs, an attempt was made to gather data on the occurrence of intestinal infections. However, the main focus for the epidemiologist in the team was to assess the interest in and feasibility of mounting an epidemiological study of the particular waste reuse practice in the area. This was time-consuming and consequently the data collected on the occurrence of infections was not as complete as would have been desirable. Review of the chapter drafts by in-country personnel has in part made up for this deficiency. An exhaustive review of the literature, however, was not attempted, so some existing data may not have been quoted.

It should be stressed that the sections in each chapter which deal with the potential health risks of the reuse practice therefore contain judgements made with the data available and are not the result of strict scientific analysis. They could be considered as "informed speculation", and are meant to be useful to decision-makers who would otherwise find it hard to translate international guidelines into guidelines suitable for their specific circumstances.

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A - WASTEWATER USE IN AGRICULTURE

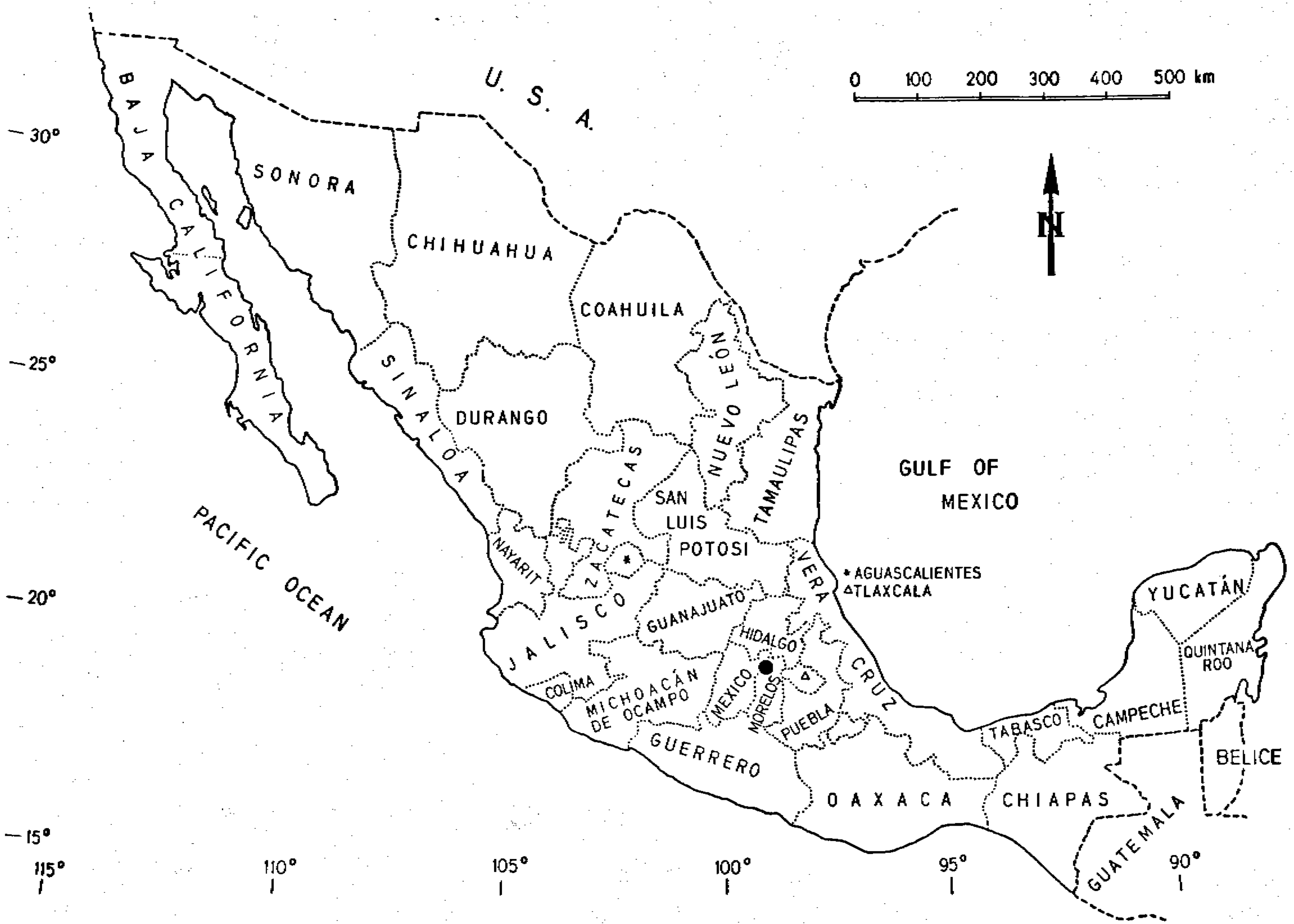
Aa - USE OF UNTREATED WASTEWATER

2 MEXICO

Acronyms

CIECCA	-	Centro de Investigación y Entrenamiento papa el Control de la Calidad del Agua
CPNH	-	Comisión del Plan Nacional Hidráulico
DDF	-	Departamento del Distrito Federal
I.D.	-	Irrigation District
PAHO	-	Panamerican Health Organization
RDD	-	Rural Development District
SARH	-	Secretaría de Agricultura y Recursos Hidráulicos
SEDUE	-	Secretaría de Desarollo Urbano y Ecología
UNEP/WHO	-	United Nations Environment Programme World Health Organization

MEXICO



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JALISCO
GUANAJUATO
HIDALGO
VERA CRUZ
COLIMA
MICHOACÁN DE OCAMPO
MEXICO
MORELOS
PUEBLA
GUERRERO
OAXACA
TABASCO
CAMPECHE
YUCATÁN
QUINTANA ROO
CHIAPAS
BELICE
GUATEMALA
GULF OF MEXICO
PACIFIC OCEAN
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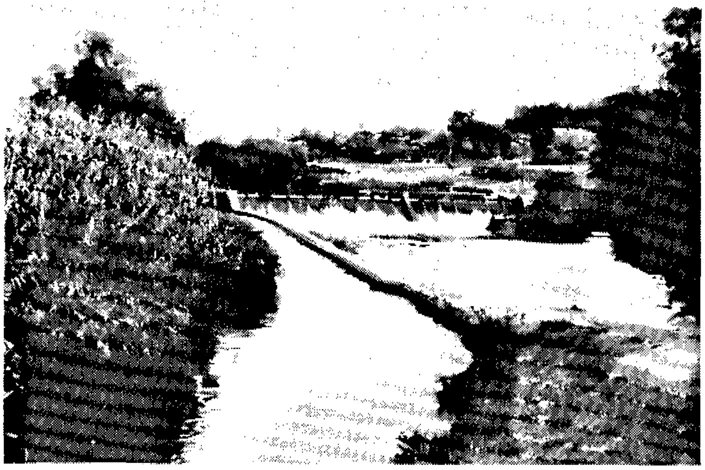


Photo 2.1

Gran Canal de Desagüe (Great Drainage Canal): Diversion of raw wastewater at Tequixquiac
(Photo: Ing. Humberto Romero A.)

Photo 2.2

The "Chinampas" at Xochimilco are irrigated with wastewater-contaminated canal water

Photo 2.3

Part of the 77,000 ha land area in Rural Dev. District No. 063 (I.D.03 and 100, Mezquital Valley), irrigated with wastewater from Mexico City

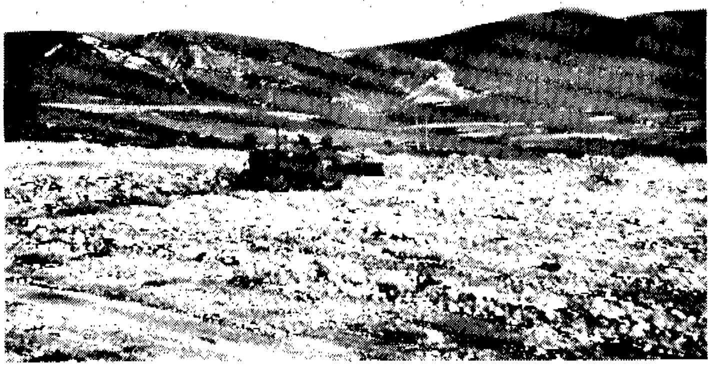


Photo 2.4

Reclamation of land in Mezquital Valley for wastewater-irrigated cultivation
(Photo: Ing. Humberto Romero A.)

Photo 2.5

Irrigation appurtenances in Irrigation District No. 03

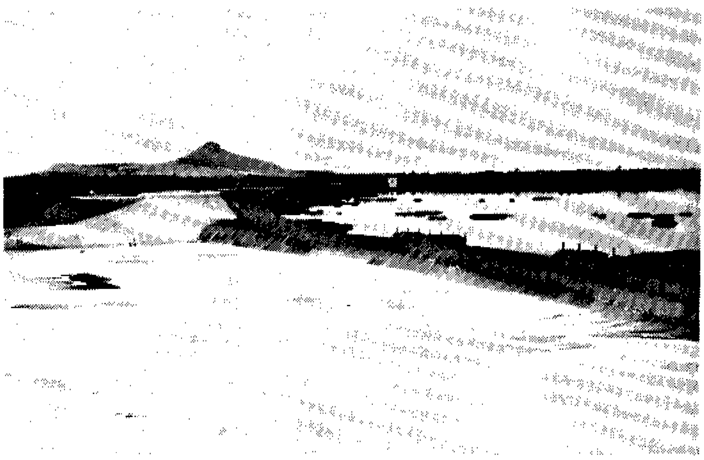


Photo 2.6

Spillway of Endho reservoir into which wastewater from Mexico City is discharged; undecomposed hard detergents lead to foam formation

V

Photo 2.7

Discussion with owners of wastewater-irrigated farmland in Mezquital Valley

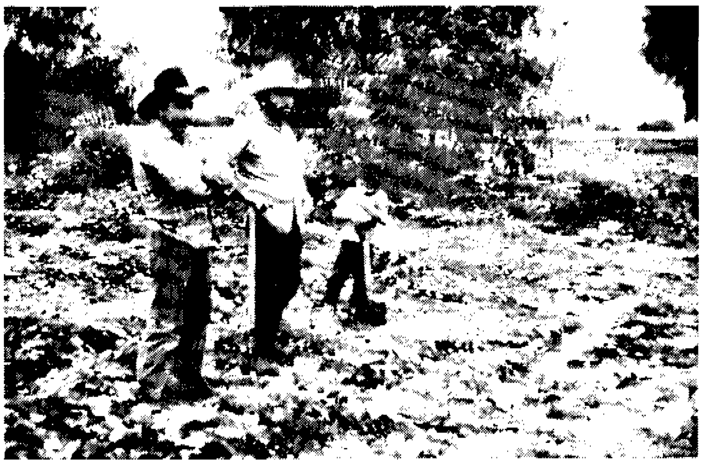


Photo 2.8

Farmers in their wastewater-irrigated chilli field near Endho reservoir

Photo 2.9

Furrow irrigation of a chilli field with untreated wastewater in Mezquital Valley

Photo 2.10

Lago de Texcoco project near Mexico City: land reclamation by "washing" the saline, high-pH soil with treated wastewater

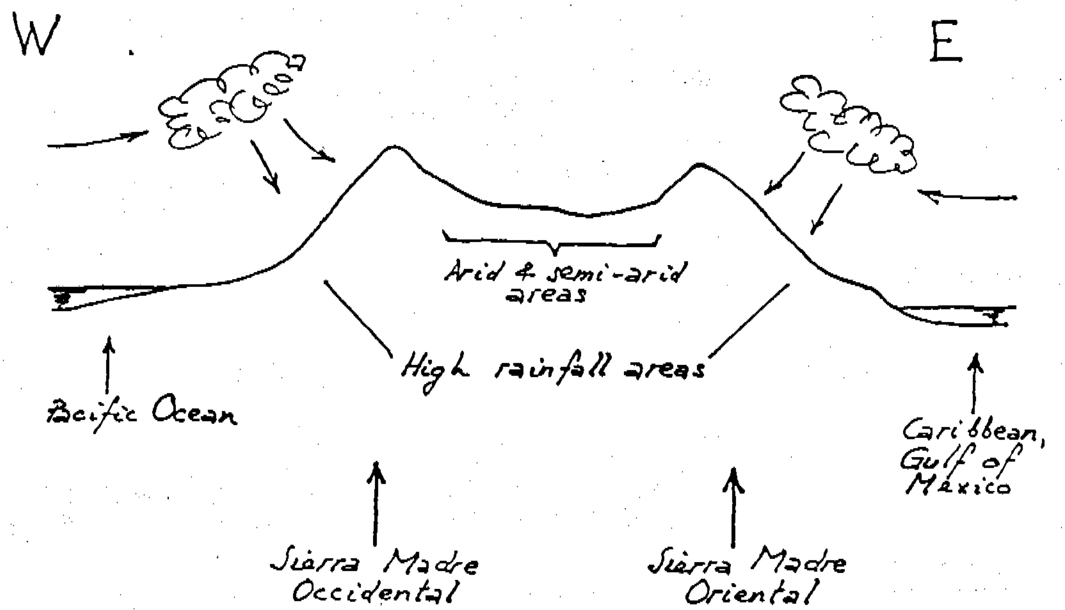
Photo 2.11

Mexico City: tanker truck being filled with secondary STP effluent for park irrigation

2.1 Geographical Features

- Climate, Water Resources and Agriculture

A simplified cross section of the country from east to west illustrates topography and climate.



Mexico has an uneven seasonal and geographical distribution of rain. 85% of the rain falls below 1000 m a.s.l., whereas 70% of the population live above this altitude (the Metropolitan Area of Mexico City with 18 million inhabitants is situated at an altitude of 2200 m) (Cuadra M. 1981). The subtropical and tropical coastal belts and slopes of the Sierras receive much rainfall all year round, whereas the higher and "inner" areas of the country receive only little rain. 77% of Mexico's territory is classified as semiarid or arid. The mean annual rain for the whole country, which falls mainly between the months July to September, amounts to 760 mm.

Of the total area of Mexico of 2 million km^2, 80% are unsuitable for agriculture. In 1981, approx. 10% was arable land, 30% meadows and pastures and 20% forests. Irrigation is needed in most areas.

The main crops grown are maize (43% of the cultivated land), sorghum (10%) and wheat (5%) (The Statesman's Yearbook 1985). Maize, beans and chilies are the main products of the staple diet of most Mexicans.

Large parts of the inner highlands, including the Valley of the Federal District with the metropolitan area of Mexico City, are densely populated. In order to feed the fast growing population and reduce food imports, great efforts are undertaken through government support to increase agricultural production. This would not be possible without extensive recycling of the municipal wastewater and drainage water for irrigation.

- Demography, Water Supply and Sanitation

Mexico's population totalled approx. 80 million in 1987, growing at a rate of 2.9%per year. In the years 1940-1982, the overall mortality rate declined from 23 to 5.9 per 1000 inhabitants, and the infant mortality rate from 126 to 33. 68% of the country's population live in urban areas.

According to the official statistics, water supply and sanitation coverage in 1985 were distributed as follows (WHO 1987):

	Urban	Rural
Water Supply		
• House connections	48%	
• Public standpost	30%	
• "Safe water"		50%
Sanitation		
• Sewage	44%	
• "Other means" (Septic tanks, latrines)	27%	
• "Adequate sanitation"		3%

2.2 Current and Planned Wastewater Reuse

- Overview

Climate and demography set, to a great extent, the scene and rationale for what constitutes a highly developed system of physical and organizational infrastructure catering for wastewater reuse. So-called Irrigation Districts exist which are geographical and administrative entities as well as subsidiary bodies of the Ministry of Agriculture and Water Resources (SARH). They manage water distribution and irrigation, and provide agricultural extension services. Six of the Districts (03[1], 09, 28, 30, 88, 100[1]) make use of wastewater and surface runoff from urban areas. Most of the drainage water and sewage from Mexico City is reused in Irrigation Districts 03, 28, 88, and 100. The government has developed plans for wastewater reuse in 11 more Irrigation Districts. Table 2.1 lists names, irrigated hectarage, number of users and major crops cultivated for the command area of Irrigation Districts with existing and planned wastewater reuse (Tejeda G. et al. 1983).

- History of Water Supply and Drainage in the Valley of Mexico

On a geological time scale, the metropolitan area of Mexico City, which was previously an open plain or basin, is nowadays called the "Valley". The formation of ring-like sloped mountains formed through volcanic eruptions, deprived the basin of its natural drainage. Weathering of the volcanoes resulted in the accumulation of sediment layers of several hundred meters depth. Prior to the "conquista", the invasion of Mexico by Spain in the 16th century, parts of the Valley were covered by 2000 km^2 of lakes.

The Valley covers a total drainage area of 9600 km^2. Dikes were built by the Aztecs to prevent or reduce both the flooding of the ancient city of Mexico and the mixing of the waters of the then Lake of Texcoco which was of high salinity, with the sweet waters of the other lakes. After the "conquista", the dikes were torn down. Due to a lack of natural drainage, this lead to a constant threat of inundations of the urban areas. Over the past three centuries, several large gravity drainage canals were therefore built to channel surface and wastewater from the Valley to the Tula river basin north of Mexico City (see Fig. 2.1). The reuse of wastewater in agriculture probably dates back to the introduction of sewerage schemes, i.e. to 100 years or more.

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[1] Integrated into Rural Development District No. 063

Table 2.1 Irrigation Districts with Current and Planned Use of Wastewater

District No.	Name of District	State	Area irrigated ha	Total area which can be irrigated ha	Annual wastewater flow available as % of total irrigation water supplied	Major crops grown
Wastewater reuse existing						
03[1]	Tula[2]	Hidalgo	43,000	48,000	> 100%	Alfalfa, maize, wheat, oats, green tomatoes, chillies
09	Cd. Juárez	Chihuahua	3,000	17,500	3.5	Cotton, alfalfa, oats wheat
28[1]	Tulancingo	Hidalgo	300	1,100	54	Pasture, maize, alfalfa
30	Valesquillo	Puebla	17,600	33,800	58	Maize, alfalfa, beans, chillies
88[1]	Chiconautla-Chalco-Texcoco	Mexico	4,300	4,300	> 100	Maize, alfalfa, oats, beet root
100[1]	Alfajayucan[3]	Hidalgo	14,700	28,900	> 100	Maize, beans, wheat, green tomatoes
Wastewater reuse planned						
10	Culiacan y Humaya	Sinaloa		223,000	1.3	Wheat, sorghum, sugar cane
11	Alto Río Lerma	Guanajato		102,000	5.6	Wheat, sorghum, maize, beans
14	Río Colorado	Baja California Norte		207,000	1.5%	Cotton, wheat, barley, alfalfa
16	Estado de Morelos			34,600	2.6	Rice, maize, green tomatoes, sugar cane
17	Región Lagunera	Coahuila & Durango		150,000	2.1	Cotton, maize, wheat, alfalfa
20	Morelia y Querendaro	Michoacán de Ocampo		33,900	7.2	Maize, wheat, sorghum, barley
26	Bajo Río San Juan	Tamaulipas		79,500	1.5	Maize and sorghum
41	Río Yaqui	Sonora		93,800	1.3	Wheat, cotton, alfalfa
61	Zamora	Michoacán de Ocampo		17,900	2	Wheat, peas, potatoes, strawberries
75	Valle del Fuerte	Sinaloa		223,000	0.2	Cotton, knapweed, wheat, sugar cane
82	Río Blanco	Veracruz		1,600	2.6	Maize, water melons, green tomatoes

[1] Using wastewater and runoff from Mexico City

[2] 15,800 users in District

[3] 21,800 users in District

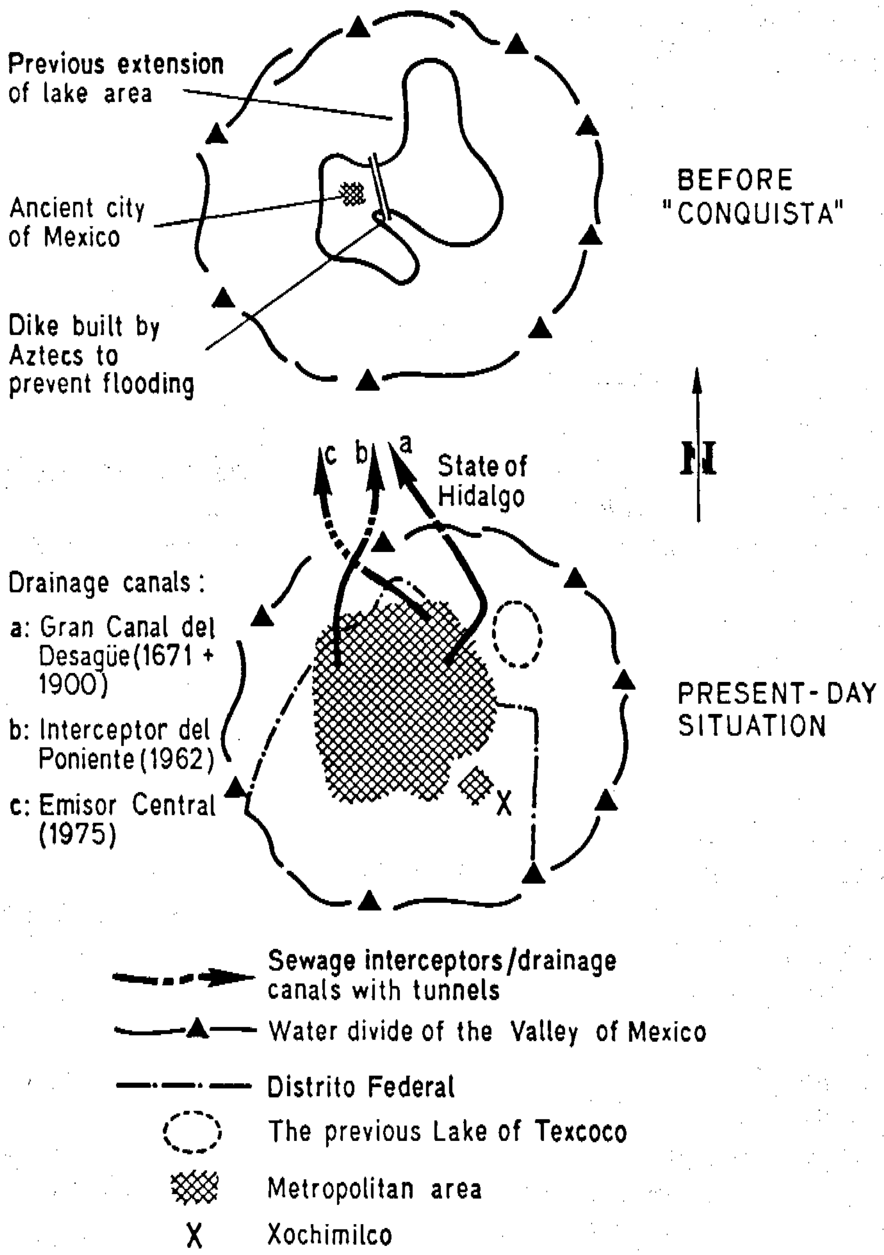

Fig. 2.1 Drainage History in the Valley of Mexico (schematic)

A first major drainage canal was constructed in the 17th century. It links the Valley of Mexico City with the Tula river basin in the State of Hidalgo to the north. Tula river is a tributary to the Panuco river which discharges into the Gulf of Mexico. Parallel to the ancient interceptor, a large sewage canal - the "Gran Canal del Desagüe" (Great Drainage Canal) - was built in 1900 and expanded in 1975. The "Gran Canal" carries most of the wastewater during the dry periods. It also provides wastewater (52 MM^3/yr) for irrigation in Irrigation District 88 within the Valley's watershed.

In 1962, an additional canal, the **Interceptor del Poniente** (Western Outfall) became operational. It discharges into the river Salto, a tributary of Tula river. Finally, in 1975, a third drainage scheme, the **Emisor Central**, was put in operation. It has a capacity of 200 m^3/s, carries mainly storm runoff through a 50 km long tunnel and discharges into the river Salto near its confluence with river Tula, downstream of the Requena reservoir (see Photo 2.1; Cuadra M. 1981; Romero A. 1987; Sanchez D. 1988). Both canals discharge, after passing through tunnels of 10 km length, into the Cuautitlan (Salado) river, a tributary of Tula river, near Tequixquiac. The canals helped to regulate the water levels in Texcoco and Zumpango lakes. While, in earlier days, the main function of the intra-watershed canals was to transport surface water and prevent flooding, the functions of the canals are, at present, to transport both wastewater and storm runoff away from the metropolitan area. Fig. 2.1 is a simplified schematic representation of the drainage history in the Valley of Mexico City.

On average, **a total of 55 m^3/s of untreated urban wastewater and drainage** water are "exported" from the Valley to the Tula watershed area, north of Mexico City, where it is reused in Irrigation Districts 03, 28 and 100 (Tejeda G. et al. 1983; Sanchez D. 1988). Thereof, 30-35 m^3/s are raw wastewater. The section below contains a detailed description of the reuse of Mexico City's wastewater in Irrigation District 03 covering part of the Tula river watershed area which is also called Mezquital Valley.

The **depletion of groundwater resources** is one of the major factors which has caused desertification in the Valley. At present, 60 m^3/s of groundwater are extracted by 8000 wells throughout the Valley. In addition, 20 m^3/s are "imported" from outside the Valley to help satisfy the city's water demand. Groundwater recharge amounts to 30 m^3/s, i.e., only half of the amount extracted. A recharge deficit exists due to this over-extraction and due to a centuries-long deforestation, which has led to increased surface runoff and reduced infiltration. Growing urbanization reduces the infiltration surfaces through which groundwater replenishment was possible.

For over ten years now, the government is making intense efforts to stop and reverse land degradation. One of the related programmes, the "Proyecto Texcoco", is described in more detail in a section further below. The basic concept of the "Proyecto Texcoco" is to:

- reduce municipal water consumption,
- increase the recycling of water within the Valley, and
- reduce import of water to the Valley's watershed.

In a parallel effort to cut down water consumption and import, 2 million low-volume (4-6 l) flush toilets will be introduced in Mexico City in the near future to replace the conventional 10-15 l flush systems. Efforts are undertaken by non-governmental organisations to introduce no-flush toilets in low-income housing.

Some of the wastewater generated in Mexico City is treated within the city limits. There are 9 sewage treatment plants treating a total dry-weather-flow of 5 m^3/s by activated sludge and chlorination. Information about the reuse of this treated wastewater is contained in the last section of Chpt. 2.2.

The depletion of groundwater resources seriously affects also the "chinampas" in the Xochimilco canals in South Mexico City. The "chinampas" are small artificial islands heaped up by the Aztecs in the lake which once covered a good part of the Valley of Mexico and of which but a minor fraction exists as "Canals of Xochimilco" nowadays. On these artificial islands, the Aztecs developed an intensive agriculture. The "chinampas" extended over 80,000 ha in ancient days. Today, only 1,500 ha remain, with the canals serving as a tourist attraction. For a long time, the "chinampas" formed the main food supply area of the City. Nowadays, they provide the basis of living for vegetable and flower farmers on average holdings of 300 m^2 per family, which are cultivated all year round (see Photo 2.2). This economically and ecologically important area is threatened in several ways:

(1) By the continuous drop of the water level in the "lake" (now the canals) due to intensive groundwater extraction. This forces the farmers to pump-irrigate their fields with canal water, while previously, water levels were high enough to allow wetting of the root zones by rising of the water through capillary action.

(2) Through the discharge of raw or partially treated wastewater from the southern part of the City into the Xochimilco canal system, the irrigation water used by the "chinamperos" has thus become hygienically unsafe. This has forced farmers to partly change from vegetable to flower farming. Flowers apparently achieve high retail prices on the City markets.

(3) Through expansion of the urban residential and commercial zone.

• Reuse of Wastewater from Mexico City in Mezquital Valley, Tula River Basin (Irrigation District 03)[1,2]

Geographical features

Irrigation District 03 comprises 16 municipalities with a population of 300,000 in 1985 (Sanchez D. 1988). There are a few towns (Tula, Actopan, Mixquiahuala, the seat of the Irrigation District headquarters) and a number of villages ranging in size from a few hundred to a few thousand inhabitants. The area is predominantly agricultural. Employment through agriculture amounts to 50-70%. A large oil refinery (Pemex) and local, small-scale industries are found in the area.

Domestic water supply and sanitation

Domestic water for the urban areas is supplied mainly from wells. Most houses have in-house plumbing with at least one tap. Flush toilets with septic tanks are rather common. Pit latrines, too, are frequently installed. Reportedly, many houses have bathrooms with showers. In villages, in-house water connections are rare; people still fetch their water either from public standposts, which are normally supplied from springs or rivers, or they use wells.

Tula river basin consists of flat land interspersed by volcano-shaped hills, rising a few hundred meters above the plains (see Photo 2.3). A chain of volcanoes forms the dividing line between the basin and the "Valley" to the south (the basin of Mexico City). Average rainfall in the I.D.s' area amounts to 494 mm/year, while 1905 mm are evaporated. The average temperature is 17°C. The District lies at a mean altitude of 1990 m a.s.l. The small amount of rainfall indicates that the climate is semiarid, and that therefore year-round intensive cultivation can only be sustained with imported water and wastewater which is impounded in reservoirs. Photo 2.4 shows uncultivated land under reclamation in the Mezquital Valley.

Irrigation works

The reclaimed land in the Mezquital Valley is intensively cultivated. A first-time-visitor - particularly one coming from a temperate zone where agriculture depends exclusively on direct rainfall - is struck by the many large, medium-size and small irrigation canals criss-crossing the area.

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[1] I.D. 03 and 100 form part of the Rural Development District 063

[2] Bordering Irrigation District 03 to the north is I.D. 100 which was established in 1978, and which forms part of the same hydrographical system, drawing water from within the Tula watershed as well as importing wastewater from Mexico City.

The extent of the irrigation infrastructure, consisting of impoundments, dams and spillways, concrete-lined canals, earth channels and field trenches, and numerous gates, make apparent the dependency of agriculture on water sources other than direct rainfall.

Impoundment reservoirs and irrigation systems are interlinked and channels servicing different irrigation command areas cross each other (see Photo 2.5). There are now approximately 200 km of principal canals and 350 km of lateral channels. Drainage canals total 56 km (Tejeda G. 1983).

Reportedly, irrigation culture was introduced in the Tula area before Spanish colonialization. In colonial times, the land was divided up in "haciendas". On these, agriculture may have been less intensive than nowadays, and requirements for irrigation water therefore relatively low. Present agriculture in the Basin has been shaped by the change in land ownership brought about through the land reform at the beginning of the 20th century, and the call for increased production due to the growth of the nearby metropolitan area. The complex network of irrigation canals is a manifestation of the continuous expansion of irrigated agricultural land within the river basin, in response to the increasing wastewater supply, to the demand of agricultural products and to the market requirements of the nearby metropolitan area.

The proportions of untreated wastewater and "uncontaminated" surface water flowing through the basin's irrigation schemes varies seasonally and geographically. During the dry season, i.e. from February to May, irrigation water imported from the Valley consists exclusively of wastewater, and most of it is used directly for irrigation without passing through impoundment reservoirs. In summer, i.e. from June to September, agricultural water demands are satisfied, to a large extent, by rainwater, and much of the imported wastewater passes into and through the basin's reservoirs and rivers. From September to February, a substantial portion of the imported wastewater is used for irrigation, too.

Fig. 2.2 schematizes the hydrographic situation of the Valley of Mexico and Tula river basin along with the interceptor canals and the Irrigation Districts 03 and 100. River runoff and the distribution of irrigated water in the basin are regulated by several impoundment reservoirs and intake dams on the drainage canals and rivers. The largest reservoirs are Endho (1230 km^2 drainage area), Requena (700 km^2), and Taxhimay (430 km^2) (see Photo 2.6).

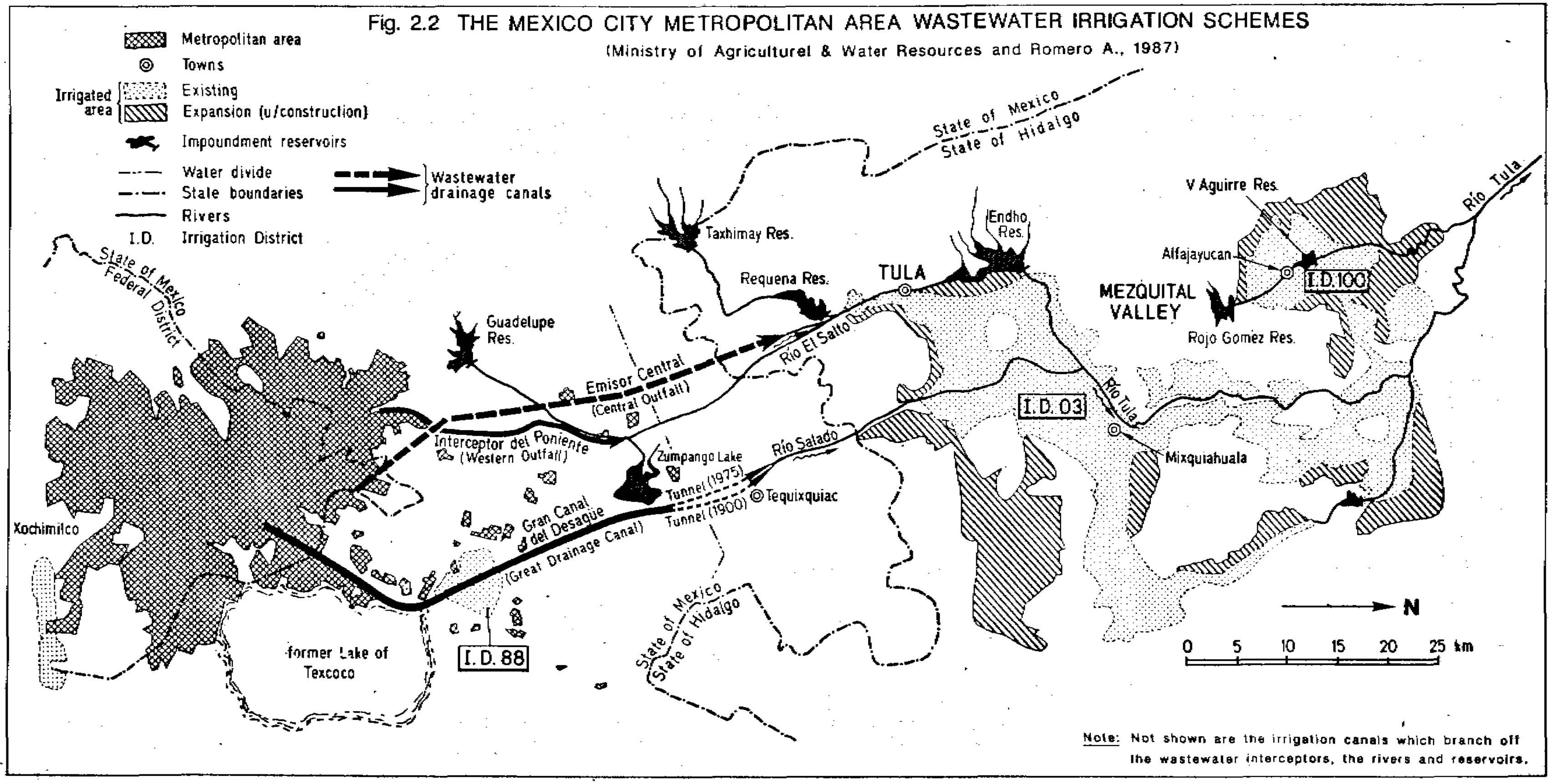

Fig. 2.2 THE MEXICO CITY METROPOLITAN AREA WASTEWATER IRRIGATION SCHEMES
(Ministry of Agriculturel & Water Resources and Romero A., 1987)

In addition to the surface water infrastructure, there are 12 deep wells which, however, do not fall under the jurisdiction of the District. Under the Irrigation District's authority, 43,000 ha are irrigated at present (Tejeda 1983). Figures on the **supply of irrigation water** in I.D. 03, as furnished by various sources of information, are somewhat conflicting, but the values presented below can be considered realistic approximations (Cuadro M. 1981; Omar C. 1985; Romero A. 1987; Sanchez D. 1988).

- Total supply ("fresh" and wastewater) — 1,580 MM^3/yr
- Thereof, sewage and storm runoff from Mexico City (80% of total irrigation water, the remainder being natural runoff from within the Tula river basin) — 1,260 MM^3/yr = 40 m^3/s
- Dry-weather sewage supply from the interceptor canals — 1,070 MM^3/yr = 34 m^3/s

On the basis of the above figures, the irrigation rate is determined at approx. 2.5 m/yr. This seems a high rate, even when channel losses are being accounted for, but evaporation rates are high, too. In arid zones, such excess irrigation is a sensible practice, since it prevents the accumulation of salts in the soil. It is believed that the continuous use of wastewater which supplies organic matter and plant nutrients, has, in general, improved the properties of the shallow soils (Sanchez D. 1988).

Microbiological quality of the irrigation water

The following waters of different origins are used for irrigation in the District:

- River water containing no or only little contamination from urban wastewater.
- Impounded river water diverted from the reservoirs and the reaches downstream of the reservoirs which are fed by the spillway overflows. These waters carry residual loads of the wastewater constituents discharged into the reservoirs through the main collector canals.
- Wastewater from the main collector canals (Gran Canal de Desagüe, Interceptor del Poniente, Emisor Central) composed of sewage and urban storm runoff
- Mixtures of impounded water and raw wastewater.

Accordingly, the concentrations of contaminants - both chemical constituents and pathogenic organisms - vary in time and place. The larger impoundment reservoirs such as Endho might act as "sinks" for certain constituents and should allow for some die-off or removal of pathogens. These processes depend mainly on the wastewater retention time and temperature. The District carries out regular sampling and analysis of irrigation water for chemical and physical parameters related mainly to plant physiology and soil properties. Pathogenic organisms or their indicator organisms are determined only occasionally. A research programme, supported by PAHO, was started in 1986 in Rural Development District 063 to determine the microbiological quality of irrigation waters, soils and crops, as well as the effect of the impoundment reservoirs on pathogen removal. The main parameters analysed are total coliforms, faecal coliforms, faecal streptococci, helminth (nematode) ova, and protozoal cysts (quantitative determination), and *Salmonella* and *Shigella* (qualitative determination).

Earlier, as well as more recent analyses show that the level of indicator bacteria in the irrigation water (total and faecal coliforms) varies widely within the District. Results indicate that FC concentrations tend to be substantially above the newly proposed guideline value of 10^3/100 ml (geometric mean) for unrestricted irrigation. In general, faecal coliform levels in the irrigation water are around 10^6-10^8/100 ml. However, most of the area is used for restricted irrigation. Several kinds of crops may not be cultivated, in particular root crops and crops growing near the ground which may be eaten raw (see the following paragraph for more details on crop restrictions). Thus, in trying to achieve public health protection, emphasis is laid on devising restrictions in cultivation rather than wastewater treatment. It is interesting to note that FC levels reaching the fields are still relatively high, even though some of the wastewater passes through the impoundment reservoirs in Mezquital Valley before being diverted into irrigation canals. The retention time within Endho reservoir (see Fig. 2.2) might be in the order of 1-2 months[1], but it is probably much less in smaller reservoirs (not shown in Fig. 2.2). Some limited die-off might occur while the wastewater is conveyed over approx. 60 km from Mexico City to the Irrigation District (travel time: approx. 1.5 day). The effect of this travel time on pathogen levels should, however, not be overestimated. Also, the question might be raised here, whether, perhaps, faecal coliform bacteria (but not the pathogenic organisms) multiply during the wastewater's journey through the canals and reservoirs.

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1 This estimate is based on the following assumptions: reservoir surface = 22 km^2, avg. depth = 2.5....5 m, yearly inflow of wastewater = 500 MM^3 and of river water = 200 MM^3 (based on a 1,200 km^2 drainage basin and 500 mm yearly rainfall)

Operation and administration

"Irrigation District" designates both an organizational entity as well as the geographical area served with irrigation water by the Irrigation District administration. The "Districts" are subsidiary to the Ministry of Agriculture and Water Resources (SARH; see also Chpt. 2.3).

Administrative operation of the Irrigation District in Tula river basin was taken up in 1904. In 1926, laws were created by which the federal government was vested with increased power and control over water resources. I.D. 03 was fully established in its present geographical extension and organisational form by presidential decree in 1955. Its policies are established by a directing committee which comprises, among others, representatives of SARH, "Reforma Agraria" (a government coordinating body), credit banks, and the farmers.

The main functions of the District are:

- Operation and maintenance of irrigation and drainage canals; maintenance of access roads
- Allocation of irrigation water
- Administer farmers' crop selection schedules and control crop restriction
- Agricultural extension service.

The District is divided into four administrative areas through which the day-to-day irrigation operations and water allocations are managed. Farmers requiring water, place their demands with the local I.D. branch office specifying time and plot where water is required. In 1985, the water fee amounted to 40 Pesos/ha per irrigation cycle which is equivalent to 20 Pesos/1000 m^3, approximately (335 Pesos = US$ 1.00 in 1985). These levies do not allow for cost recovery. Construction and management of the irrigation infrastructure and the District's agricultural services are subsidized by the state. Farmers irrigate every 10-30 days, approximately, depending on the type of crop. The farmer, each year, specifies the crops he is going to plant and irrigate with water allocated by the I.D. The Ministry of Health (Secretaría de Salubridad y Asistencia) sets the basic rules for crop restrictions, and the District's directing committee which is composed of, among others, representatives of SARH, the Mexico Rural Bank, farmers' cooperatives, small farmers' associations, and the "Reforma Agraria" (a committee formed by various ministries), specifies in detail the crops which may not be cultivated under its jurisdiction. In I.D. 03 these are:

- Lettuce ("lechuga")
- Cabbage ("col")
- Beet ("acelga")
- Coriander ("cilantro")
- Radish ("rãbano")
- Carrot ("zanahoria")
- Spinach ("espinaca")
- Parsley ("perajil")

Adherence to these restrictions is monitored mainly by the District's canal and gate operators who are in close contact with the farmers. Maize ("maíz"), beans ("frijol"), chili and green tomatoes ("jitomate") which form the staple food for the majority of the population, do not fall under these restrictions, neither does alfalfa, a fodder crop.

The regulations for wastewater irrigation in I.D. 03 are an example of a health protection strategy which focuses on "soft" measures, i.e. on crop restrictions rather than on "hard measures" (see also Chpt. 1.3 for a discussion of health protection strategies). "Hard measures", i.e. treatment of the wastewater to a standard allowing unrestricted irrigation, would be unfeasible in view of the huge wastewater flows which would have to be treated and the correspondingly high economic cost associated with such a treatment. In smaller towns, however, partial treatment (e.g. in a pond scheme) might be technically and economically feasible.

The farmers and the agricultural pattern

Most farmers living in the Tula basin area have settled there long ago. The average holding is 1-3 ha/family. About half of the farmers are grouped in cooperatives ("ejidos"), a system which developed through the land reform which took place after the revolution in the early 20th century; the others are, to a large extent, smallholders (pequenos proprietarios). Tenure is distributed as follows (Omar C. 1985):

Holding (ha)	% of tenants	Surface (ha)
0.1 - 1.0	57	
1 - 2	21	31,000
2 - 5	17	
5	5	12,000

On the average, the families number five members. Most of the families require additional sources of income besides farming, as their holdings are too small to generate sufficient income. Many farmers also work as hired labourers on other people's farms.

The **major crops** in terms of hectares cultivated are alfalfa (a forage crop), maize, wheat, barley, tomatoes and beans. For alfalfa, there are up to eight cuts in each growing cycle. The crop is dried after cutting, i.e. prior to being fed to cattle.

On the main square of a little town, two farm owners were interviewed about the wastewater irrigation practice on their farms (see Photo 2.7). They each own 10 - 20 ha of land and employ labourers to cultivate it. One of the interviewed farmers also runs a small trucking business. They provided the following information:

- The main crops cultivated on their fields are maize, alfalfa, wheat, and sunflowers; in higher areas where spring water is available, vegetables are grown.

- Workers are recruited in nearby towns and villages for tilling, irrigation and harvesting; e.g. 50 workers are employed to harvest 5 ha of chili in 15-day intervals during 3 months. Approx. 3000 labourers live in the area and can be recruited for farm work.

- All irrigation is with wastewater or diluted wastewater, using flood irrigation; water is received from the I.D. and supplied to the border of the field; ditches are then opened and closed by wooden stop blocks; water is further distributed by opening and closing the furrows.

- For maize, irrigation takes place after sowing and then after two months in 25-days intervals, e.g.; alfalfa is irrigated and cut once a month.

- The farmers expressed their concern about the high content of non-biodegradable detergents frequently found in the irrigation water. According to them, it leads to the "burning" of plant leaves.

- Some mineral fertilizer is used to complement the nutrients supplied by the wastewater.

- The land is tractor-tilled.

- The semipermanent irrigation workers are given boots which they wear to prevent injuries to their feet and damage to their shoes; boots are not worn in soft soil during sowing.

- The schooling level of the casual labourers averages 3-4 years; approx. 10% are illiterate.

- When asked about the health status of "their" workers, the farmers said they did not know of any problems.

Near Endho Reservoir, we met two other farmers, smallholders, who were also interviewed (see Photo 2.8). They were there irrigating one of their chili fields with dark-greyish water, consisting mostly of wastewater (see Photo 2.9). One farmer wore boots, one shoes and the small son of one of them waded barefoot in the field.

- Each farmer owns about 1.5 ha. They also work as hired labourers on other farms.

- They complain about being out-of-work for up to 1-2 months/year due to diseases such as stomach problems ("amoeba") and skin infections, which they attribute to the use of wastewater for irrigation.

- The farmers prefer to irrigate with wastewater instead of fresh water because of its nutrient content, but in spite of the health problems they are experiencing by using the wastewater.

- The Lago Texcoco Project

The main objectives of this project are the reclamation of saline soils for crop production and the halting of further desertification. The project area extends over 9,000 ha of land in the part of Mexico Valley which was once covered by the Lake Texcoco before desertification. It lies at the eastern edge of Mexico City and borders the international airport. It is property of the federal government. Since its start up in 1975, several thousand hectares of desert land have been reclaimed as pasture land by "washing" the salty, high pH desert soil with sewage (see Photo 2.10). At the same time, a large "pond" ("Lago Dr. Carillo") was created. This lake, which is 10 km^2 large, receives river water from mountains bordering the Valley (30%) and treated sewage (70%). Sewage is treated in a 1 m^3/s activated sludge plant and in a 0.5 m^3/s waste stabilization pond system with 18 days total retention time (concentric, semicircular layout of facultative and maturation ponds; internal recirculation). The lake water will be used to irrigate land which has been previously irrigated with groundwater, and for reuse in nearby industry. Plans exist to also develop fish culture. Theoretical retention time of water in the lake amounts to as much as 0.5 years. This is certainly enough to produce water which is safe for unrestricted irrigation and aquaculture.

Project activities further include reforestation in the Texcoco area to reduce wind erosion, and the implementation of a recreational park with a bird sanctuary.

The project gives the impression of a well-conceived and rather successful effort to stop desertification and reclaim land, while recycling the city's waste and drainage water to reduce import of water into the Valley and diminish groundwater extraction. Water is in great need in the area as yearly rainfall amounts to 570 mm only. The reclaimed land is likely to yield high economic value.

- Wastewater Reuse for Green Belt Irrigation in Mexico City

Reuse of chlorinated effluent from secondary STPs for park and lane irrigation is common practice within the Federal District of Mexico. There are 35 km of underground pipelines distributing effluent of 9 activated sludge treatment plants. In the dry season, the plants treat 5 m^3/s of wastewater, of which 1 m^3/s is distributed through the pipe reticulation systems. The sludge produced in eight of the nine STPs is discharged into the city's sewerage system and eventually transported to Irrigation District 03 in the Tula watershed area north of Mexico City.

In the wet season, i.e. during the months of June to September, there is generally less reuse. STPs are then under extensive maintenance and repair, and run at reduced capacities. Bypassed sewage is drained to the main sewerage and drainage system.

The "Cierro de Estrella" STP, which is located in the City's southeastern zone, is the largest STP in Mexico City, and has an installed capacity of 1,400 l/s. Municipal sewage is treated by activated sludge. The effluent is chlorinated and then reused in two ways:

- 200 l/s are used to irrigate parks and lanes by means of tanker trucks and a piped distribution system. Some wastewater is also sold and trucked to industries for toilet flushing and irrigation of green areas.

- 1,200 l/s are transported through a 72" force main and a gravity canal to Xochimilco, where it is used to maintain flows and levels in the Xochimilco canals which serve crop cultivation on the "chinampas", and as recreational area. In future, it is planned to use part of this effluent also for an irrigation scheme in the Tlahuac area further to the southeast. However, uncontrolled use of the canal water reportedly already occurs to irrigate fields adjacent to the canal.

"Chapultapec" STP is located in Chapultapec Park, which borders the City's main commercial district to the west. It treats the sewage of a nearby residential zone. The plant has a dry weather flow of 120 l/s. The effluent is primarily used to irrigate the adjacent park and fill the park's lakes. Some sewage is trucked away for park irrigation and sold to industry (see Photo 2.11).

2.3 Institutional and Regulatory Framework

Institutions

The following four institutions are of major importance for the planning, implementation and control of water resources management, wastewater collection and treatment, wastewater reuse and related public health aspects on a nationwide basis and for the Federal District of Mexico City:

- Ministry of Agriculture (Secretaría de Agricultura y Recursos Hidráulicos, SARH)
- Ministry of Health and Welfare (Secretaría de Salubridad y Asistencia)
- Ministry of Urban Development and Ecology (Secretaría de Desarollo Urbano y Ecología, SEDUE)
- Department of the Federal District (Departamento del Distrito Federal, DDF)

SARH controls the use of all natural waters. This includes the management of water and reusable wastewater for irrigation through Irrigation Districts (I.D.). Irrigation Districts are subsidiary bodies of SARH of which there is, at present, a considerable number operating in various States. Wastewater and urban runoff are used in 6 Districts. There are plans to introduce wastewater reuse in 11 more Irrigation Districts. The federal government, through SARH and its I.Ds, provides for irrigation infrastructure and distributes water and wastewater at subsidized rates. SARH sets standards for natural water quality and wastewater discharges as well as for water used or reused for irrigation. SARH, furthermore, specifies the crops which may be cultivated by irrigation with wastewater or contaminated natural water which do not meet the quality standards for unrestricted irrigation. Within the central body of SARH, the National Water Resources Planning Commission (Comisión del Plan Nacional Hidráulico, CPNH) is the unit largely dealing with the planning and conceptualization of wastewater reuse through Irrigation Districts. Its tasks include the development of suitable wastewater treatment technology and research in wastewater management including reuse. CPNH further comprises the national water pollution research laboratory (Centro de Investigación y Entrenamiento para el Control de la Calidad del Agua, CIECCA).

Beside CPNH, SARH also comprises planning and implementing bodies which deal with watersheds of national importance, such as e.g. the Commission for Lake Texcoco (Comisión Lago Texcoco, CLT), the works of which are described in Chpt. 2.2. above.

SEDUE is the Ministry dealing with urban water supply, sewerage and sewage treatment, as well as housing. It is also responsible for environmental control. It advises the municipalities which are in charge of construction, and operation of the physical works. It also provides services in the implementation of these tasks. SEDUE also comprises a water pollution control laboratory.

DDF, through its Division for Public Works and Services (Secretaría General de Obras y Servicios), caters for sewerage and sewage treatment within the limits of the Federal District (Mexico City). The reuse of wastewater treated in the city's sewage treatment plants for the irrigation of parks and lanes falls under its responsibilities. The hydraulic works section of the "Secretaría" has got its own quality control lab and, reportedly, carries out routine testing for total and faecal coliforms of chlorinated effluent from secondary STPs earmarked for reuse.

- Regulations for Wastewater Reuse

Quality standards for water used to irrigate crops or for recreational purposes, are specified in the water pollution control ordinance enacted by the government of Mexico in 1973[1]. The ordinance stipulates the following quality standards:

- For water used to irrigate vegetables which can be consumed raw, or fruits which may come in contact with the soil:

  ≤ 1,000 TC[2] / 100 ml

- For water used for recreational and industrial purposes:

  ≤ 10,000 TC / 100 ml monthly average
  ≤ 2,000 FC / 100 ml monthly average
  No sample with > 20,000 TC / 100 ml
  No sample with > 4,000 FC / 100 ml

1 Reglamento para la Prevención y Control de la Contaminación de Aguas
2 Indicated in the original document as "bacterias coliformes"

- Spray-irrigated water or wastewater should not contain more than 200 coliforms/100 ml.

In the I.D.s command areas, irrigation water contains variable proportions of untreated wastewater or wastewater which has passed through impoundment reservoirs. Therefore, the hygienic quality of the irrigation water varies in time and place and is difficult to predict. It may frequently exceed the standard of 1000 TC/100 ml required for unrestricted irrigation. SARH, therefore, restricts the crops which may be irrigated with water distributed under its authority (see also Chpt. 2.2). Compliance with theses restrictions is controlled by the Irrigation Districts. Crop restriction is the measures taken if farmers violate the restrictions. Raw-eaten vegetables must be irrigated with groundwater or be cultivated in higher areas where surface waters are relatively uncontaminated.

2.4 Health and Epidemiological Aspects

In this section, discussion will not be limited to water and excreta-related infections but these will be discussed in the wider context of the most important causes of morbidity and mortality in the country. This will allow the reader to assess the importance of the water and excreta-related infections that might be associated with the waste reuse practice in comparison with the predominant diseases in the area. The reader is also referred to Section 1.2, where the health risks associated with wastewater use are summarised, and to Section 1.4, where the difficulties involved in evaluating the health effects of a specific reuse practice are outlined. The data available do not allow an accurate assessment of the health risks to be made, so the following sections contain epidemiological judgements which should be considered as "informed speculation" rather than strict scientific analysis.

• Important Components in the Endemic Disease Situation

Mexico is a middle-income country with quite a high life expectancy and relatively low infant mortality (see country background). The pattern of disease includes both chronic and infectious diseases. The most important causes of mortality have shown some changes over the last 20 years. In 1970, infectious diseases such as influenza and pneumonia, enteritis and other diarrhoeal diseases were the top two causes of death, whereas in 1983 these had decreased to become the fifth and third highest causes of death respectively (Table 2.2). Heart diseases increased in importance, changing from fourth to first place, and malignant tumours rose from sixth to fourth place.

Table 2.2 10 Principal Causes of Mortality in Mexico (1970-1983

Cause	Deaths per 100,000 1970		1983	
Influenza and pneumonia	170.6	(1)*	36.5	(5)
Enteritis and other diarrhoeal diseases	141.7	(2)	45.8	(3)
Accidents and violence	71.0	(3)	61.4	(2)
Heart diseases	68.3	(4)	68.2	(1)
Perinatal mortality	51.5	(5)	32.0	(6)
Malignant tumours	37.6	(6)	41.0	(4)
Cerebrovascular disease	24.7	(7)	21.9	(9)
Measles	24.3	(8)	-	
Cirrhosis of the liver	22.8	(9)	22.2	(8)
Tuberculosis (all forms)	19.9	(10)	-	
Diabetes			25.3	(7)
Homicide			17.3	(10)

* Rank order for the year in question given in brackets
Source: Vital Statistics, Department of Epidemiology, Ministry of Health

Table 2.3 **Rate of Diarrhoea in Children Under 5 Years (2-week recall)**

State	Rate of diarrhoea per 1000	State	Rate of diarrhoea per 1000
Tabasco	28.2	Quintana Roo	16.4
Chiapas	26.2	Jalisco	15.9
Guerrero	24.1	Tlaxcala	15.7
Yucatan	23.1	Queretaro	15.4
Veracruz	22.7	Nuevo Leon	15.2
Campeche	20.1		
		Baja California Norte	14.8
Tamaulipas	18.8	Durango	13.4
Puebla	18.1	Estado de Mexico	11.8
Colima	18.0	San Luis Potosi	11.6
Oaxaca	17.8	Distrito Federal (Mexico City	11.2
Michoacan	17.6		
Coahuila	17.2	Guanajuato	11.0
		Chihuahua	10.8
Mayarit	16.8	Zacatecas	10.3
Morelos	16.8	Aguascalientes	9.9
Sinaloa	16.8	Baja California Sur	9.0
Hidalgo	16.7		
Sumora	16.7		
Mexico, average: 16.7			

Information from the National Health Survey in 1988 has shown that the rate of diarrhoeal disease varies in different regions of the country (Table 2.3). The rate is highest in children under 5 years of age, as elsewhere in the world, and decreases in early adult life, though the rate appears to rise again in later adult life (Fig. 2.3). Respiratory infections are a more important cause of morbidity, however, in every age group.

Similar trends to those shown at national level are apparent in records from Tula Health District (State of Hidalgo) show that of cases reporting to state-run clinics, 19% were of gastroenteritis, and 18% suffered from parasitic infections (see Table 2.4). The vast majority of parasitic infec-

Table 2.4 Principal Causes of Morbidity and Mortality in Tula Health District 1984

Morbidity

Cause	Cases	%
1. Acute respiratory infections	14,256	57.9
2. Gastroenteritis	4,724	19.2
3. Amoebiasis	2,702	11.0
4. Parasitoses	1,751	7.0
5. Influenza	323	1.3
6. Chicken pox	145	0.6
7. Mumps	134	0.5
8. Bronchopneumonia	119	0.5
9. Arterial hypertension	97	0.4
10. Amoebic dysentery	73	0.4
All others	304	1.3
Total 1	24,628	

Mortality

Cause	Cases	%
1. Injury, poisoning and violence	59	15.4
2. Pneumonias	58	15.1
3. Cirrhosis and other chronic liver infections	37	9.7
4. Malignant tumors	31	8.1
5. Intestinal infectious diseases	26	6.8
6. Coronary aesthaemic disease	21	5.5
7. Diabetes	20	5.2
8. Perinatal infections	17	4.4
9. Cerebrovascular diseases	16	4.2
10. Other forms of heart disease	16	4.2
All others	82	21.4
Total	383	

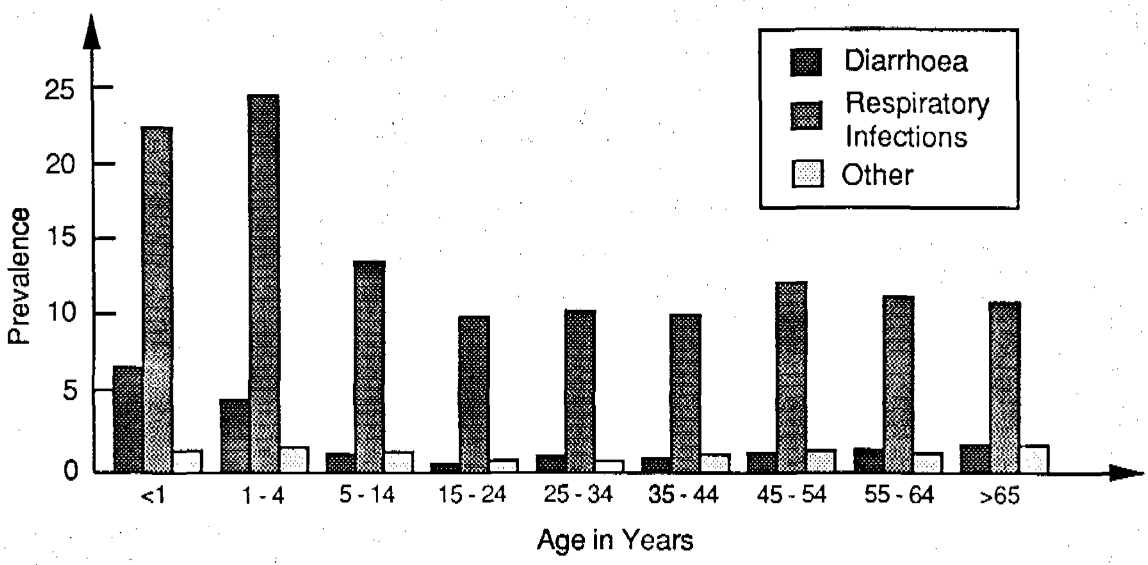

Fig. 2.3 Prevalence of Acute Diseases by Age Group (2-week recall period)
(Source: National Health Survey, Departement of Epidemiology, 1988)

tions presented (11%) were of amoebiasis[1]. The Tula Health District includes several towns, industrial and agricultural areas, including an irrigation district where untreated wastewater is used in agriculture. The extent of the contribution of wastewater use to the prevalence of intestinal infections is discussed in the section "Potential Impact of the Existing Use Practice" below.

Community based studies have indicated that soil-transmitted helminths are a major problem in many parts of Mexico. Reported *Ascaris* prevalence rates ranged from 43% in Tabasco to 93% in the State of Guerrero, with lower infection rates (3 to 13%) among city dwellers (Aguilera 1984). The prevalence of *Trichuris* is similar to that of *Ascaris*, except that the prevalence is often higher in the more tropical zones (coastal belts) and lower in the more temperate zones. Surveys in Hidalgo State indicate that the prevalence of both *Ascaris* and *Trichuris* peaks in the 5-14 year age group (70%) and 80%, respectively), but is also high in the 0-4 year age group (50% and 45%, respectively) and in those

1 It was not made clear from the records how "amoebiasis" was differentiated from "amoebic dysentery"

over 15 years old (50% and 40%, respectively) (Vallejo, pers. comm.). The prevalence of hookworm infections greatly varies according to climatic and soil conditions, fluctuating between 6 and 71% in the tropical zones. In the semiarid zones, the climate and soil conditions are less favourable for the larvae, and prevalence tends to be low. In Mexico City, the prevalence of hookworm is as low as 0.3 to 2.2%. Aguilera (1984) suggests that *Ascaris* is often a cause of clinical complications in children, and the treatment of such cases is costly to the health service. The high prevalence rates and the social and economic repercussions of soil-transmitted helminthiases led him to suggest that control programmes should be started (including health education) and could be used as an entry point for other primary health care activities.

Water Supplies and Hygiene Behaviour

The situation nationally regarding safe water supplies and sanitary waste disposal varies greatly between urban and rural areas. Over 90% of urban households have good water and sanitation, whereas only 40% of rural households have safe water supplies and even fewer (12%) have good sanitation.

In the areas where wastewater is used in agriculture, the majority of the farm workers live in nearby towns and not next to their fields. In these areas, many water supplies are through in-house connections, but some people are supplied from communal standpipes, and domestic water supplies are collected in metal containers, and transported by donkey to the houses. Some houses are situated adjacent to irrigation channels, and although the irrigation water is not used for domestic purposes, it appears that young children may sometimes be found playing in the water.

In the fields, several practices occur that may cause exposure to wastewater and enhance disease transmission. Farm workers involved in controlling the flow of irrigation water may use their hands in addition to their tools in forming earth dams. Children accompanying their parents to the fields often do not wear shoes and may play in the fields while irrigation is in progress (photo 8). Clean water supplies do not appear to be present in the fields, making good hygiene difficult for the farm workers.

• Potential Impact of the Existing Use Practice

Studies have been made on the health impact of the use of raw wastewater in agriculture by students at the School of Public Health in Mexico City. The first study (Sanchez Leyva 1976) investigated in the Irrigation Districts 03 and 88, the effect of the use of wastewater on diarrhoea and parasitic infections in school children. Data was collected through clinical examination, questions on recall of diarrhoeal disease episodes over the previous 3 months, and examination of stool specimens for the presence of parasites. No consistent significant excess prevalence of gastrointestinal complaints or protozoan and helminth infection was found in children from communities irrigating with wastewater as compared with children from the control community, who used clean water for irrigation. Shuval et al. (1986) have suggested that the use of storage reservoirs may act as sedimentation basins, providing a reduction in the number of helminth eggs and protozoal cysts in the effluent, and that this could explain the finding of no excess helminth or protozoan infection (Sanchez Leyva 1976) among children in wastewater irrigating communities.

The second study (Rivera Ramirez 1980) investigated the effect of the use of wastewater in Irrigation District 03 on the incidence of gastrointestinal disease in the general population between 1975 and 1979, the period during which the wastewater irrigation network was expanded. Data were collected through a record review, using the medical files of the main government Health Centre. The authors concluded that risk of amoebiasis was greater in the area where wastewater was used for irrigation than in the control area not practising wastewater irrigation.

Critical comments on both these studies are given in Shuval et al. (1986). In particular, the length of the recall period (Sanchez Leyva 1976), the reliability of the information gathered from the local health clinic, and the influence of confounding factors such as drinking water quality (Rivera Ramirez 1980) were questioned. In addition, no information was gathered on the actual exposure of the subjects, who may possibly not have come into contact with the wastewater. No data was obtained on the microbiological quality of the wastewater, so it is not clear whether the subjects in both studies were exposed to the same level of contamination.

The third study investigated the effect of the use of wastewater in Guadalajara on signs and symptoms of disease and on the prevalence of parasitic infections in agricultural workers (Rivera Ramirez 1983). The intention was to study workers using the treated effluent from waste stabilization ponds, however, it was found that the influent to the ponds was diverted by the farmers, so that raw sewage was being used. Therefore, the study compared 50 agricultural workers using raw sewage for irrigation (exposed group) with 50 workers using groundwater for irrigation (control group). Data was collected through questionnaires and through the examination of stool specimens for the presence and identity of protozoan cysts and helminth eggs. From the questionnaires, an excess prevalence of symptoms of diarrhoea (6%) and dermatitis (30%) was found in the exposed group compared to the control group. However, these data are questionable since the three-month recall period is too long to be reliable. From the stool examinations, a significant excess prevalence of infection was found for *Giardia lamblia* (17% in exposed and 4% in control group) and *Ascaris lumbricoides* (50% in exposed and 16% in control group), whereas no significant difference was found in the prevalence of infection with *Entamoeba histolytica, Escherichia coli, Endolimax nana, Iodamoeba* and *Enterobius*. However, the prevalence of infection with *E. histolytica* was very high (about 80%) in both groups. The authors concluded that the high prevalence of parasitic disease in both groups was due to poor environmental sanitation, poor hygiene habits and lack of health education. However, they recognised that the study method (including study size) was not sufficiently sensitive to small differences between the two groups. The large differences seen in the cases of *Giardia* and *Ascaris* infection are therefore particularly striking.

Although no firm conclusions can be drawn from these studies, due to the methodological problems involved, they do indicate certain possible impacts which could be investigated further:

a) Where raw wastewater is used in irrigation, farm workers are likely to be at increased risk of *Ascaris* and *Giardia* infections, possibly also *E. histolytica* infection. There may be an increased risk of diarrhoeal disease, but this should also be tested in the children of farm workers. Where crop restrictions are practised (as in District 03), there will be no risk to crop consumers, but in the absence of restrictions, consumers would also be at risk. These conclusions are consistent with the model of health risks due to wastewater use (see Sect. 1.2).

b) Where wastewater is kept in storage reservoirs before being released for irrigation, a form of partial treatment may occur, through sedimentation of helminth eggs and possibly protozoan cysts. The extent of any reduction in risk through this process is not yet clear, and requires further investigation.

The impact of raw wastewater use on diarrhoeal disease, protozoan and helminth infections and the effect of sedimentation in a storage reservoir is being investigated in a new epidemiological study. This is being done by staff from the Department of Infectious Disease, National Institute of Nutrition in Mexico City, in collaboration with the London School of Hygiene and Tropical Medicine and funded by the Commission of European Communites. The study is taking place in Irrigation District 03 and is supported by staff of the irrigation district.

- Implications for the Control of Health Risks

(i) In areas where raw wastewater is used and crop restrictions are successfully enforced, the general public including crop consumers are protected. Additional measures, however, need to be taken to protect the health of agricultural workers. Where possible, some treatment of the wastewater is desirable (to remove helminth eggs and protozoan cysts); in other cases, control of human exposure could be tried through health education programmes and provision of protective clothing, and control of the irrigation method could be attempted.

(ii) In areas where wastewater is not currently used, but will be used in future, some treatment of the municipal wastewater before use in agriculture should be considered. Where only partial treatment is possible, then crop restrictions will also be needed to protect the health of crop consumers. Vegetable crops, however, could be grown if full treatment is given to the wastewater, as in a series of waste stabilization ponds of around 25 days' retention time.

(iii) The level of infection of rural populations with intestinal parasitic infections appears to be high in areas where wastewater is not used as well as places where it is in use, indicating that other issues of environmental sanitation and personal hygiene also need to be addressed.

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3 CHILE

Acronyms

DGA	-	Dirección General de Agua (Directorate of Water)
EMOS	-	Empresa Metropolitana de Obras Sanitarias
INTA	-	Instituto de Nutrición y Tecnología de los Alimentos
M.H.S.	-	Metropolitan Health Service
PAHO	-	Pan American Health Organization
SENDOS	-	Servicio Nacional de Obras Sanitarias
S.M.R.	-	Santiago Metropolitan Region

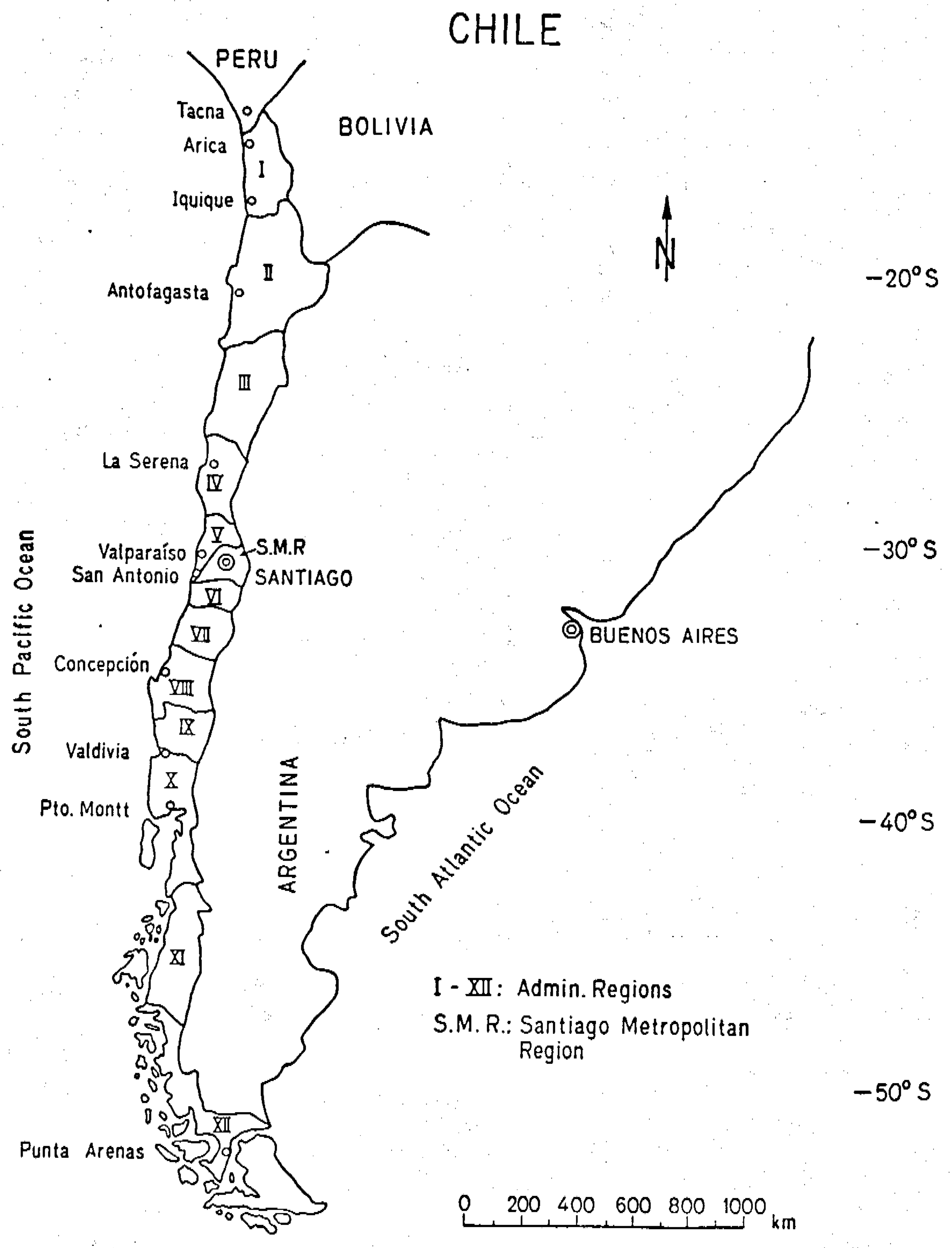
CHILE
PERU
BOLIVIA
Tacna
Arica
I
Iquique
II
Antofagasta
III
La Serena
IV
V
Valparaíso
San Antonio
S.M.R
SANTIAGO
VI
VII
Concepción
VIII
IX
Valdivia
X
Pto. Montt
XI
XII
Punta Arenas
South Pacific Ocean
ARGENTINA
BUENOS AIRES
South Atlantic Ocean
N
−20° S
−30° S
−40° S
−50° S
I - XII: Admin. Regions
S.M.R.: Santiago Metropolitan Region
0 200 400 600 800 1000 km

Photo 3.1

Wastewater-irrigated farmland on the outskirts of Santiago

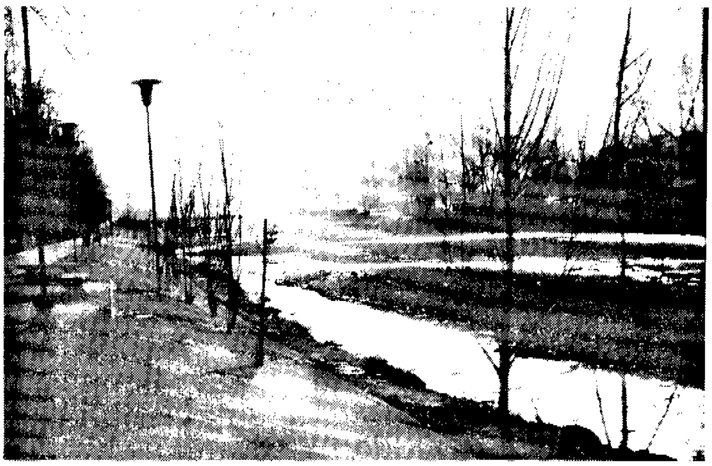

Photo 3.2

The Río Mapocho is the receiving water body for part of Santiago's raw wastewater

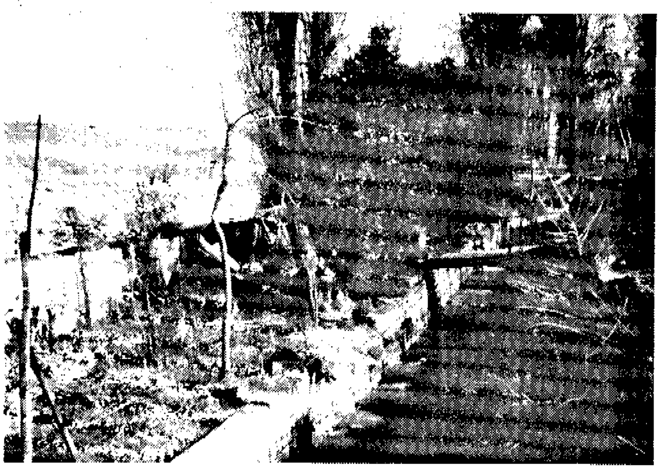

Photo 3.3

An irrigation canal (right-hand side) carrying the mixture of river and wastewater from the Río Mapocho (left-hand side) to nearby farmland

Photo 3.4

The Zanjón de la Aguada. Santiago's main wastewater collector

Photo 3.5

A vegetable retailer purchasing wastewater-irrigated lettuce at the field site

Photo 3.6

Irrigation worker

Photo 3.7

Harvesting wastewater-irrigated lettuce

3.1 Wastewater Reuse in the Santiago Metropolitan Region (S.M.R.)[1]

- Existing Practice

All of Santiago's sewage (population: 4.6 million in 1988) is used to irrigate the city's adjacent farmland (Fig. 3.1 and Photo 3.1). The principal wastewater reuse areas are located in the municipalities of Maipú, Pudahuel, Quilicura and Conchalí which lie in the southwest, west and north of Santiago. The irrigated land is situated mostly in the immediate vicinity of the expanding residential and industrial areas of the city.

The Santiago Metropolitan Region (S.M.R.) forms part of the Maipo river basin which stretches over 90 km from the Cordillera in the east to the Pacific coast in the west. The Río Mapocho[2] (Photo 3.2), which is the main tributary of the Río Maipo, receives, on its passage through Santiago, numerous discharges of raw wastewater from the city's main sewers. There are, in the Metropolitan area, several diversions, from where the wastewater-laden river water is transported to the cultivation areas through large irrigation canals (Photo 3.3). Further downstream of the city, part of the river flow is diverted for use as irrigation water in Curacaví, an area W of the Mapocho sub-basin. 70-80% of Santiago's raw sewage, however, are collected by the **Zanjón de la Aguada**, a large open drainage canal mainly transporting sewage (BOD = 100 mg/l; 10^6-10^8 FC/100 ml during dry weather) (Photo 3.4). Most of its flow is reused for irrigation in Maipú and Pudahuel, W of Santiago. It was this area which the team visited.

In Santiago City the sewage is discharged as follows (1983-84):

	m^3/s	No. of sewer outlets
• into the Río Mapocho	3.5	32
• into the Zanjón de la Aguada	6.0	59
• into the Río Maipo	0.2	4
Total	9.7 m^3/s	

[1] The field study of wastewater reuse in Chile, only covered the metropolitan area of Santiago. The extension and intensity of reuse in this area in association with the enteric disease situation provide a wealth of illustrative material. Time was too short to visit other reuse sites, a few of which exist on a minor scale outside S.M.R..

[2] Mean flow upstream of the city = 8 m^3/s

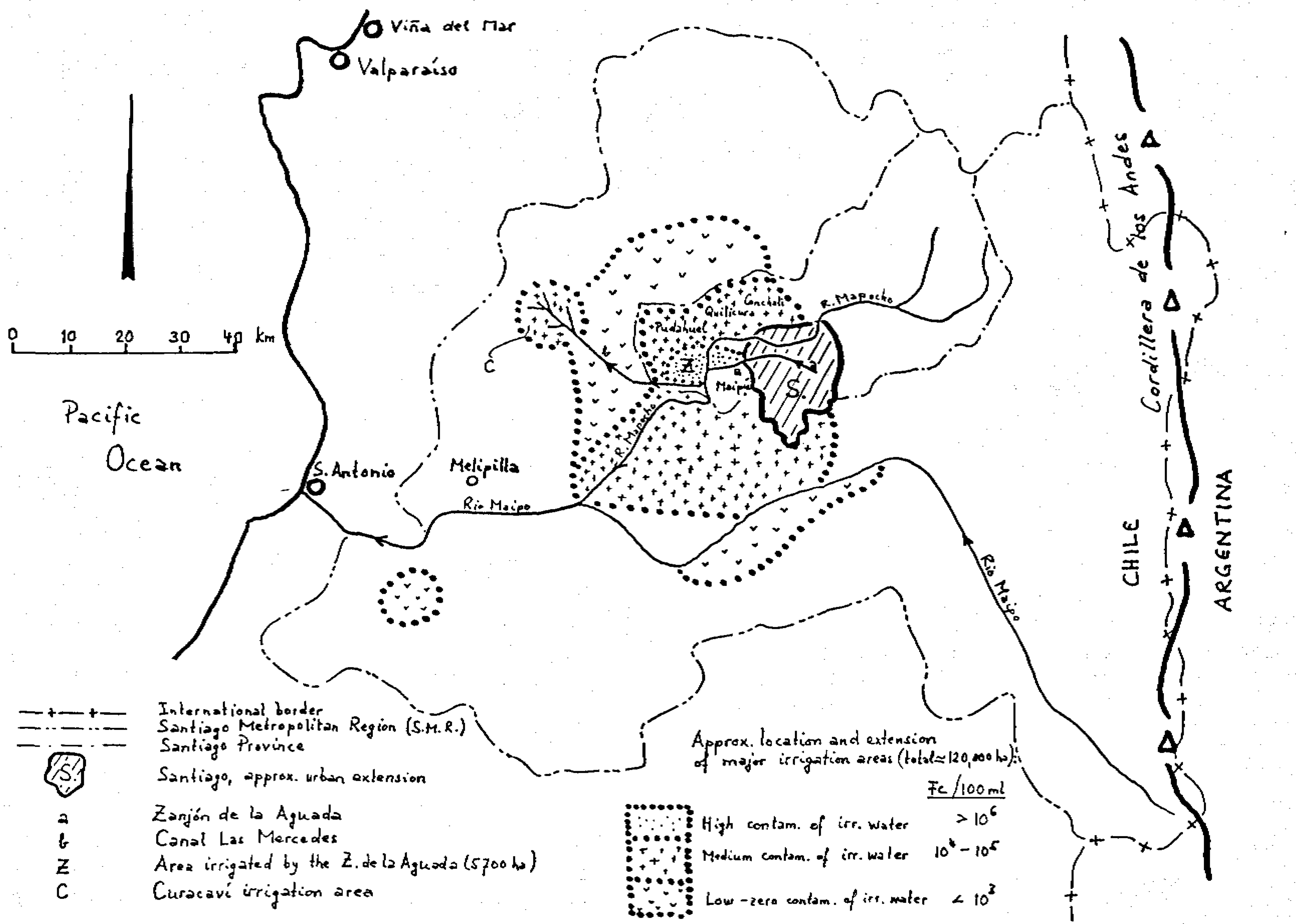

Fig.3.1 Drainage and Irrigation in the Santiago Metropolitan Region

The extent of dilution depends on the seasonal flows in the rivers. At low flows, the river runoff downstream of the sewer outfalls consists mainly of wastewater. Theoretically, therefore, it is river water which is used rather than wastewater. This is reflected in the difficulty the authorities are faced with in enforcing crop restrictions. This situation contrasts situations e.g. in Tunisia or Saudi Arabia, where the treated wastewater is distributed without prior discharge into river courses. Non-observance of crop restrictions by the farmers may lead to a denial of wastewater aportioning.

The use of river water contaminated by wastewater has been practised for several decades. Over the years, substantial investments have been made towards the building of canals and appurtenances. Several hundred kilometers of concreted and earth canals convey the mixture of water and sewage, and thereby feed an irrigation system which comprises one of the world's largest wastewater reuse flows.

The climate in the Santiago area is temperate, with an average rainfall of 340 mm/a occurring mainly during the winter months from April to September. Intensive agriculture is thus dependent on irrigation. Irrigation is most intensive during the summer months, i.e. from October to March. In the S.M.R. approx. 120,000 ha (1976) are sewage-irrigated; most of the irrigation water used contains only low levels of contamination. 25,000-30,000 ha are estimated to be irrigated with rather highly contaminated water (> 10^4 FC (faecal coliforms)/100 ml). The area receiving wastewater from the Zanjõn de la Aguada, (6 m^3/s average dry-weather flow) comprises 5700 ha (1982). Most of S.M.R.'s vegetables are cultivated here, i.e. on approx. 3000 ha. Out of which, approximately 1000 ha[1] are used to cultivate vegetables which are consumed uncooked, notably lettuce, cabbage and cellery. On a 300 ha area irrigated with untreated sewage which has been prohibited for these types of crops by the Metropolitan Health Service (M.H.S.) in 1983, farmers still grow raw-eaten vegetables (e.g. lettuce). Other crops grown are cereals, grapes and low-growing fruits.

The vicinity of the city with its large consumer population is an important rationale for the cultivation of vegetables in the Zanjõn de la Aguada perimeter. Vegetables can be sold fresh and transport cost are thereby low on account of the short distances (Photo 3.5). The overall production of raw-eaten vegetables in S.M.R. amounted to 47,000 tons in 1976, or 12 kg/-inhabitant, respectively.

60% of the land, consisting of holdings between 10 and 100 ha, in the Zanjõn de la Aguada area belongs to land-owners who employ peasant farmers

[1] Figures contained in various reports for hectarage planted with raw-eaten vegetables in S.M.R. ("hortalizas de consumo crudo") vary between 730 and 2100 ha. One report lists 1200 ha for the Zanjõn de la Aguada area alone.

or farm labourers. 20% are family-run farms (< 10 ha) and 20% are owned by construction firms which have purchased the land for speculative resons, i.e. urban expansion.

While visiting the irrigation sites in the Zanjón de la Aguada area, the team observed how farm labourers furrow-irrigated the land with raw sewage originating from the Zanjón de la Aguada (Photo 3.6). Other labourers were observed harvesting lettuce from a field which was covered by faecal matter (Photo 3.7). Harvested vegetables are trucked, transported by bicycle-carts, or hand-carried to the city's wholesale, stationary or shifting retail market.

Sewage-irrigated vegetables are not distributed according to a fixed geographical pattern. Therefore, individual markets probably sell vegetables with variable degrees of contamination.

- Future Developments

Until a few years ago, government's health expenditures were mainly put into providing curative and preventive health services. The use of raw wastewater to irrigate vegetable crops was not considered a problem and consequently, no investments were made to change the wastewater management practice. Meanwhile, however, results of investigations which were carried out in recent years showed that the use of untreated wastewater most probably does contribute to the high incidence rate for typhoid fewer (see Sect. 3.3). There are now plans to upgrade the wastewater management system such that health safeguards will be provided.

A **Sewerage Master Plan** for Santiago was devised by a French/Chilean consortium in 1983/84. The main objective is to change from the present pattern of raw sewage discharge into water courses and raw sewage irrigation to controlled sewage collection, treatment and use. In a first implementation phase, over 50 km of large interceptors shall be constructed (see Fig. 3.2). In a second phase, treatment shall be provided. The plan of conveying in future all sewage to the Curacaví agricultural area for treatment and reuse might be implemented only at a pace which would be compatible with the economic interests of the land-owners, who are at present using the city's sewage in the peri-urban area. In the absence of a strict land use policy, substantial portions of the peri-urban land now under cultivation will probably be given up and sold due to the land pressure from the expanding city.

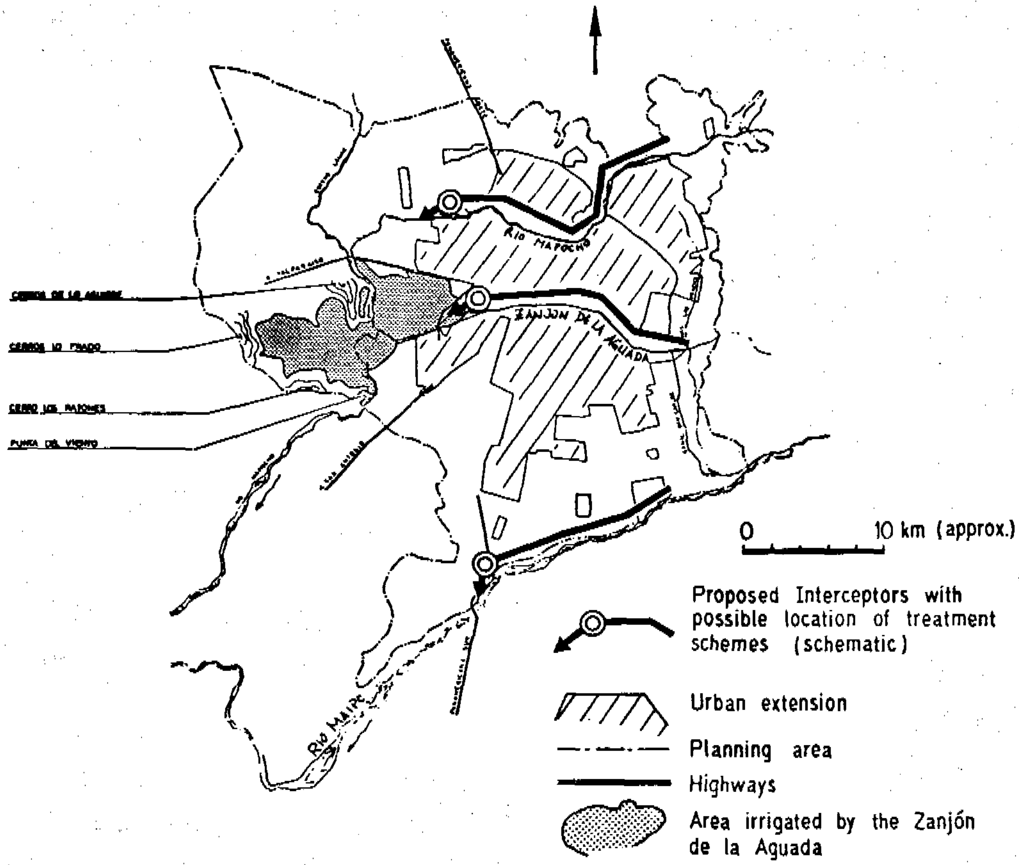

Fig. 3.2 Proposed Sewage Management for Santiago
(Source: Sewerage Master Plan, 1983, and personal communication)

The waste stabilization pond area required to treat the future sewage flows of Santiago was estimated at approx. 1000 ha. The feasibility of such a scheme has been questioned because of the excessive demand for land which is reserved for agriculture or urban development. Plans existed in 1985 to set up ponds, activated sludge and trickling filters to pilot-test the viability of their treatment and efficiency.

Some professionals dealing with wastewater management have expressed their scepticism vis-à-vis an approach which concentrates on the treatment of all wastewater from Santiago as sole strategic option to reduce health risks. It is questionalbe whether the relatively low percentage of raw-eaten vegetables which pose potential excess risks of infection to consumers (lettuce, e.g.) justifies a treatment of <u>all</u> wastewater to the standard of $\leq 10^3$ FC/100 ml required for unrestricted irrigation. In recent years, S.M.R. health authorities had limited success in trying to prohibit cultivation of certain crops.

3.2 Institutional and Regulatory Framework

At the central and local level, various government **authorities** are directly or indirectly involved in the management of water and wastewater and the control of public health. The institutions and their main involvements are listed below.

• **Ministry of Health** (with 21 Health Service Offices outside S.M.R. + Metropolitan Health Service)	- Approval of wastewater collection, treatment and disposal/reuse schemes - Monitoring and control of environmental pollution and health aspects of water supply and wastewater reuse, - Industrial hygiene, - Preventive and curative health services
• **Ministry of Public Works**	
- **SENDOS**, Servicio Nacional de Obras Sanitarias (central + regional offices)	- Planning, funding, implementation and operation of water supply, sewerage and sewage treatment works.
- **DGA**, Dirección Gen. de Agua	- Issuing water rights for specific uses - Controlling the use of water
- Dirección de Riego	- Planning and implementation of irrigation schemes
• **EMOS**, Empresa Metropolitana de Obras Sanitarias	- Water supply and wastewater management for S.M.R.
• Ministry of Agriculture	

The Ministry of Health and SENDOS both operate their own water and wastewater quality control labs.

The **land-owners** who use river and wastewater for irrigation, are organized as "Juntas de Vigilancia" and "Asociaciones de Canalístas". These groups of proprietors are reportedly quite strong and influential. Their tasks include the distribution of canal water according to the assigned water rights, and the maintenance and repair of canals.

Restrictions regarding the use of wastewater in agriculture and crop cultivation are regulated in general terms in the "Código Sanitario" (sanitation code). Sewage and "other waters declared contaminated by the authorities" may not be used to irrigate low-growing vegetables and fruits which are usually consumed uncooked. A decree enacted by the Ministry of Public Works in 1978 stipulates that water used to irrigate such crops must not contain more than 1000 FC/100 ml. This regulation is also contained in the Chilean Standards ("Norma Chilena Oficial") specifying the water quality requirements for the various uses, and listing the crops which may be irrigated only if the water contains ≤ 1000 FC/100 ml (see below).

Starting in 1975, the Metropolitan Health Service (M.H.S.) has made repetitive attempts to enforce the above regulation in S.M.R.. Success was rather limited. An intensified campaign, reportedly supported by police action, started in 1983. As a consequence, a few land-owners shifted cultivation from restricted (raw-eaten vegetables) to non-restricted crops (e.g. grapes). The M.H.S.-resolution, which is based on national laws and regulations, lists the crops which are designated for restricted and non-restricted irrigation, respectively:

• Restricted:	lettuce	carrots
	chicory	coriander
	parsley	strawberries
	radish	
• Not restricted:	artichokes	cabbage
	cellery	

In general, enforcement of the said regulations appears to be difficult and of very limited success. Land owners associations, as well as market and socioeconomic forces probably act as the main factors preventing effective control and enforcement.

3.3 Health and Epidemiological Aspects[1]

- Important Components of the Endemic Disease Situation

Chile is very different from other countries which use untreated wastewater in agriculture. Since it does not lie in the tropical zone, it does not have the same endemic tropical and parasitic diseases. The country is geographically quite isolated, and comparable in some ways to an "island", bordered by the Pacific Ocean to the West, the Andes to the East, and the

[1] The reader is also referred to Section 1.3 where health risks associated with wastewater use have been summarised and to Section 1.4 where the difficulties involved in evaluating the health effects of a specific reuse practice have been outlined.

Atacaman desert to the North. A very high percentage (over 80%) of the population live in urban areas. Chile is technologically quite advanced, has a high level of literacy, and places great emphasis on the provision of social and health services. A National Health Service has been in existence for over 35 years, with an emphasis on preventive services. All Chileans have access to a Health Centre (1320 Health Centres in Chile) and 98% of deliveries occur in hospital. Mother and child health programmes are well-developed, including an established immunization programme, free milk for the first few months of a child's life, education classes and curative care. Measles and pertussis have been greatly reduced by vaccination, while poliomyelitis has been eradicated. Television is relatively cheap and widespread, and health education messages released by the Ministry of Health are frequently televised. Infant mortality rate is very low (about 19 per 1000 in 1987), when compared to that of some countries in southern Europe. This not only reflects Chile's high level of health services but its totally different disease situation compared with countries of similar per capita GNP but with less developed health services.

Chronic as well as infectious diseases account for the most important causes of disease in Chile. The medical services therefore need to deal with both problems. The main transmissible diseases notified are typhoid (and paratyphoid) fever and infectious hepatitis (Table 3.1). The rate of typhoid fever is particularly high, (over the period 1966 to 1983 (Fig. 3.3)) about 80 to 200 cases per 100,000 have been reported in Santiago and a decrease in the rate was seen in 1984. The rate in the Santiago Metropolitan area has been consistently higher than in the rest of Chile. The

Table 3.1 Number of cases of selected notifiable diseases in Chile in 1983 and 1984 (Source: Ministry of Health Statistics)

	All Chile (population about 11 million)		Santiago Metropolitan Area (population about 4 million)	
	1983	1984	1983	1984
Typhoid and paratyphoid	13,922	9,124	9,774	5,728
Infectious hepatitis	10,650	12,815	4,128	6,561
Measles	6,750	4,781	2,883	2,216
German measles	12,925	6,587	7,484	3,008
Diphtheria	78	153	19	31
Meningitis	117	97	35	21
Syphilis	7,352	5,725	2,856	1,991

occurrence of such a high rate of typhoid in Santiago Metropolitan area is particularly unusual considering the high coverage of potable water supplies and excreta disposal facilities. Within the metropolitan area, the rate of typhoid fever is significantly higher in areas of lower socio-economic status than in areas of high socio-economic status (Tables 3.2 and 3.3), though the rate remains relatively high even in the latter areas. The rate of diseases that are susceptible to vaccination is also higher in the low socio-economic areas, so this may be a general phenomenon, and not only seen in sanitation-related diseases.

Two groups of diaseases have been compared by Boccardo et al. (1985); those whose control depends on the quality of basic sanitation, food quality and hygiene education (group A) and those whose control depends on vaccination (group B). It can be seen from Fig. 3.4 that while the rate of group B diseases has decreased dramatically since 1961, the rate of group A diseases remained almost constant and actually increased over the last decade. This suggests that a problem of sanitation and/or food quality and hygiene remains. The contribution of wastewater irrigation to this situation is discussed in the section below on the potential health impact of the current reuse practice.

Tab. 3.2 Morbidity due to typhoid and paratyphoid fever in different health districts of Santiago Metropolitan Region, 1985

Health District	Cases	Cases per 1000	Socio-economic status of area
Norte	500	85.4	
Occidente	518	53.5	
Oriente	495	50.2	HIGH
Sur	1751	176.7	LOW
Sur-Oriente	310	43.5	
Central	474	91.1	
Country as a whole	7565	62.7	

Source: Annual statistics, Ministry of Health, Chile (adapted)

Table 3.3 **Morbidity due to several transmissible diseases in two areas of Santiago (cases per 100,000 persons)**

	Conchalí - San Miguel[1] (low socio-economic status) 1968-1972	1982	Providencia - Las Condes[2] (high socio-economic status) 1968-1972	1982
Typhoid fever	144.9	254.8	50.4	43.1
Whooping cough	20.3	2.1	12.1	0.7
Scarlet fever	63.4	85.2	24.1	11.9
Measles	141.8	55.0	42.2	6.9

[1] In district Norte and Sur
[2] In district Oriente

Source: Boccardo et al. (1985)

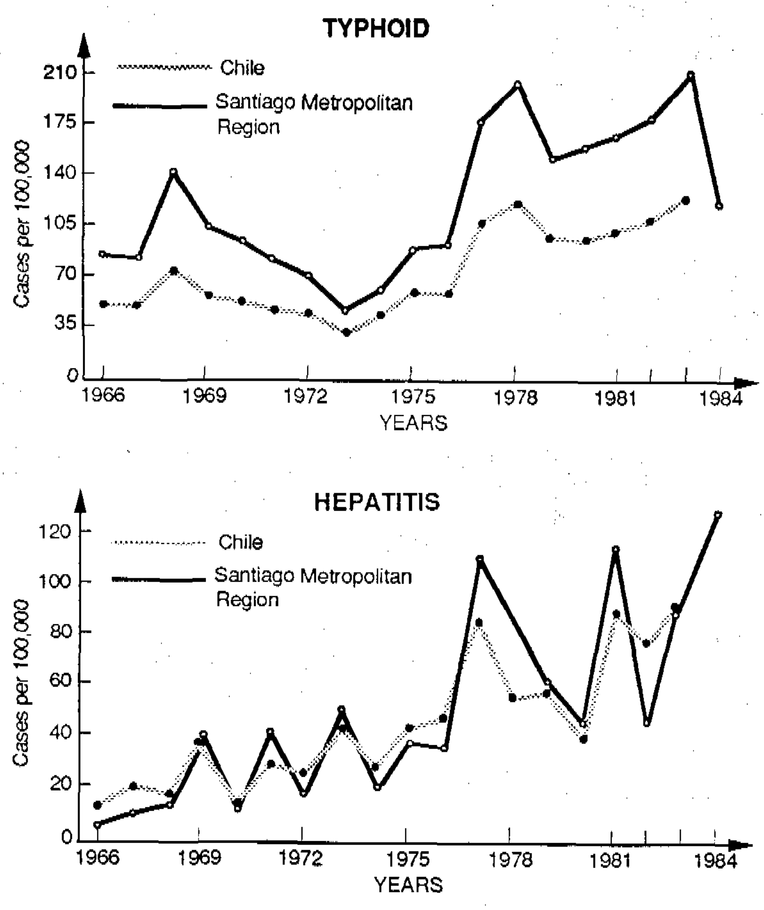

Fig.3.3 Morbidity due to Typhoid Fever and Hepatitis in Chile and in Santiago Metropolitan Region , 1966 - 1983
Source: Annual statistics, Ministry of Health (Data for 1984 from another source)

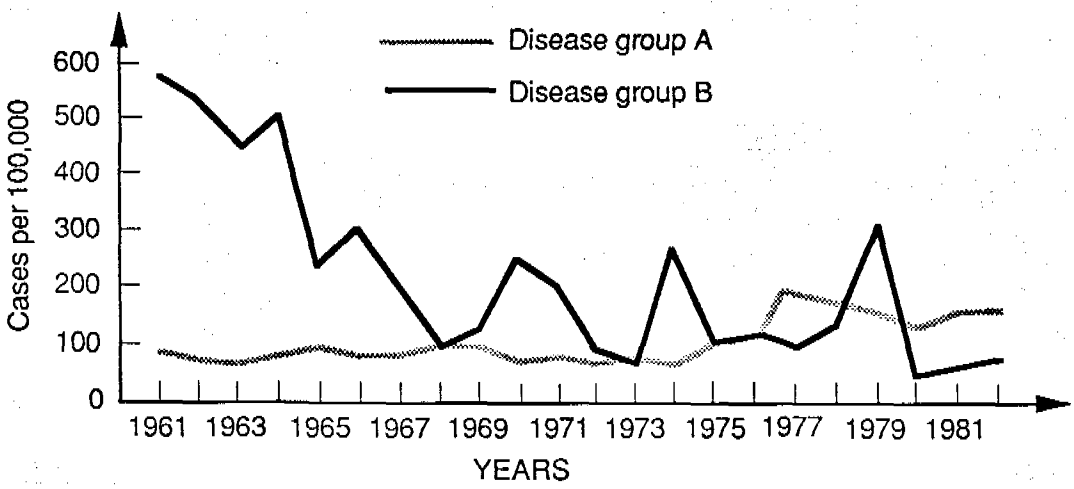

Fig. 3.4 Morbidity in 2 Groups of Infectious Diseases in Chile, 1961 - 1982

Disease Group A: typhoid and paratyphoid fever, bacterial dysentery, infectious hepatitis, amoebiasis, brucellosis, hydatidosis, trichinosis, rabies and tetanus

Disease Group B: measles, whooping cough, diptheria and poliomyelitis

Source: Annual statistics of notifiable diseases, Ministry of Health, Chile

Mortality due to diarrhoeal diseases has decreased, particularly over the last 10-15 years. The rates of diarrhoea in children are low, on average less than 2 episodes per year in children under 5 years (Brunser 1985) and each episode is short (2-3 days) with little dehydration.

Morbidity due to intestinal helminth parasites has also decreased, showing a marked decline in most regions of Chile over the period 1948 to 1980 (Schenone et al. 1981). In the Santiago area for example (zone III), infection with *Ascaris* has declined from about 23% to 1% and *Trichuris* from about 25% to 3% (Table 3.4). The rate of infection with intestinal protozoa has not in general shown such a decline. In 1980 the rate was around 20% for both amoebic infection and *Giardia* infection in zone III. The decline in intestinal nematode infections may be related to the gradual improvement of excreta disposal facilities, but it is possible that the pattern of amoebic infection may show a relationship with the use of sewage in Santiago (see below, "Potential Impact of the Existing Use Practice").

Table 3.4 Changes in Percent Infection Rates for Intestinal Helminths and Protozoa in Different Zones of Chile over the Periods 1948-1954 (a), 1962-1972 (b) and 1970-1980 (c) (from Schenone et al. 1981)

(The 5 biographic zones are numbered from North (I) to South (V); the Santiago area is in zone III)

Zone	Ascaris lumbricoides			Trichuris trichiura			Hymenolepsis nana			Entamoeba histolytica			Giardia lamblia		
	1948-1954	1962-1972	1970-1980	1948-1954	1962-1972	1970-1980	1948-1954	1962-1972	1970-1980	1948-1954	1962-1972	1970-1980	1948-1954	1962-1972	1970-1980
I	1.3	1.0	0.3	4.8	1.7	0.3	8.3	5.4	4.3	14.7	8.0	8.5	17.0	13.8	14.0
II	16.3	6.3	2.5	19.3	1.8	0.8	9.6	8.1	6.0	13.2	9.9	10.8	12.9	23.6	16.3
III	23.1	4.3	0.9	25.2	10.5	3.4	9.5	6.2	7.7	18.6	16.9	23.2	12.9	22.8	18.1
IV	53.5	48.1	20.7	60.9	56.7	28.5	1.2	2.6	1.3	10.6	7.4	16.5	7.7	8.3	15.8
V	1.3	1.4	0.5	14.6	24.0	5.9	0.5	4.1	2.7	3.2	2.9	4.8	9.7	22.8	20.5

a. Neghme & Silva, 1956; b. Ramirez et al., 1972; c. Schenone et al., 1981

Water Supplies, Excreta Disposal and Hygiene Behaviour

In the 1970s, major progress was made with regard to the supply of potable water in the urban sector. Coverage increased from 62% in 1970 to 93% in 1980 (Juricic 1982), and was thought to be 100% in 1983 (see country background). A central supply system now provides filtered, chlorinated drinking water direct to the home. In the urban sector, the proportion of the population with indoor sanitation connected to the main sewerage systems increased from 36% in 1970 to 70% in 1980 (Juricic 1982). However, only 2% of the wastewater receives any treatment, while the remaining discharged into rivers.

Progress in water supply and excreta disposal is less advanced in the rural sector (amounting to 20% of the whole population of Chile). Potable water supplies are provided in towns with over 200 inhabitants; the percentage served increased from 17% in 1970 to 49% in 1981. Less emphasis was put on the sanitation sector, and therefore only about 10% of the rural population dispose of latrines. Current objectives for the 1981-1990 decade include an increase to 100% both in potable water supply (in urban and rural zones) and in urban sewerage connection. Increased rural sanitation coverage and provision of wastewater treatment are some of the targets set for the year 2000.

The greater availability of water supplies in the urban areas of Chile and the higher level of education compared with similar urban areas of other countries, may suggest higher levels of personal hygiene. However, this is not always the case, and hygiene habits are not always ideal, especially in poorer sectors of the community. There is some evidence indicating that poor families use more water and have a better hygiene practice when relocated from temporary dwellings to better housing facilities (Alvarez, pers. comm.). Studies of faecal coliform levels in the environment, on hands and vegetables suggest that faecal contamination is widespread, while other studies indicate a common occurrence of asymptomatic infections, thereby revealing a contamination which may not lead to the outbreak of the "disease" (Brunser, pers. comm.). Further studies on the influence of environmental contamination and hygiene practices on diarrhoeal diseases and typhoid fever are being carried out by Dr O. Brunser and his team at the Institute of Nutrition, University of Chile, Santiago.

- Potential Impact of the Existing Use Practice

The potential health impact of the use of untreated wastewater in Santiago has been reviewed by Shuval (1984), and the impact on typhoid fever is reported by Shuval et al. (1986). The main points raised are summarised here, and supplemented by further data gathered in Chile.

The prevalence of protozoan and helminth infections and an estimate of the number of infected persons in different biographic zones of Chile in 1980 is shown in Table 3.4 (Schenone et al. 1981). The prevalence of the intestinal nematodes, *Ascaris* and *Trichuris*, is very low in the Santiago area (zone III) but higher in a more humid agricultural area in the South (zone IV). Use of sewage in Santiago does not appear to be causing increased infection with intestinal nematodes, although in other situations (e.g. India) a significant excess can be attributed to use of raw sewage in irrigation. The number of infected people passing eggs into the sewage system in Santiago is relatively low, and possibly insufficient to maintain transmission through this route. The prevalence of *E. histolytica* infection is, however, more prevalent in Santiago region than in the rest of the country. The detection of *E. histolytica* cysts in wastewater from an irrigation canal near Santiago led Horwitz (1954) to suggest that irrigation with wastewater could be a vehicle for transmission of amoebiasis to the consumers of contaminated crops. Schenone, however, felt that poor personal hygiene and poor food sanitation in public restaurants may be an important contributary factor. The explanation for the observed distribution of infection is therefore not certain, but it is probable that several transmission routes are involved, with sewage irrigation as only one factor.

The most important possible impact of the practice of sewage irrigation is its impact on the incidence of typhoid fever. Recent research on the epidemiology of **typhoid fever** in Chile has mainly been done and is still being continued by the Chilean Typhoid Fever Control Program in the Ministry of Health, led by Dr Catherine Ferreccio, in collaboration with a team of scientists from the University of Maryland, led by Dr M. Levine. The main circumstantial evidence linking the high typhoid rates with sewage irrigation of salad crops is summarized below (after Shuval et al. 1986):

i. the seasonal increase in typhoid fever coincides with the seasonal onset of sewage irrigation in summer;

ii. the incidence of typhoid in Santiago is much higher than in other cities in Chile where there is no sewage irrigation; however, this is only the case during the summer irrigation months, and the rates are similar in the winter months;

iii. typhoid fever rates do not increase in summer in the lakes region where many people from Santiago spend the summer vacation. This suggests that such people may be removed from the source of transmission, and do not bring person to person transmission factors with them;

iv. typhoid fever rates in infants (0-2 years) are low, suggesting that short-cycle person-to-person contact is not a dominant form of transmission in Santiago;

v. cases of typhoid are distributed among all socio-economic neighbourhoods in Santiago, and are not confined to lower class areas;

vi. *S. typhi* has been isolated from wastewater canals used to irrigate land growing salad crops (Sears et al. 1984).

The highest incidence, however, is in children aged 8-13 years, which suggests that factors other than the consumption of contaminated vegetables may be important. A case-control study (Black et al. 1985) to identify risk factors for endemic typhoid fever in children found that:

a) significant risk factors included eating lunch at school, sharing food with class-mates, and consuming flavoured ices bought outside the home;

b) significant protective factors included travel out of Santiago, and other activities (e.g. swimming in a lake or the ocean) which implied a vacation outside Santiago.

Studies (Morris et al. 1984) on the families of paediatric index cases of typhoid fever have indicated that there are very few secondary cases in the households, and that in most cases the index case ingested the vehicle of transmission outside the household.

Many observations are still unexplained, e.g. the isolated nature of each case (no clustering), the difficulty in culturing *S. typhi* from suspected agents (e.g. lettuce) and the difficulty in understanding where the proliferation stage occurs. The hypothesis that typhoid fever is linked with a high prevalence of cholelithiasis (gall bladder disease) is not accepted by all research workers in Chile. However, it may be that gall bladder disease leads to a higher number of *S. typhi* carriers, so that more bacteria enter the sewage system. The number of chronic carriers has been estimated by Levine et al (1982). Further studies centre on the possibility that food hygiene plays a major role but that only a certain proportion of the population (e.g. 20%) are susceptible.

The available evidence suggests that sewage irrigation may explain the excess of typhoid infection seen in Santiago compared with the rest of Chile, but it does not account for all the cases of infection and does not explain the abnormally high rates in the rest of Chile. The outbreak in 1976-77 affected all the country, and the age distribution of infection is the same in all sites; the differences between Santiago and the rest of Chile are in the actual rates and the seasonal effects. Treating the sewage in Santiago, i.e. affecting the long cycle of transmission, may therefore only reduce the rates by about 40% (Ferreccio, pers. comm.). Improvement of the hygiene of food handlers who sell food in the schools and on the streets and the treatment of chronic *S. typhi* carriers also need to be done before the rates of infection can be reduced. The reduction in infection rates seen in 1984 (Fig. 3.3) has been attributed both to the vaccination of groups at highest risks and to prohibition of growing certain crops; the role of each intervention has been difficult to interpret (Ferreccio, 1987). A report of the work of the Typhoid Fever and Enteric Infections Control Programme of the Ministry of Health provides summaries of its work from 1981 to 1987 (Ferreccio et al. 1987).

In **summary**, the health impact of the existing indirect use of untreated wastewater in irrigation in Santiago includes:

a) increased risk of typhoid fever among consumers of vegetable crops

b) increased risk of amoebiasis and possibly other gastro-intestinal infections among consumers of vegetable crops, and possibly also among farm workers

c) <u>no</u> increased risk of intestinal nematode infections among farm workers or crop consumers is indicated.

3.4 Implications for Control of Health Risks

The possible health protection measures that could be adopted include treating the wastewater before use and restricting the crops grown. Crop restrictions have been found to be difficult to enforce (Monreal, pers. comm.), particularly since the sewage has been discharged into the river and is not under the control of the authorities. Control of the crops grown may be more feasible once the new interceptors are built to convey the sewage underground through Santiago; in that case, farmers could only be given rights to use it if they comply with the restrictions. There is a strong demand for salad crops in Santiago, however, which means that any restriction on the crops to exclude salad vegetables would be unpopular with the farmers.

Treatment of the sewage would be a preferable solution, to allow unrestricted irrigation to occur. Since the main risks associated with wastewater reuse in Santiago are of bacterial infections, a treatment technology which can produce high bacterial removal is necessary. Waste stabilization ponds would be suitable, if an appropriate area of land were available to hold the required number of ponds. Since temperatures fall to quite low levels in winter, though, the retention time needed to produce an effluent of less than 1000 faecal coliforms is likely to be higher than in most of the other countries discussed in this document. Intestinal nematode infections do not appear to be a problem in Santiago, so the ability of the treatment technology to remove helminth eggs is not critical. Conventional secondary treatment followed by chlorination could in this case also be considered, to kill any bacteria present, as long as good maintenance of the plant could be achieved and money were available for recurrent costs of the chlorine needed. The effectiveness of chlorine on amoebic cysts, however, is less clear, and would depend on the chlorine dose applied, the quality of the effluent, the contact time and the temperature. It is possible that tertiary treatment (including filtration) before chlorination would be necessary to allow the chlorine to be effective against amoebic cysts.

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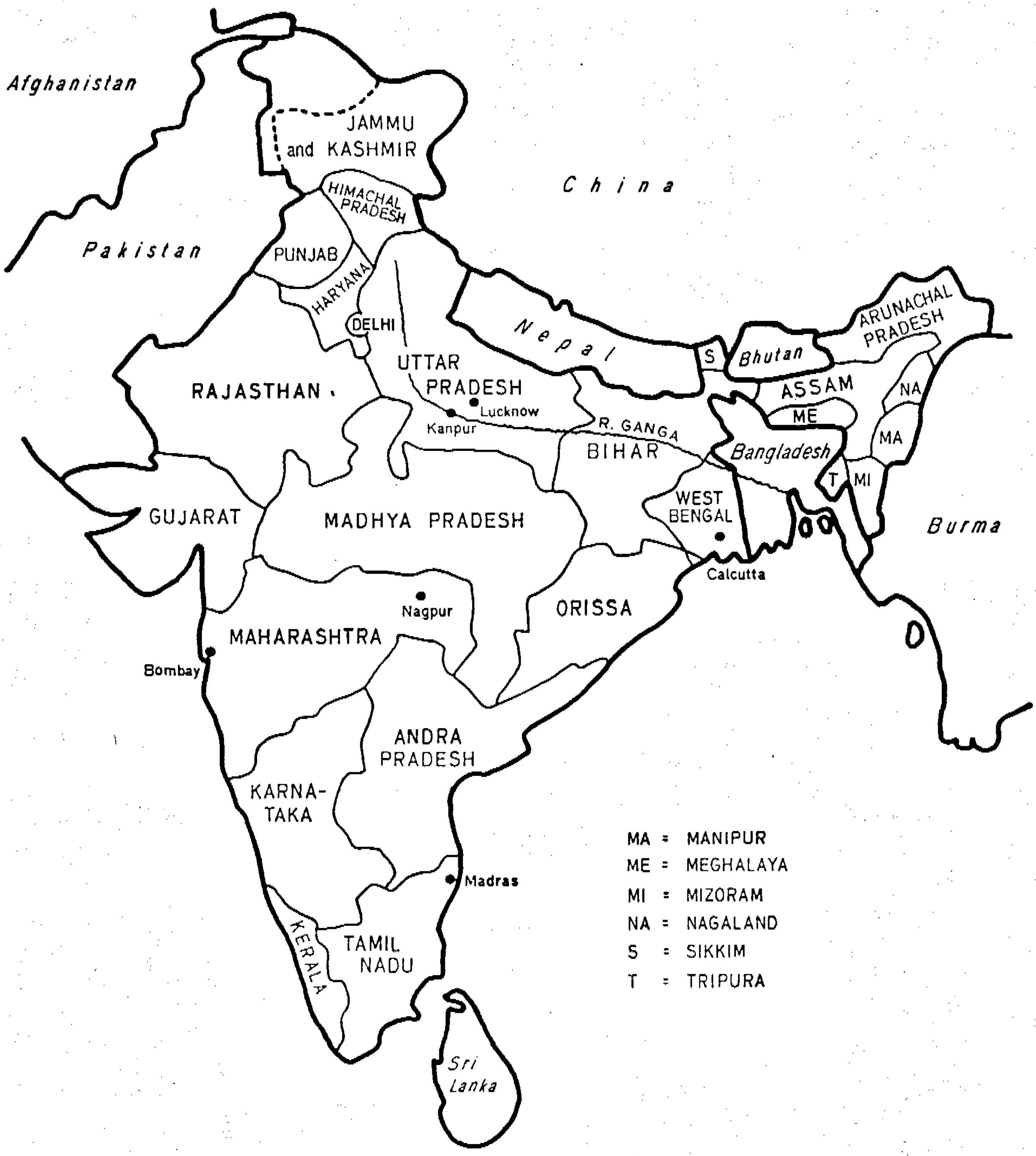
4 INDIA

Acronyms

Jal Sansthan	Municipal Water and Sewerage Corporation
Jal Nigam	State Water Corporation
Mahapalika	(municipal) Corporation
Nagar Palika	Municipal Council
NEERI	National Environmental Engineering Research Institute, Nagpur

I N D I A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Sri Lanka
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PUNJAB
HARYANA
DELHI
UTTAR PRADESH
Lucknow
Kanpur
R. GANGA
RAJASTHAN
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ARUNACHAL PRADESH
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WEST BENGAL
Calcutta
GUJARAT
MADHYA PRADESH
ORISSA
Nagpur
MAHARASHTRA
Bombay
ANDRA PRADESH
KARNA-TAKA
Madras
KERALA
TAMIL NADU
MA = MANIPUR
ME = MEGHALAYA
MI = MIZORAM
NA = NAGALAND
S = SIKKIM
T = TRIPURA

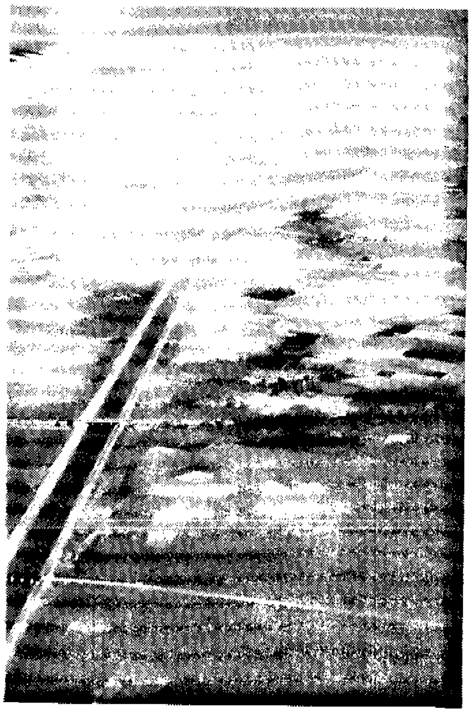

Photo 4.1

Irrigation canal carrying river water near Lucknow, Uttar Pradesh

Photo 4.2

Outfall 1 of the Kanpur (U.P.) wastewater force main. The wastewater is used to irrigate 1300 ha of rice, wheat, forage and flower fields

Photo 4.3

Part of the farming area on the outskirts of Lucknow (U.P.) irrigated until 1982 with untreated wastewater

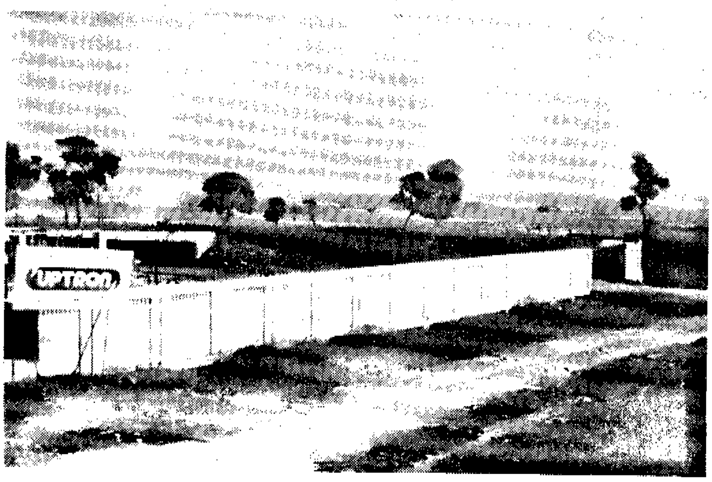

Photo 4.4

Industrial expansion to the farming area near Lucknow which was previously irrigated with wastewater from the city of Lucknow (U.P.)

4.1 Wastewater and Nightsoil Use in India - an Overview[1]

• Excreta and Wastewater Disposal

In **rural areas** excreta disposal is practised on-site, i.e. mainly through open defecation and, in a few places, through dry latrines. In **urban areas**, the excreta disposal and sanitation infrastructure is organized as follows:

- Approximately 30% of the households have neither toilet nor latrine facilities
- About 40 % of the households have bucket or dry latrines, from which excreta are manually collected
- 20 % are connected to sewerage systems,
- A small percentage has water-borne disposal with septic tanks and soakage pits.

Although piped water supplies are installed in about 65% of the urban communities, sewerage systems exist in about 10% of the cities. The percentage of houses served by an in-house water supply is probably higher in large cities than in small towns (e.g. in Kanpur, U.P., 75 % of the population dispose of house connections). Of the 60 million people who live in towns with more than 100,000 inhabitants, about half are connected to sewerage schemes. Sewage production is about 120 ℓcd. Thus, 3-4 MM^3 of sewage are produced daily in these cities. The total wastewater flow in India has been estimated at 10 MM^3 per day (cited in Shende et al 1988). About one third of the sewage produced is subjected to treatment. The country disposes of 1,000 sewage treatment plants, of which 150 are waste stabilization ponds. Aerated lagoons are projected to treat city sewage in New Delhi and Bombay. Investigations of sewage treatment plant performance commissioned by the Central Board for the Prevention and Control of Water Pollution, have shown that a large percentage of the sewage treatment plants does not function properly or is out of order.

Since the beginning of the Water and Sanitation Decade, there exists a programme to seek and implement low-cost solutions for excreta collection and disposal in urban areas: Between 1981 and 1984, 800,000 twin-pit pour-flush latrines were installed in more than 100 towns. The construction of another

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[1] In India, too, the team's travel lasted one week, so the number of sites which could be visited, was very limited. Given the vastness of the country, the account of reuse practices presented in this chapter is limited as well. There is, unfortunately, a lack of published information in reuse aspects in India.

700'000 units is now under way. The demonstration projects supported by the Federal Government of India and UNDP, will eventually provide adequate excreta disposal to a large number of the urban population. This will contribute to a gradual replacement of indiscriminate defecation and excreta collection from bucket latrines by scavengers. At the same time, it is a sound alternative to centralized sewerage schemes, which in many cases are economically and financially unaffordable.

Large portions of excreta collected by scavengers in urban areas are transported to the nearby rural areas where they are used on the fields. Similarly, wastewater from many cities in India is reused on farmland bordering the urban areas. This chapter provides an overview of the reuse situation nationwide, while Chpt. 4.2 gives an account, sketchy though, of agricultural wastewater reuse in Uttar Pradesh, notably Kanpur and Lucknow, which were visited by the authors themselves to observe reuse practices. Chpt. 12 contains a detailed description of the reuse of wastewater for fish production in Calcutta.

- Rationale for Reuse

In India, there is a distinct **seasonal rainfall** pattern, i.e. in most areas, the rainy periods last from June to October with rather dry weather during the remaining months. Coastal belts receive medium to high annual rainfall (Madras 1270 mm, Calcutta 1600 mm, Bombay 2080 mm), while in Uttar Pradesh and other continental areas, the yearly rainfall is low. In New Delhi, on the western border of Uttar Pradesh, rainfall amounts to only 670 mm per year. Additional water sources must therefore be tapped in these climatic zones to provide irrigation water in the dry season, and possibly also to complement direct rainfall during rainy periods. In some areas of Uttar Pradesh, wastewater constitutes as much as 20 % of the irrgation water.

Since raw or only partially treated sewage is used for irrigation in India, only minor investments had to be made, such as for low-lift pumping stations and main irrigation canals. It is assumed that wastewater reuse is an economically attractive alternative to groundwater extraction or surface impoundment, even if higher investments for treatment will eventually have to be made. This will probably be the case more so in the future and particularly where groundwater resources are already used to their limit and where the growing demand of urban water supply competes with the use of groundwater for irrigation.

Besides climatic, water resources and nutrient related aspects, prevention of river pollution is an important factor in wastewater reuse. Though, historically, sewage farming in India might have developed mainly to augment irrigation water in a seasonally semi-arid climate rather than for pollution control purposes, this aspect now plays an important role in the Ganges clean-up programme which was started recently: reuse of treated wastewater in agriculture has been selected as the strategy for wastewater management.

In other semiarid areas such as Peru, Chile, Mexico, and Tunisia, where wastewater irrigation is practised, the increasing demand of fast growing urban populations for vegetable and animal produce (milk and meat) appears to be the decisive rationale for farmers to produce vegetables and forage crops on the wastewater-irrigated fields bordering the urban zones. In India, too, vegetables are an important part of the diet of the majority of people, and market demands in the growing urban areas are likely to further increase in the years to come.

- Wastewater Reuse[1]

An estimated 2/3 of the wastewater produced in inland cities is used on land, whereas sewage from some of the coastal towns and cities is discharged into the sea[2]. Sewerage schemes have been installed or extended in many cities in recent years. The area under irrigation has increased from 12,000 ha in 1971 to 73,000 ha in 1985.

Wastewater irrigation appears to be practised in at least 200 places with the oldest sewage farms being in operation for five or six decades. Wastewater use takes place exclusively through surface irrigation which ranges from uncontrolled flooding to ridge and furrow, border-strip, and check basin irrigation. The more capital-intensive methods of sprinkler and subsurface (drip) irrigation are not practised on sewage farm. Shende (1988) judges that "sewage farming is often done in a crude and irrational manner, although experience over decades has been gained". He thereby

[1] Most of the information presented in this chapter is taken from Shende et al. (1988)

[2] Plans existed to store in impoundment reservoirs, large flows of sewage produced in the Bombay metropolitan area for use in irrigation. However, the land which was earmarked for sewage farming and which would have been within an economic distance from the lagoons, is also contested by industrial development. This might be one of the reasons, why, reportedly, the reuse plan was given up or changed to ocean disposal (personal communication).

refers to several aspects of sewage farming, such as the hydraulic management (water distribution, application rates), adequateness of drainage, nutrient balancing, and health implications (microbial quality of sewage, crop selection and control). Below are some of the specific shortcomings listed by him:

- Many farmers overirrigate to achieve maximum fertilization effects. As a consequence, nitrogen application rates may reach the ten-fold of "normal" rates. Surplus nitrogen is then lost either through ammonia volatilization, denitrification and leaching of nitrate into the subsoil and groundwater. Overirrigation appears to be linked to the fact that in many places sewage charges are based on the area under irrigation (and possibly crop type) rather than on quantities of sewage used.

- Reportedly, plots are often improperly levelled. This leads to uneven distribution of sewage, ponding in furrows and on plots and air logging in the soil. Odour nuisance, and fly and mosquito breeding are often the consequence.

- Proper drainage appears to be widely lacking. This enhances the risk of soil salination, particularly where groundwater levels are high or where soils have low permeability[1].

- According to some researchers, sewage farm workers are at an actual risk of acquiring worm infections which is greater than the risk of workers farming on freshwater-irrigated land (see also Chpt. 4.3, Health and Epidemiological Aspects).

- There is, apparently, no control over the selection of crops which are irrigated with wastewater. A survey done by NEERI a few years ago showed that all types of edible crops, consumed both raw and cooked, are grown on sewage farms irrespective of the quality of sewage used (see also Table 1).

Table 4.1 summarizes the main features of the selected sewage farms which were surveyed by NEERI (Shende et al. 1988). Apparently, mainly **forage crops** are cultivated on the farms surveyed. **Vegetables** and **paddy** are grown on half of the farms. **Maize** and **cereals** are other important crops irrigated with sewage.

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[1] The risk of salinisation is not limited to wastewater use. It also exists where freshwater is used for irrigation.

Table 4.1 Features of Some Selected Sewage Farms in India (Shende et al. 1988)

Location (State)	Command area (ha)	Volume of sewage used (1000 m^3/d)	Application rate (m^3/d,ha)	Application rate (ℓ/s,ha)	Treatment if any	Dilution if any	Soil type	Crops grown
Ahmedabad (Gujarat)	890	300	337	3.9	nil	nil	Sandy loam	- Paddy, maize, pochia grass, jowar, wheat, lucerne
Amritsar (Punjab)	1214	55	45	0.5	nil	1:3	Sandy clay	- Maize, sorghum, berseem, lucerne
Bikaner (Rajasthan)	40	14	337	3.9	nil	nil	Sandy	- Bajra, wheat, grasses, vegetables
Bhilai (Madhya Pradesh)	607	36	60	0.7	stab.ponds	nil	Sandy and clayey loam	- Paddy, maize, wheat, tuwar, vegetables
Delhi	1214	227	187	2.2	prim.+sec.	nil	Sandy loam, loamy sand	- Jowar, bajra, maize, barley wheat, pulses, vegetables
Gwalior (Madhya Pradesh)	202	11	56	0.6	nil	nil	Silty and clayey loam	- Paddy, maize, andguar, jowar cowpea, wheat, potato, berseem, vegetables
Hyderabad (Andhra Pradesh)	607	95	157	1.9	primary	1:1.5	Loam	- Paddy, para-grass
Jamshedpur (Bihar)	113	9	80	0.9	secondary	nil	Clayey loam	- Miscell. grasses, berseem, jowar, maize
Kanpur (Uttar Pradesh)[1]	1416	32	22	0.25	nil	1:1	Loam and silty loam	- Wheat, paddy, maize, barley potato, oats, vegetables
Madras (Tamil Nadu)	133	7	51	0.6	nil	nil	Sandy to silty loam	- Para-grass
Madurai (Tamil Nadu)					nil	nil	Red sandy loam	- Guinea grass
Trivandrum (Kerala)	37	9	232	2.7	nil	1:1	Sand	- Para-grass

[1] See also Chpt. 4.2

Presumably, the selection of crops to be irrigated depends mainly on the type of soil, on the socioeconomic situation of the farmers, and on market demands in the particular area. Smallholders and poor farmers may tend to cultivate and sell vegetables, because with the small holding hardly any profit can be made from forage crops. Since most vegetables have shorter growing periods than other crops, they yield a more regular cash income.

In some of the cases listed in Table 4.2, the wastewater undergoes treatment or partial treatment prior to use. Pathogenically "safe" sewage can be produced only where stabilization ponds are used. Furthermore, in a few cities, the **wastewater is diluted** prior to application. Whether and to what extent surface (river) or groundwater is used for this purpose has not been investigated.

In general, sewage irrigation is practised mainly during dry periods. In the rainy season, sewage is largely discharged into receiving water bodies. This is done at times and in some places also during wet spells in the dry season. Sewage discharged into dry river beds will then not be diluted by natural river flow and therefore pose a potential health risk to downstream users.

Besides formal use of sewage, whose distribution usually falls under the jurisdiction of the municipal Councils or Boards ("Nagar Palika"), there seems to be widespread and frequent informal use of sewage and sullage for irrigation purposes. Wherever wastewater is available, it is either diverted from open drains or pumped from river beds.

Although there is a law or ordinance prohibiting wastewater irrigation on raw-eaten vegetables, vegetable irrigation with sewage is still widely practised. Apparently, there is little or no enforcement of the law regulating the selection of crops in relation to the hygienic quality of the wastewater applied. Except for the construction, operation and maintenance of wastewater conveyance systems and the administration of wastewater allocation to the farmers, government bodies are not routinely involved in the monitoring and control of the health and agricultural effects of wastewater reuse. To date, in order to reduce health risks, treatment of wastewater prior to application is practised only in a few cases. Treatment of large sewage flows has so far not been affordable to the public sector.

- Use of Nightsoil

The government of India decided several years ago to gradually replace the urban bucket latrines or "service privies" by pour-flush double-pit latrines mainly (see also Chpt. 4.1) and since made intensive efforts. This will bring about a decrease in the handling and use of raw nightsoil by scavengers and farmers and thus contribute to reducing the risks of disease transmission. However, due to the widespread existence of service privies and the long period required to have all of them replaced, the use of raw or insufficiently stored nightsoil is at present still occurring, particularly in the areas surrounding urban centres. Nightsoil is collected from the bucket latrines or "service privies" in towns and cities and transported to trenching and storage grounds. Collection from latrines to transfer points within the city is mostly done manually by scavengers. From the transfer grounds nightsoil is hauled by carts or trucks to the trenching grounds or delivered directly to farmers. Reportedly, some farmers store the excreta in pits prior to use. An interesting question here is whether farmers apply nightsoil prior to sowing or planting only, or also during the growing period. In the first case, the excreta might have been in storage for some time before being applied to the fields, if nightsoil has not been purchased only just when need arises and used fresh. Health risks may vary in intensity, depending on the respective practice in use.

In a number of municipalities in the Calcutta metropolitan area, nightsoil is reportedly co-composted with solid organic wastes (e.g. market refuse) on trenching grounds and then sold to farmers. Presumably, this takes place under predominantly anaerobic conditions. Often, the great demand for the "compost" prevents the material to be stored long enough and become hygienically safe.

It appears that collection and use of nightsoil go essentially without control, i.e. in many situations nightsoil is used fresh and its handling involves considerable potential health risks. The low-cost sanitation programme which has been started in many towns and cities with the support of the Federal Government (see also Chpt. 4.1), and through which twin-pit pour-flush latrines are propagated to replace bucket latrines, will bring about a change in the nightsoil collection and use pattern. If properly operated, pour-flush latrines with alternatingly operated leaching pits produce a fecal product which is safe for handling and use in agriculture.

- The Ganges Pollution Control Project

The Federal Government and the State Governments in the Ganges river basin have engaged in an intensive programme which aims at reducing the pollution of the river Ganga. The first phase of the programme, which covers the years 1985-90, comprises the implementation of sewerage and sewage treatment infrastructure in a number of major cities situated along the river. Federal and State Governments have set aside the equivalent of US $ 250 million for studies, design and construction works during this phase. In Uttar Pradesh, six large cities are earmarked to receive sewage treatment installations during this period. Kanpur and Varanasi (Benares) are among the six cities.

The general concept for treatment and disposal of wastewater is to select such technologies and options which will allow optimum productive use of the wastewater. Digestion of sewage sludge to produce methane and electrical energy, and **reuse of the treated sewage** in agriculture and forestry are the resource recovery options which, according to Uttar Pradesh Government bodies, are strongly favoured and contemplated for implementation. The final selection of sewage treatment methods was still pending in 1985. The use of waste stabilization ponds (WSP) is not considered feasible for large cities with populations of several 100,000 or more. The large land requirements of ponds at cities' outskirts conflict with the demand for land by the expanding cities and the agricultural use. For this reason, officials give preference to "conventional" treatment by primary and secondary (activated sludge, trickling filter) methods. WSP or oxidation ditches are considered feasible only for small towns with not more than a few 10,000 inhabitants.

Conventional secondary treatment would be geared exclusively towards satisfying water pollution control standards (i.e. to improve the biochemical and biological quality of the Ganga). Such treatment, however, hardly contributes to reducing the potential health risks from pathogens as retention periods in the treatment plants amount to only a few hours, in contrast with days or weeks in stabilization ponds. There is, therefore, only negligible die-off of pathogens in conventional plants. In the light of the apparent impracticability of using WSP in large cities due to the large land requirement of such schemes, some officials propose to introduce and enforce restrictions for the **selection of crops** which may be irrigated with wastewater as an alternate means to minimize consumer health risks. However, a minimal degree of wastewater treatment for parasite removal would be required to protect the health of the farmers and labourers (see also Chpt. 1.3.).

The impression was gained that the task of selecting the optimum wastewater treatment and disposal strategy for large sewage flows is indeed very challenging because conflicting criteria are to be considered. These comprise:

- River quality standards to be satisfied
- Pathogen levels to be minimized
- Scarcity/high cost of land near urban areas, which exclude or renders difficult the use of WSP for pathogen reduction
- Economic and financial limitations, which restrict the use of equipment and energy-intensive treatment installations or chemical disinfection
- Increasing demand for irrigation water to enhance agricultural production.

Several decades ago, **Calcutta** devised a very sensible system of wastewater management: Sewage is treated in ponds which also serve for **fish production.** The wastewater passes through series of ponds of variable sizes which are skillfully managed by fishermen. Pond BOD loading rates are low and correspond to loading rates for maturation ponds (Bartone 1989). The wastewater is subsequently used for irrigation. Chpt. 12 contains a detailed description of the wastewater-based fish production in the Calcutta "Wetlands".

Similar systems might be considered as potential wastewater management options in the Ganga Project. Yet, in contrast to the Calcutta pond system, highly loaded primary ponds would be required ahead of maturation/fish ponds in order to remove organic matter and to save land. The economic and financial gains from fish production may balance or at least partly outweigh the WSP investment cost of which the land cost may constitute a large fraction.

4.3 Wastewater Irrigation in Uttar Pradesh

- Overview

There are over 20 sewage irrigation schemes in Uttar Pradesh according to one source (personal communication). However, in a listing drawn up by the U.P. Water Corporation and Dept. of Agriculture, only 24 schemes are registered. The majority of the schemes were set up as engineered systems and comprise the collection canals within the cities, as well as low-lift pumping stations, the main outfalls to the agricultural areas, distribution channels and major appurtenances. Most towns and cities with sewerage systems have apparently sewage farms. In some places, there is also informal or uncontrolled use of sewage for irrigation, i.e. farmers divert or pump sullage or wastewater from open drains.

In some areas, sewage constitutes up to 20 % of the irrigation water used. The major water sources are groundwater extracted by tubewells and river water conveyed by canals. The actual relative contributions from the three types of sources vary from place to place. Photo 4.1 shows a view of a rural area and irrigation canal near Lucknow.

Rainfall in Uttar Pradesh is rather scarce and resembles that of semi-arid areas. In New Delhi, e.g., the mean annual rainfall is 670 mm, with a maximum of approx. 1,300 mm and an average minimum precipitation amounting to 200 mm only. The rain is seasonal, i.e. 80 % falls during the months of June to September.

As in other sewage farms elsewhere in India, various kinds of crops are cultivated in Uttar Pradesh's sewage irrigation schemes, i.e. among others, paddy and miscellaneous kinds of **cereals. Vegetables** are widely cultivated, too, as they are favoured cash crops and constitute an important part of the diet of many city dwellers.

The majority of the farmers in Uttar Pradesh are smallholders with holdings of less than 1 ha. 25 % of the farmers have holdings of 1-2 ha, and 4 % own > 4 ha. Most smallholders also work as casual labourers on other people's farms or in industry. Presumably, many farmers who own land within the irrigation command areas - either irrigated with sewage or freshwater - belong to the group with medium to large holdings.

According to information from the U.P. Department of Agriculture, salinisation of U.P. soils has reached alarming levels. 1.2 million hectares (12,000 km^2) of agricultural land have excessive salt contents or are alkaline. It is thought that this is due mainly to lack of proper drainage in areas where irrigation is practised[1].

The 24 sewage utilization schemes contained in the listing of U.P. Jal Nigam (U.P. Water Corporation) and Dept. of Agriculture for 1984/85 comprise a total irrigation area of about 3,000 ha. The farms range in size from only 10 ha up to 1,300 ha (Kanpur), with an average size amounting to 200 ha. Irrigation rates calculated from the figures listed for command areas and flows of reused sewage range from as little as 0.1 ℓ/s•ha to as much as 10 ℓ/s•ha.

The sewerage schemes and sewage irrigation infrastructure have been or are constructed by U.P. Jal Nigam (U.P. Water Corporation) and then handed over to the respective city governments. It is the task of the municipal "Jal Sansthan" (water corporation) or "Mahapalika" (development corporation), to operate and maintain the main works of sewage irrigation systems. Reportedly, many schemes do not function as projected or have completely broken down. The reasons for this state of affairs are delays in the handing-over of responsibilities, lack of maintenance, and shortcomings in the construction and operation of the schemes.

- Kanpur

Kanpur is a large, industrialized city with a population of about 1.8 million. The city borders the river Ganga (Fig. 4.1). Water supply infrastructure consists of house connections (75 %), and public standpipes and wells with handpumps (25 %). About 50 % of the inhabitants are served by the sewerage system.

In unserved areas people use bucket latrines whose content is then collected by scavengers. Collected excreta are partly transported to storage or trenching grounds and partly discharged into the sewerage system through special discharge "privies".

Sewage collected in the northern areas of the city is conveyed to the 1,300 ha (13 km^2) sewage farm in the north-eastern sector of the city. According to the information obtained by the Kanpur Municipal Corporation, at present, approximately 50,000 m^3 of sewage are used daily in the command area. Sewage, which is diluted with freshwater at a ratio of 1:1 to 1:2, is screened and conveyed by low-lift pumps through a 1 km force main to the outfall at the head of the gravity distribution system (Photo 4.2). There

[1] Salinisation of soils in irrigation cultures is a phenomenon which occurs world- wide and which has been observed since ancient times. The book "Losing Ground" by Erik P. Eckholm (Pergamon Press 1976) contains instructive accounts of such case histories.

are about 30 km of concrete and earth canals of which at least 9 km were reportedly constructed by Jal Nigam. These works were implemented in 1950. Upon completion, they were handed over to Kanpur Jal Sansthan (Water Corporation) for operation and maintenance. Jal Sansthan is leasing the distribution system to Kanpur Mahapalika (Municipal Corporation) which is in charge of the system's management. The pumping station is operated and maintained by Jal Sansthan. Mahapalika owns itself 340 ha within the command area which are let to 84 persons. 900 ha are privately owned by about 2,000 farmers. The farmers, both owners and lessees, are members of a farmers association, which takes care of the distribution of wastewater and formally coordinates with the authorities. The lease rate for municipal land was Rupees 40/acre•year (R. 100/ha•yr) in 1985 and sewage used by farmers letting municipal land costs R. 250/acre•yr. The charge to private cultivators for the use of sewage depends upon the kind of crops cultivated and the hectarage under irrigation. Fees are collected by the Corporation's operators.

Generally, wastewater is used during dry seasons, only. In the monsoon, it is discharged into the Ganga. Reportedly, the supply of sewage does not meet the demand by farmers. This appears to be partly due to the pumping station working below capacity. Whether it might also be due to uncontrolled expansion of the command area was not inquired.

At the time of the visit to the irrigation area, i.e. in November, most paddy fields were already harvested and the fields were being flooded to prepare them for the sowing of the "winter" crops (wheat e.g.). Besides paddy, marigold was also grown in the command area. Wheat, forage crops and flowers are other important crops cultivated. Vegetables are also grown, however, it is difficult to assess to what extent, since the cultivation of wastewater-irrigated vegetables is officially prohibited.

With the assistance of officials of the Kanpur municipal authorities, a farmer who cultivates land within the command area was interviewed. The discussion took place outside a small teashop which is located near the main wastewater canal where farmers, farm workers and passers-by regularly gather. The following information was obtained:

- The farmer is 34 years old, has a wife and four children and has attended secondary school. His home is in a little village further away.

- The farmer owns 4 ha and rents 4 ha from the Kanpur Mahapalika.

- The family can make a living from the 8 ha it has under cultivation. It has owned the land for several generations.

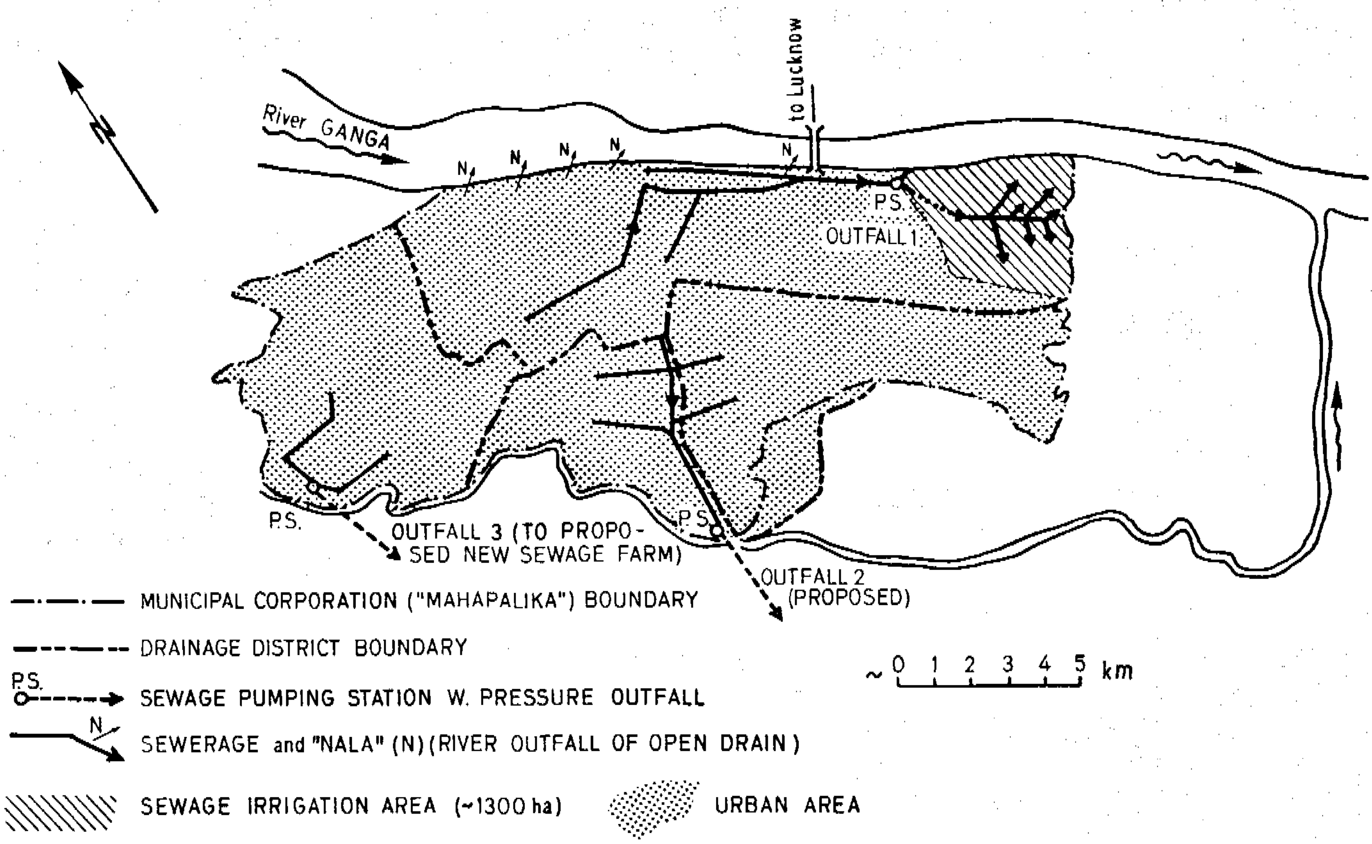

Fig.4.1 Plan Indicating Sewerage and Sewage Irrigation in Kanpur (U.P.)

- The farming population within the command area is quite stable, probably because there is shortage of sewage, and expansion of the command area is therefore not possible.
- The largest holding in the area might be in the order of 16 ha, but some farmers own as little as 0.4 - 0.8 ha.
- In times when farm work is intensive, such as during sowing or planting and during harvesting, up to 20-25 casual labourers are employed.
- The farmer cultivates rice, wheat, forage, and some vegetables (potatoes, e.g.).
- Allocation of wastewater is based on actual requirements during periods of surplus, and by a roster set up by the Mahapalika (Mun. Corporation) during periods of shortage.

- Normally, no mineral fertilizer needs to be applied. Occasionally, though, the farmer purchases urea.

- Domestic water supply in the area is from open and handpump-equipped wells. Supply appears to be sufficient.

- Excreta disposal is by open defecation.

- The farmer said that he does not suffer from any particular disease. When asked where he takes his children when they have diarrheal attacks, he answered that they hardly ever fall ill.

The Kanpur Development Authority has issued a land use master plan which should regulate further city development. Reportedly, the city is expanding along its southern border. Whether this conflicts with a newly planned, second sewage farm proposed for implementation in the same area (Fig. 4.1), is not known. It will be interesting to see whether the land use plan can be used to prevent the loss of agricultural land to urban development in the existing and planned sewage farm areas!

- Lucknow

One of the first sewage farms of Uttar Pradesh was set up in Lucknow, the State capital, in 1913. Sewage irrigation was continuously practised until 1982 when it was abandoned. Lucknow numbers a population of approximately 1.2 million, and is located along the southern banks of the Gomti River, a tributary of river Ganga. Parts of the city are situated below the river's flood levels and are therefore protected by dikes. Sewage and storm runoff are collected at four pumping stations. Since the closure of the sewage farm, all sewage is pumped into the river. Previously, a fraction of the daily sewage flow of 18,000 m^3 was pumped to the command area located on the north-eastern banks of Gomti river (Fig. 4.2). According to Shende (1985), 150 ha (1.5 km^2) of the sewage farm was abandoned in Lucknow. The farm land was owned by the Municipal Government and let to farmers. When pressure on land increased due to urban expansion, lease contracts with the farmers were not renewed and the land was sold to the Capital Development Authority, which in turn sold it to land developers. Construction of industrial enterprises is now taking place on the land which was previously irrigated (Photos 4.3 and 4.4). There is no nearby alternate land available where sewage farming could be taken up again.

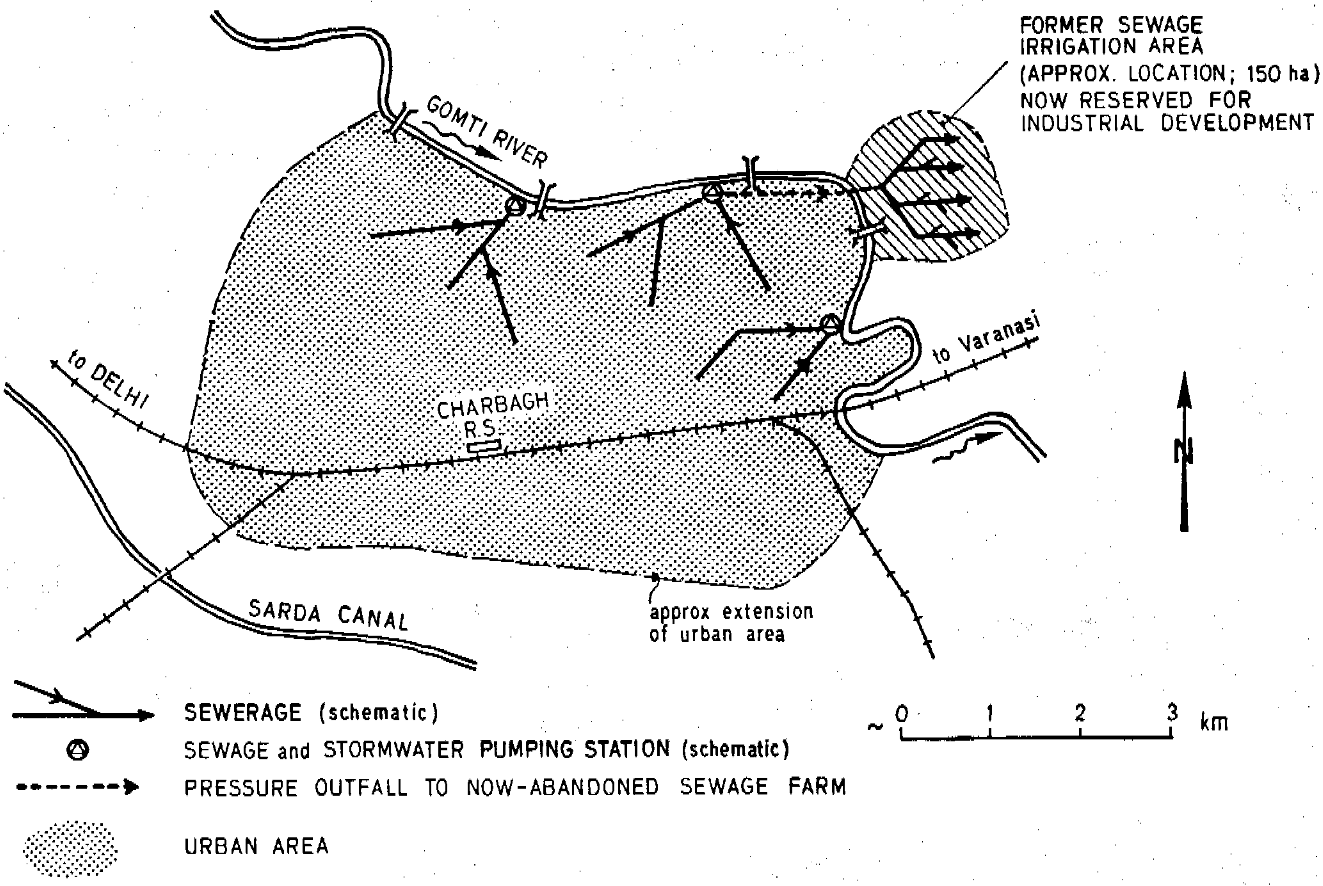

Fig.4.2 Schematic Plan of Sewerage and Former Sewage Irrigation in Lucknow (U.P.)

Thus, the fate of the Lucknow sewage farm serves as an interesting showcase for the growing competition between agriculture and urban expansion with regard to land in the vicinity of large cities. With this kind of competition, the farmers, agriculture on the whole and the concepts of an ecologically sound wastewater recovery will, in most cases, be fighting a losing battle against the strong interests of real estate developers. Only far-sighted environmental strategies coupled with strong political will, as well as the creation and enforcement of land use plans could guarantee the conservation of existing sewage farms or the creation of new farms on the fringes of large cities.

4.3 Research on Domestic Wastewater Treatment and Reuse at National Environmental Engineering Research Institute (NEERI), Nagpur

Studies on the elimination of enteric parasites during sewage treatment processes (Panicker and Krishnamoorthi 1978) have indicated the superiority of waste stabilization ponds over conventional treatment processes in the removal of parasites. More recent studies have explored the survival of bacteria and human enteroviruses in stabilization ponds.

A project on safe and optimum utilization of domestic and industrial wastewaters in agriculture is under operation as a part of "All India Coordinated Research Project on Microbiological Decomposition and Recycling of Farm and City Wastes". The project includes

1. Long-term field study on the effect of irrigation with differentially diluted raw sewage sludge with nutrient fortifications on the growth and yield of crops and soil properties,

2. Long-term microplot study on the effect of irrigation with untreated, primary treated and secondary treated sewage at moderate and high intensities on the growth and yield of crops and soil properties,

3. Microplot study on the effect of wastewaters of varying BOD on the physiological responses of crops, and

4. Studies on the interaction of indigenous soil microorganisms with those brought by sewage, with special reference to survival of pathogens.

Studies are also being conducted on the utilization of effluent for the cultivation of *Citrus reticulata* (Orange). This is desired to develop cultivation methods for the proper control of sewage effluent constituents in the soil anhd plant. The methods are also expected to conserve environmental quality and produce acceptable orange fruit. Treated wastewater is also being used to grow forest, avenue, flowering plants, grass and garden plants to aid land preservation and beautification.

The studies on the use of effluent concentrate mostly on agricultural and environmental parameters. Useful results are obtained regarding crop yields and management practices. Monitoring of microbiological parameters on the crops grown in these experimental plots, however, does not occur, so it is difficult to assess the possible health effects associated with this reuse. Since most of it would come under the category of restricted irrigation, it would mainly be the effect on farm workers that would be of interest. The health effects on farm workers of using untreated sewage has been investigated by Krishnamoorthi et al. (1973, see Section 4.5), though the effect of use of treated sewage has not yet been studied.

The survival of indicator bacteria, *Salmonella* sp., helminth and protozoa on vegetables was studied using vegetables from Nagpur sewage farm compared with vegetables from the market. The results depended greatly on how the wastewater was managed and the time period between irrigation and harvest (Panicker, pers. comm.). If leafy vegetables were sampled 2 or 3 days after irrigation, faecal coliforms and *Salmonella* could be detected; helminth eggs were detected on some samples. If sampling occurred one week or more after irrigation, then no contamination was found. The quantity of bacteria found on the vegetables from the market, however, was often as much as on those from the sewage farms, due to the amount of handling through the marketing process and through the use of contaminated water to freshen up the vegetables.

4.4 Institutional and Regulatory Framework

In each State, "Jal Nigam" (the **Water Corporation) is** the body responsible for the design and construction of urban water supply, sewerage and sewage irrigation schemes. U.P. Jal Nigam, which is reponsible for air and water pollution control, water supply, sewerage and sanitation works in urban and rural areas, employs 6,000 public health engineers in its central, district and divisional offices, and disposed of an annual budget of US $ 150 million **in** 1985. The local **municipal governments** ("Nagar Palika") **or corporations** ("Nagar Mahapalika") take over the works from Jal Nigam and become responsible for their operation and maintenance. In some larger cities, these tasks are carried out by "Jal Sansthan", the **municipal water and sewerage corporation.** In Uttar Pradesh, Jal Sansthan is present in eight cities. Pollution control, for both air and water, fall under the responsibility of the **State Pollution Control Boards.** The Boards lay down, among other things, effluent standards for wastewater discharges into rivers and wastewater reuse on land.

The sewage irrigation infrastructure, i.e. screening/pumping stations, dilution water pumping and conveyance, distribution canals and appurtenances are operated and maintained by the local government bodies (Municipal Corporation or Water Corporation). These institutions also collect fees, based on hectarage and/or type of crop, for delivered wastewater. Where the municipality possesses its own irrigated land, as e.g. in Kanpur, it also issues lease contracts and administers the collection of rents.

National effluent standards exist which have been issued by the Indian Standards Institution. However, these are not legally binding for the State authorities. Legal power and enforcement rests on the State authorities. Each state creates its own pollution control legislature. In setting pollution control standards, the state authorities are guided by the Central (Federal) Pollution Control Board which is composed of delegates of all State Pollution Control Boards. **Reuse of wastewater in agriculture** (control of wastewater quality, crop restrictions) falls under the responsibility of the **State Pollution Control Boards. Regulations** state that **crops eaten raw may not be irrigated with** sewage, neither treated nor untreated. In spite of the existence of this legal basis, actual enforcement by State authorities ruling over local authorities is impossible in most cases. This is presumably an important reason why, in Uttar Pradesh, none of the cities have sewage treatment facilities (except for screening and dilution). Other major reasons for not treating sewage might be the constraints on financial resources in the public sector and/or the unavailability of reasonably-priced land for low-cost treatment through stabilization pond systems. In **Uttar Pradesh**, effluent standards were enacted in 1983, based on the 1976 Water (Prevention and Control of Pollution) Act. The standards comprise a list of about 20 parameters pertaining to chemical, physical and biochemical quality of sewage discharged into rivers or on land (e.g. BOD_5=30 mg/ for river discharge, 200 mg/ for reuse in agriculture). In the standards for land discharge, there are **no microbiological quality parameters** such as fecal coliforms.

The **State Health Department** is traditionally responsible for the monitoring of drinking water, wastewater and natural water quality. However, it plays only a minor role in control and enforcement of standards.

For the **Ganga pollution control project** (see Chpt. 1.5), special effluent standards have been formulated. The wastewater disposal strategy, opted for by the Federal and State governments, comprises sewage farming as a major component. Wastewater and sludge treatment shall be chosen in order to achieve maximum resources recovery (energy, nutrients and water). BOD_5 standards were set at 20 mg/ for effluents discharged into rivers, and at 100 mg/ for reuse in agriculture. Microbiological standards as quality parameters for irrigation have not been issued so far.

4.5 Health and Epidemiological Aspects

As a background to this section the reader is referred to section 1.2, where the health risks associated with wastewater use have been summarised, and to section 1.4, where the difficulties involved in evaluating the health effects of a specific reuse practice have been outlined. The data available do not allow an accurate assessment of the health risks to be made, so the following sections contain epidemiological judgements which should be considered as "informed speculation" rather than strict scientific analysis.

• Disease, Sanitation and Hygiene

Most gastrointestinal infections are endemic in India. However, the rates of infection vary widely from place to place, and within different sectors of the community. The variation in climatic conditions between different parts of the country, in addition to socioeconomic factors, render any generalization about the endemic disease pattern difficult. Studies revealed a mean hookworm infection in several villages around Nagpur of 28.5% (all ages), whilst ranging from 16.9 to 41.8% (Panicker et al. 1980). However, rates are lower in urban areas (11-20% in suburbs of Delhi). Investigations on farm workers from 5 different areas in central and south India gave a mean hookworm prevalence of 32.6%, with a range of 14.3 to 61.8%. The range greatly varied also for *Ascaris* infection, from 0.9% to 30%, with a mean of 13.4% (Krishnamoorthi et al. 1973). Diarrhoeal disease is endemic, and the prevalence also varies among the different communites. Studies, using WHO guidelines for sample surveys of diarrhoeal disease morbidity (NICED 1985), have indicated that in two rural areas of West Bengal, the rate of occurrence of a diarrhoeal episode in children under 5 years of age was 20% (in 2 weeks), whereas in urban Calcutta it showed a rate of 7.5%.

Increasing numbers of urban sewerage schemes are being installed. At the same time, the implementation of low-cost sanitation programmes provide many people with access to excreta disposal facilities. However, a large percentage of the vast population still has no excreta disposal facilities, and many have poor access to water supplies (see country background). Open-field and roadside defecation are still widespread.

As in most cultures, several aspects in the Indian culture influence sanitary practice and thereby also the impact of the use of human wastes. First, a number of people are used to handling animal dung, drying it, and using it as fuel. Second, in India as in most Asian countries, anal cleansing is performed with water applied by hand, and there is generally no tradition of washing the hands afterwards with soap. Third, the handling of human wastes (e.g. nightsoil) is generally restricted to the lower caste members of the Indian society. It would seem likely, therefore, for excreta-related diseases to be higher in this group. However, with the increase in sewerage and the disposal of wastewater on land, other groups are also coming more into contact with human excreta. Any consideration of the impact on health of the use of wastewater in irrigation, therefore needs to take into account other social and cultural factors which have an influence on the occurrence or transmission of gastrointestinal infections.

- Potential Impact of the Existing Use Practice

Only 37% of the sewage receives primary treatment, and 8% receives secondary treatment before disposal (Shende et al. 1988). Therefore, most of the wastewater used in irrigation is untreated, and the rest is treated in a way that allows little, if any, removal of pathogenic microorganisms.

Studies on the health impact of the use of untreated wastewater in irrigation have been carried out by Krishnamoorthi and others at the National Environmental Engineering Research Institute (NEERI) at Nagpur.

Intestinal parasite infections of farm workers on sewage farms in Jaipur, Madras, Hyderabad, Trivandrum, and Poona were studied by Krishnamoorthi et al. (1973). The results were subsequently re-analysed and reported in detail by Shuval et al. (1986). Sewage farm workers carried a significant excess of hookworm and *Ascaris* infections ($p < 0.01$) compared with the controls (prevalence of 70% compared with 33% for hookworm and 47% compared with 13% for *Ascaris*). The intensity of infection was also higher among the sewage farm workers than the controls (that is, farm workers using fresh water for irrgation). The number of sewage farm workers with medium and high infection levels was more than double that in the controls. The actual intensity of infection (eggs per gram of faeces) is not known since it was scored as + (rare), ++ (common) and +++ (high) infection. The workers were initially classified according to age, sex, occupation, and experience in the farm, but no details of this were reported. Variation in infection levels due to degree of exposure was therefore not investigated.

Information on other diseases and clinical examinations, presented in CPHERI Technical Digest (1971), was reported by Shuval et al. (1986). 50% of the sewage farm workers, compared with 24% of the control group, were anaemic. This may have been associated with the high hookworm infestation rates. 48% of farm workers, compared with 13% of the control group, reported gastrointestinal symptoms, but no details were given on how the determinations were made. Stool samples were analysed for *Trichuris* (whipworm), *Enterobius* (pinworm), *Hymenolepis nana* (dwarf tapeworm), *Entamoeba histolytica* (amoeba), and *Giardia lamblia* in addition to *Ascaris* and hookworm. However, for the former parasites, no consistent differences were found between sewage farm workers and the control population.

This study indicates that where raw sewage is used for irrigation, a quantifiable excess of *Ascaris* and hookworm infections (double the original level or more) can occur among sewage farm workers, even in a situation where the infections are endemic in the general population and low levels of hygiene exist. It is possible that a significant excess of diarrhoeal disease also occurs, but this would need further verification, including studies on children. The possibility of an increased risk of typhoid fever among crop consumers cannot be ruled out.

Most of the sewage used in wastewater irrigation in India is untreated. It appears therefore that thousands of farm workers are at increased risk of intestinal nematode infections, and possibly other parasitic and bacterial infections. In addition, many consumers of vegetable crops may also be at risk. The increasing awareness of river pollution by sewage and its environmental as well as health hazards has led many authorities to be more interested in land disposal and therefore use of sewage in irrigation. It is likely, therefore, that the numbers at risk may increase.

- Implications for the Control of Health Risks

In many of the sewage farms, the main crops grown are forage crops and cereal crops (Table 4.1). In this case, there is no risk to consumers but a risk to farm workers, particularly of helminth infection. The most effective way to control these risks would be to institute some form of partial wastewater treatment prior to use. A waste stabilization pond system capable of reducing the concentration of nematode eggs to below the guideline level (section 1.2) would be most suitable. This could consist of an anerobic pond followed by 2 facultative ponds of about 5 days retention time each. If the addition of wastewater treatment is not possible, then the risk to workers' health could be reduced by control of human exposure and modifications to waste management practices. The managers of the sewage farm should provide protective clothes, sufficient farm tools and good hygiene facilities to the workers, to help them avoid contamination by the wastewater.

Where the crops grown on sewage farms include vegetables (Table 4.1), then a risk to both consumers and workers exists if no waste treatment is provided. Even where secondary treatment exists, this produces insufficient reduction in numbers of pathogenic organisms to reduce the health risks. In such cases, treatment plants could be upgraded by the addition of maturation ponds, to meet the quality guideline for unrestricted irrigation. Where land resources are scarce, such as in the outskirts of large cities, this combination of conventional secondary and maturation pond treatment might also be feasible. The maturation ponds serve for fish production. Where no treatment occurs, crop restrictions should be introduced until waste treatment using WSPs can be included.

The situation is more difficult to control where wastewater reuse is indirect, following sewage discharge into rivers. Crop restrictions cannot be enforced since no authority has control of the water. Where possible, it would be best to treat the wastewater before discharge, to the quality necessary to allow unrestricted irrigation. A series of waste stabilization ponds would be most suitable, given their lower maintenance and running costs and superior pathogen removal qualities in comparison with conventional treatment processes.

NEERI have been promoting the use of waste stabilization ponds to treat sewage before use in irrigation for several years. The other options for health protection do not seem to be as viable in the present situation in Indial. It would be useful if an incremental approach to the reduction of health risks was adopted; a reduction in risks could be aimed at even where elimination of risks is not feasible.

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A - WASTEWATER USE IN AGRICULTURE

Ab - USE OF TREATED WASTEWATER

5 P E R U

Acronyms

CEPIS	Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente, Lima, Peru
PAHO/OPS	Panamerican Health Organisation / Organización Panamericana de Salud
SENAPA	Servicio Nacional de Abastecimiento de Agua Potable y Alcantarillado

ii

PERU

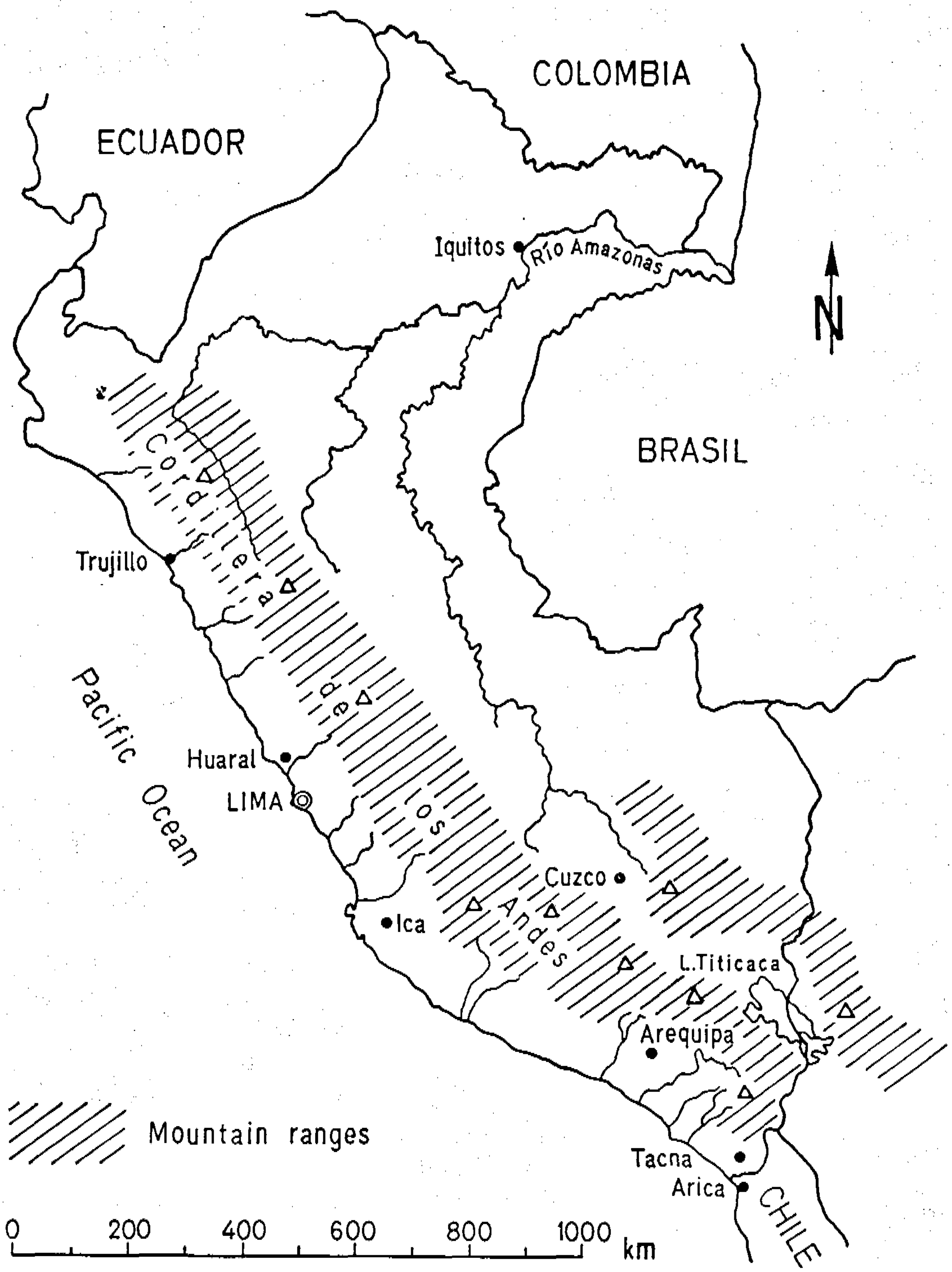
COLOMBIA
ECUADOR
Iquitos
Río Amazonas
N
BRASIL
Cordillera de los Andes
Trujillo
Pacific Ocean
Huaral
LIMA
Cuzco
Ica
L.Titicaca
Arequipa
Mountain ranges
Tacna
Arica
CHILE
0 200 400 600 800 1000 km

Photo 5.1

In Peru's arid coastal belt; oases are formed where river, ground or wastewater is available for crop cultivation

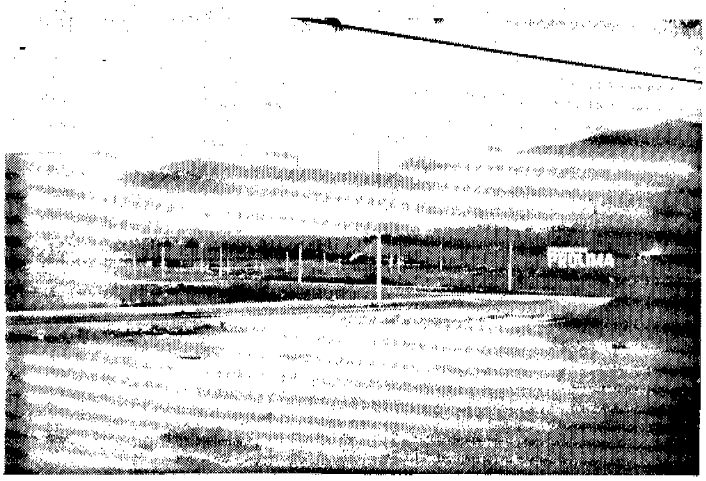

Photo 5.2

On the outskirts of Lima; new housing schemes compete with wastewater-based agriculture for valuable and scarce land

Photo 5.3

Farmers have broken a sewer line in order to draw irrigation water

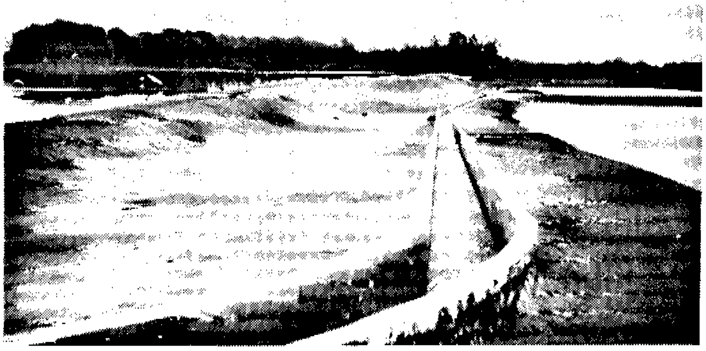

Photo 5.4

San Juan de Miraflores (Lima) WSP scheme

Photo 5.5

Banana and forage irrigation with secondary pond effluent (San Juan de Miraflores, Lima)

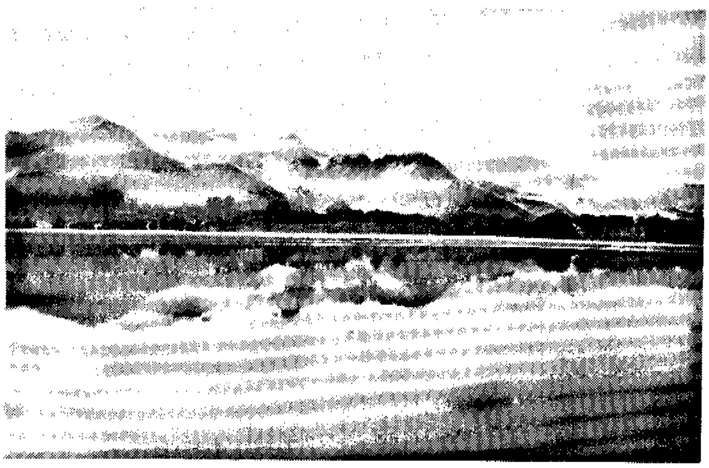

Photo 5.6

Parcona WSP near Ica

Photo 5.7

Cachiche primary WSP with grit removal chamber treating the sewage of Ica town

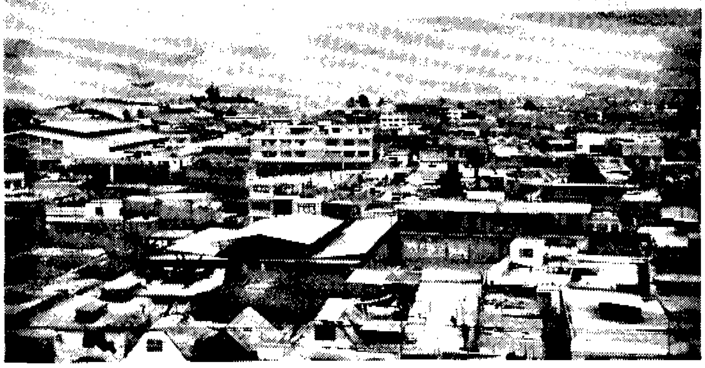

Photo 5.8

Tacna, a desert town

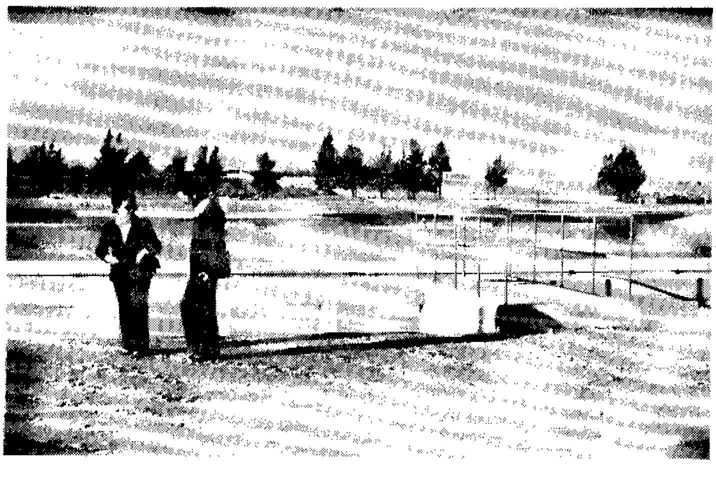

Photo 5.9

Aerated primary pond at the Tacna WSP scheme

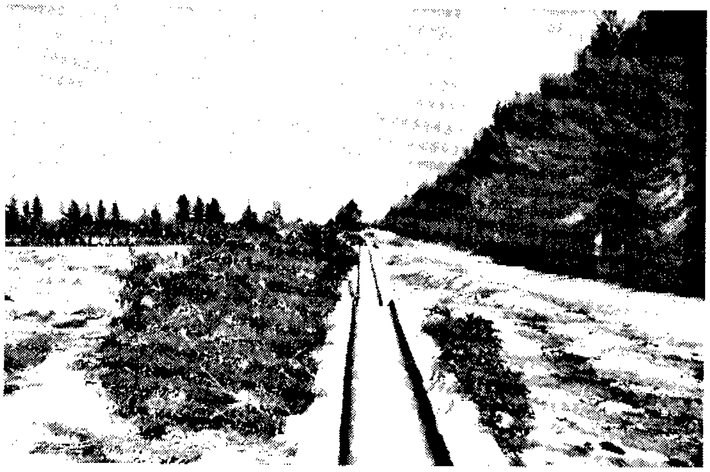

Photo 5.10

Canal transporting effluent from the Tacna WSP scheme to the nearby irrigation area

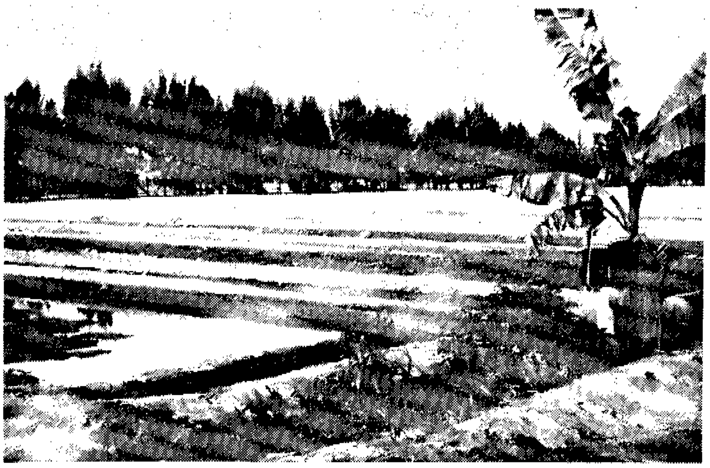

Photo 5.11

A farmer in his fields freshly irrigated with effluent from the Tacna WSP scheme

5.1 Why Farmers Irrigate with Wastewater

There exists in Perú a "wastewater-reuse-belt" which extends all the way from north to south along the Pacific coast. Over 30 wastewater reuse sites or schemes have been identified (Bartone 1985). The western slopes of the Andes which topographically divide the country from north to south receive very little rainfall ($\leq$ 15 mm/a). The coastal strip including Lima and such towns as Trujillo, Huaral, Ica, and Tacna is a true desert. There, yearly rainfall is zero or close to zero. The climate is due to continental-scale circulation in which winds moving from E to W drop essentially all of their moisture on the eastern slopes of the Andes, leaving only a small amount for higher elevations on the western slopes. Cool seasonal mists over the coastal belt are due to the Humboldt Stream, a cold sea current which flows from S to N along the coasts of Chile and Peru. Fig. 5.1 illustrates schematically the climatic and topographic situation.

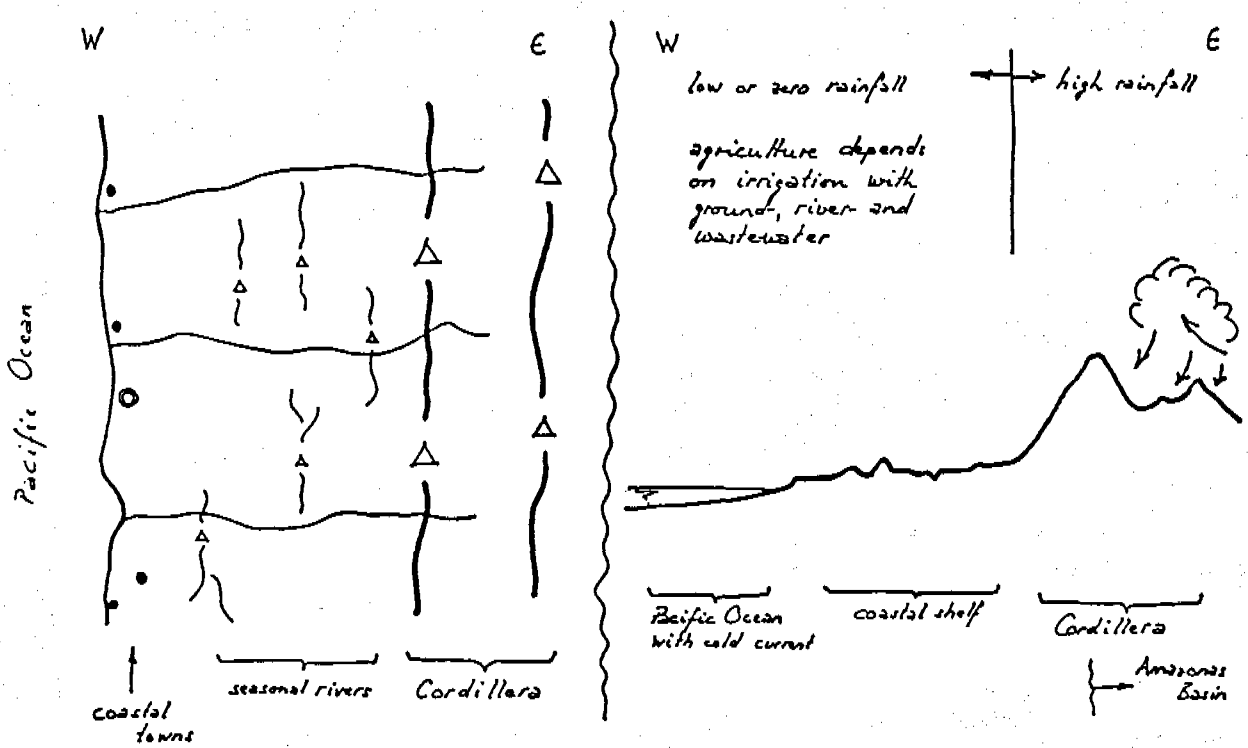

Fig. 5.1 Climate and Topography across Perú (schematic)

There are hills of bare sand and rock which increase in altitude with distance from the coast. Cultivation can take place only by irrigation. Where this is done - mainly in the seasonal river valleys flowing from E to W - the greyish-brownish landscape changes into green oases (Photo 5.1). It is easy to feel the value of water in such surroundings. Wastewater, therefore, constitutes a precious resource and is widely used for cultivation. More than 50 rivers, descending from the Andean slopes, cross the coastal belt from east to west. They are mostly seasonal rivers, and their water, often mixed with wastewater discharged from nearby towns, is used to irrigate the valley plains. Beside this indirect use of wastewater, there are many places where wastewater, treated to variable degrees, is used directly in irrigation. For many farmers, wastewater is the only available source of water which allows them to make a living. The demand for agricultural produce such as vegetables, cereal and fodder crops is high, and availability of water for irrigation and crop nutrients are probably the limiting factors of agricultural production. Both are supplied by the wastewater at minimal cost. How high do farmers, consumers and authorities rank health considerations under these circumstances?

5.2 Current Reuse Practices

- Overview

In Perû, and similarly elsewhere in Latin America, more than 50% of the urban or peri-urban population are linked to sewerage systems. Thus, sewage flows are substantial and represent a valuable resource. There are in Perû over 30 sites where wastewater is reused in irrigation, primarely in the coastal belt. In a good number of places, waste stabilization ponds have been built and are being used. Some produce bacteriologically good effluents, others are overloaded and produce effluents with relatively high bacterial counts. Some multi-cell systems are operated in parallel instead of in series. There are also ponds which are underloaded, probably because sewage flows are smaller than originally assumed. Aerated ponds and Imhoff tanks are installed in a few places. At a number of sites farmers use raw wastewater which they divert directly from sewer lines. Sewage application rates vary between 0.5 and 1 lps/ha (average 0.8). Crops grown include vegetables, fodder crops (e.g. alfalfa) and non-edible crops (e.g. cotton). Table 5.1 contains the main features of a selected number of reuse schemes which were visited by the team during the mission.

Table 5.1: Features of Some Reuse Schemes in Perú

Site visited	Wastewater characteristics	Approx. wastewater flow, lps	Approx. area irrigated with wastewater (ha)	Main crops grown	No. of families involved	Remarks
San Martín de Porras (North-Lima)	Untreated[1]	900	~1500 - 2000	Tomatoes, radish, spinach, fodder maize, "sorgo" (for making brushes)		[1]Wastewater diverted from broken sewer
			~50 - 90[2]	"	30[2]	[2]Subarea of S.M. de Porras
San Juan de[3] Miraflores (South-Lima)	Secondary pond effluent	360	57[4]	Alfalfa, maize, bananas, vegetables (onions, tomatoes, beans a.o.)	30	3Experimental, in conjunction with San Juan pond research
	Untreated		170	"	51	4With only a fraction of the total flow
Huaral	Untreated[5]	50				[5]Ponds existing but now not in operation, wastewater diverted from broken sewer
Ica-Cachiche	Primary pond effluent	270	400	Cotton, maize, grape	30 + 3 coop's. (tot. > 300)	
-Parcona[6]	River-water + primary pond effluent (proportions varying with river flow)	10 - 15	120	Cotton, fruit trees	13	[6]Use of sewage from Tinguiña
-Túpac Amaru	Untreated[7]		5	Cotton, maize	2	[7]Sewage pumped from downstream end of an uncompleted sewer line
Tacna	Secondary pond effluent[8]	180	120	Alfalfa, maize, fruit trees	47	[8]Treatment plant overloaded

- Wastewater Reuse in Lima

Lima, the capital of Perú, is located on the Pacific coast. In the metropolitan area live approximately 6 million people. It is expanding along its northeastern, eastern and southeastern fringes due to immigration of people who stem from rural areas. The immigrants mostly settle on the slopes of the hills bordering the city, and form the so-called "pueblos jóvenes" (young towns). These settlements are rapidly growing, both by their number and by the area they occupy. In other parts of the city there are planned residential housing developments under construction or in preparation. They expand onto land which has previously been used for agricultural production (Photo 5.2).

Lima is crossed from east to west by Río Rimac which has its source in the Andes and discharges into the Pacific Ocean in the Callao area (see Fig. 5.2). Río Surco, a diversion from Río Rimac, passes through the southeastern part of the city. North of Lima is the Río Chillon, also draining from east to west.

Approximately 80% of the buildings have in-house water supply. Per-capita water consumption in Lima has been estimated at 270 l/d. Lima draws 2/3 of its water from Río Rimac and 1/3 from groundwater sources which, reportedly, become more and more depleted. Some recently built-up, low-income fringe areas are served by tanker trucks through which people get their drums standing in front of their house filled every few days.

Throughout Latin America, excreta disposal in urban areas is largely by water carriage and there are flush toilets even in simple houses if there is in-house water supply. In the order of 50% of houses in Lima are connected to sewerage systems. Depending on the area, the wastewater takes one of the following courses:

a. Direct ocean discharge
b. Discharge into Río Rimac with consequent partial reuse in agriculture and partial ocean discharge
c. Reuse in agriculture.

The main areas irrigated with raw wastewater or often heavily contaminated river water[1] comprise in the order of 5000 ha (Bartone 1985; Zapater 1984). They are located in Callao and San Martín de Porras, two districts in the north of the city where vegetables and fodder crops are grown and in San Juan de Miraflores (South Lima) where forest trees are irrigated. Also in the South of Lima, an area of 57 ha is irrigated with effluent from the San Juan de Miraflores waste stabilization ponds (Matos Mar 1984). A project is being prepared to irrigate 4000-5000 ha near San Bartolo, S of Lima, using wastewater from southern Lima. It is as yet undecided how the wastewater should be treated. Primary pond treatment followed by infiltration and extraction as groundwater and a multi-stage pond system are alternatives under consideration.

Fig. 5.2 is a schematic illustration of Lima, its drainage infrastructure and the main cultivation areas irrigated with wastewater.

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[1] In Río Rimac faecal coliform concentrations of up to 10^8 MPN/100 ml have been observed. Such levels are typical of raw wastewater.

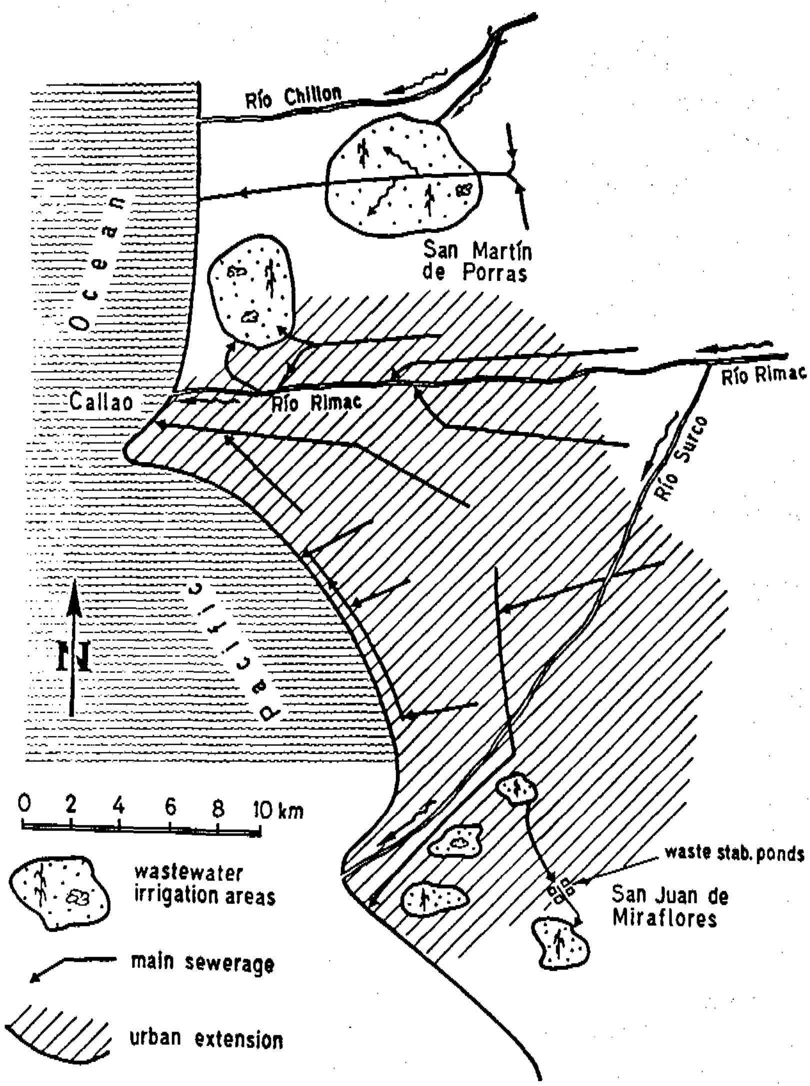

Fig. 5.2 Drainage and Wastewater Irrigation in Lima (schematic)

San Martín de Porras (North Lima)

The district of San Martín de Porras is located north of Río Rimac and covers both residential areas and cultivated land. Irrigation water is conveyed in concrete channels from Río Chillon which borders the area to the north and from a main sewage collector crossing the agricultural area from east to west.

In one area, one can find small, unlined irrigation ditches transporting raw sewage. When following the ditches to their upstream end one gets to the point where the sewage originates: a place at the border of the cultivated area where the sewage gushes up like a spring. Farmers have broken the main sewer and make use of the wastewater (free of charge) in lack of other irrigation water supply (Photo 5.3).

Who are the users of the wastewater? How is it applied? What crops are grown? How are the crops marketed? Do the farmers feel healthy?

The team received answers to some of these questions from short visits and discussions with two farmers. During the discussion with one farmer and his wife - both aged about 50 - in front of their simply-constructed one-story brick home, the following information was received:

- The family cultivates radish, spinach, tomatoes, fodder maize and "sorgo" (a plant which lends itself to make brooms). There are two harvests during the winter seasons (i.e. two rotating crops on one field). The vegetable is sold to a wholesale distribution market.

- Until 1 1/2 years ago, irrigation water in this area was supplied from Río Chillon. Now all that water is utilized further upstream.

- The familiy is one of approximately 30 farming families who are using the sewage from a particular collector. They are members of a "Small Farmers Association". The association has an elected manager. It deals with sewage distribution and related problems. There are no other cooperative activities.

- Each farmer gets sewage to irrigate once every 15 days in summer and once every 20 days in winter. The wastewater is applied by furrow and flood irrigation.

- Three family members cultivate the land. At times of heavy work load, casual labourers are temporarily employed. On other farms there are more family members employed.

- The family owns 3 ha of land; they moved here 40 years ago from a nearby area upon appropriation of land; prior to that they were involved in a small commercial enterprise. Farms in the area range from 1 1/2 to 6 ha in size.

- The family gets its domestic water supply by hauling water from the nearest public tap with a bicycle.

- The number of children in the farming community ranges from 2 to 6.

- Would the family trade wastewater for river water? No, because there is no need to buy mineral fertilizer when using sewage, whereas previously it was necessary to purchase nitrate and urea fertilizer.

- The family is not more frequently ill than prior to the use of wastewater. When somebody falls ill, health services are available at a government hospital or health post (too distant and giving unsatisfactory service?), at a Lions Club health post in San Martín or at a private practice. What does the family do when a child gets a diarrhoeal attack? It reports to a doctor or pharmacy and is sold "Bactrim", an antibiotic. According to the family, diarrhoeal attacks are rare[1].

San Juan de Miraflores stabilization ponds and irrigation area (South Lima)

The San Juan lagoons are located at the southern edge of Lima and treat the sewage originating mainly from "pueblos jóvenes" in the San Juan de Miraflores district. The WSP scheme which started operation in 1964, comprises 11 primary and 10 secondary lagoons arranged and operated in two batteries (Photo 5.4). The lagoons cover a total area of 20 ha and receive approximately 30,000 m^3/d (360 lps) of wastewater from 108,000 inhabitants.

In the past ten years, the ponds have been used extensively for field research by CEPIS and the government health authorities. Investigations aimed at assessing pond performance with respect to both organic matter and pathogen removal, and at evaluating the potential health risk resulting from the reuse of the pond effluent. Aquacultural studies are being carried out for some years now by using some of the lagoons as tertiary, quaternary and quinternary stages, in which fish were grown (see Chpt.13).

In 1985, studies of the sanitary aspects of duckweed production and use as poultry feed, and of potential groundwater contamination due to infiltration from the ponds were initiated. The results of completed investigations are documented in detail in various CEPIS reports (Yanez 1980 and 1983; Bartone et al. 1985).

Based on the data collected during three years, the following pathogen removal results were obtained at BOD loads of 250-350 kg/ha/day, 15°C average temperature in winter and 23°C in summer (Yanez 1980 and 1983; Bartone et al. 1985):

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1 However, according to investigations by IIN (Instituto de Investigación Nutricional), infants in this area experience 5-10 diarrhoeal episodes per year.

- Faecal coliform (FC) removal:

- Influent	10^8 MPN/100 ml
- Effluent from 2-cell system with total nominal[1] ret. time of 10 days	2 log reduction
- Effluent from 3-cell system with total nominal ret. time of 20 days	3 log reduction
- Effluent expected from 3-cell system with total nominal ret. time of 30-40 days	< 10^3 MPN/100 ml

- Parasite (helminth eggs and protozoal cysts) removal:

  - Complete helminth egg removal in 2-cell system with ≥ 5.5 days total nominal retention time
  - Complete parasite removal in 2-cell system with ≥15 days total nominal retention time
  - Use of baffled effluent weirs prevents carry-over of protozoal cysts from primary to secondary ponds

- *Salmonella sp.* removal:

- Influent	10^3 MPN/100 ml
- Effluent from 3-cell system with 20 days total nominal retention time	< 1 MPN/100 ml
- Effluent from 3-cell system with 30-40 days total nominal ret. time	< 0.1 MPN/100 ml

It may be inferred from these results, that a 3-log reduction of faecal coliforms in the pond system indicates complete parasite and *Salmonella sp.* removal.

Further investigations at San Juan revealed that due to short-circuiting, actual pond retention periods are often substantially shorter than the nominal (design) periods. It is important to design ponds in such a way as to minimize short-circuiting and to achieve the desired pathogen removal efficiencies at minimum pond surface requirements (e.g. by use of multi-cell systems, proper inlet/outlet arrangements, elongated pond shape).

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1 "Nominal" means "as designed". The true retention periods are usually shorter due to short-circuiting. With good design, short-circuiting can be minimized and performance would be better than indicated.

The **effluent** of the San Juan lagoons **is used for** irrigation **by a total** of 30 farm families (203 inhabitants) occupying 57 ha (Matos Mar 1984). Most of the families have settled in the area adjacent to the ponds after the ponds came into operation in 1964. 16 out of the 30 families still do not possess formal land ownership.

51 other families (255 persons) who have settled nearby use raw sewage diverted from the main sewer discharging into the lagoon system to irrigate agricultural land. That sewage was originally earmarked to irrigate adjacent greenbelt and forest areas.

The level of education in the farming community is relatively high. Domestic water supply is mostly by tanker trucks.

Typical wastewater application rates are in the order of 1 l/s,ha. The farmers receive the wastewater in turns every 5-7 days. While visiting the effluent-irrigated area, the Team met a farm labourer who is employed by one of the land owners and who was, at the time, baffling the wastewater to the desired place on the owner's field. He carried boots and used both a shovel and his hands to open and close the furrows (Photo 5.5). Alfalfa was being cultivated on the irrigated field; banana trees are growing along the main irrigation furrow. Other crops grown in the area are maize, potatoes, onions, tomatoes, squash, beans, celery and lettuce. Vegetables are partly consumed by the farmers, partly sold in retail nearby and partly by wholesale truckloads to intermediaries who sell them on markets of nearby urban neighbourhoods. Some of the farmers use the earnings from the sale of their products to invest in rental housing in "pueblos jóvenes". Overall, the proportion of sewage irrigated vegetable sold in Lima is reportedly relatively small. Most of the vegetable marketed in the capital is grown all over the country and is probably irrigated with river-water, mainly. The river water, however, if diverted for irrigation downstream from towns, is often highly contaminated due to discharges of municipal wastewater.

Another series of experiments carried out during 15 months in 1983/84 in the San Juan de Miraflores WSP scheme, investigated the production and microbiological quality of **fish** grown in tertiary and quintenary maturation ponds.

Chpt. 13 is a detailed account of the hygienic aspects of the fish culture experiments.

- Wastewater Reuse in Ica

Ica, the capital of Ica Province, is located 300 km S of Lima in the **arid coastal belt**, approximately 10 km inland. It spreads along a valley plain which is bordered by huge sand hills in the west and mountains with bizarre rock structures in the east (Photo 5.6). Ica counts a regional hospital and the Universidad Nacional "San Luis Gonzaga" which comprises 16 faculties, among them a Faculty of Medicine. Close to Ica are the Districts of Tinguina and Parcona (see Fig. 5.3). Several ministries, among them the Ministries of Health, Agriculture, Housing and Education, have got regional headquarters in Ica.

The population of Ica amounts to about 127,000 inhabitants (1985). Thereof, 94,000 have piped water supply and 77,000 are served by the town sewerage system. About 30,000 inhabitants receive water through 60 public standposts and tanker trucks. Water originates from a shallow aquifer and is extracted from 14 wells. The aquifer which also serves as irrigation water source, is being overpumped and, therefore, the water table is gradually falling. Per capita water consumption - calculated from the inflow to the waste stabilization ponds - is about 400 l/d. This is an extremely high consumption figure. It could indicate high domestic consumption and thus high standards of personal hygiene, or, on the other hand, high demand by industry or for watering gardens.

A water supply and sewerage master plan for Ica was in preparation in 1985. Latrines are reportedly used in some low-income areas. There is no emptying service. In 1985, latrines were not taken into consideration as a long-term excreta disposal option. Meanwhile, however, the Regional Health Directorate has started a latrinization programme, supported by the Interamerican Development Bank.

Fig. 5.3 shows the sewerage and wastewater reuse situation of Ica in schematic form.

In the past, problems reportedly occurred due to farmers living between the town and the Cachiche ponds and breaking the sewerage channels leading to these Cachiche ponds. They were illegally using the raw sewage. The practice was later stopped and the farmers are now using well water for irrigation. The area so irrigated comprises about 1,000 hectares.

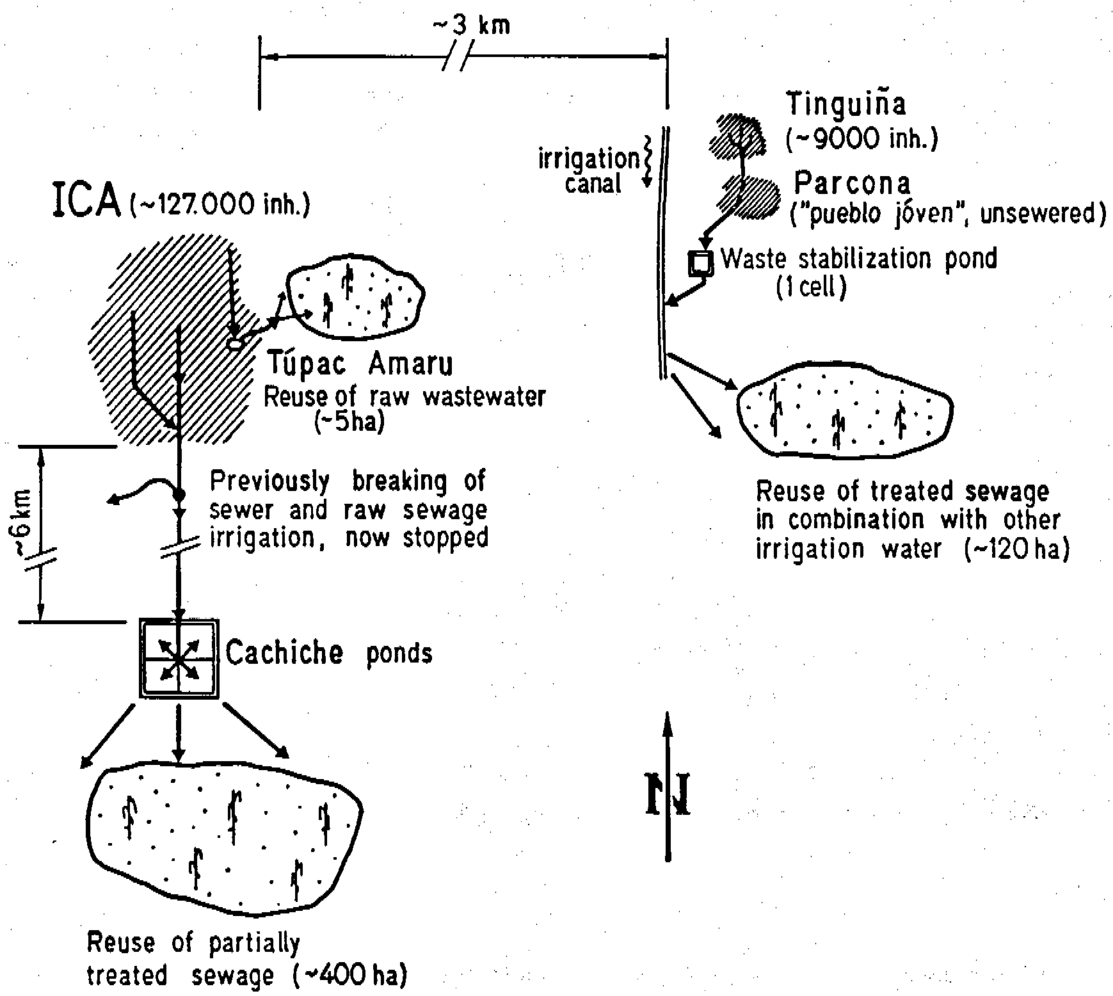

Fig. 5.3 **Sewerage and Wastewater Reuse in Ica (schematic)**

Cachiche

Most of the sewage from Ica town flows into four **lagoons** at Cachiche, 6 km to the south of the town (Photo 5.7). These were built in 1970 and drained and cleaned in 1981. The lagoons are operated by SENAPA, and maintained by one person. Since the lagoons are operated in parallel, they function only as facultative ponds. There is no maturation stage, retention times are relatively short, and only partial pathogen removal can occur.

The microbiological quality of the effluent is not monitored routinely by SENAPA, but some analyses were carried out by CEPIS. The faecal coliform content of the effluent is in the order of 10^5/100 ml. Supposedly, helminth eggs are being removed. The **effluent is used to irrigate** 400 hectares of agricultural land, divided into 33 holdings. Thirty of these are owned by independent farmers, and three by cooperatives. The size of the units ranges from 2-113 hectares. The major crops grown are cotton, maize and grape.

An explanation could not be found why the Cachiche ponds were sited so far out-of-town, with the main sewer line crossing an extended agricultural area. Was a large expansion of the town anticipated at the time, was it done for agrological or socio-economic reasons ?

Adjacent to the 400 ha of land irrigated with the primary pond effluent lies a 1,000 ha area which is irrigated by groundwater. The situation in Ica and also in neighbouring Parcona is thus characterized by a water resources situation which to date allows the use of ground and river water seasonally to irrigate vegetables. The **use of wastewater** can therefore be restricted to **non-edible crops** (e.g. cotton), or forage and high-growing crops (maize, grapes).

The team talked to the wife of a **farm worker** who is employed by a land owner in the Cachiche sewage-irrigated area. It received the following information:

- The family is employed by a farm owner who owns 9 ha of land, and also employs 2 other families. Each family works about 3 ha of land and lives on the same plot.

- The family consists of 2 adults and 3 children. The other families are similar in size, therefore 6 adults and 9 children live and work on 9 ha of land.

- The crop grown is maize. The owner allows the family to use some of the maize for home consumption. The family looks after 8 cows for the owner (watering using well water). Milk is obtained from 3 cows and the owner gives the family the milk from 2 of them. In total, there are 180 cattle on the farm.

- Payment for the farm labourer consists of a small wage plus 10 litres of milk a day plus use of some maize.

- The family grows a few fruit trees of their own but does not grow vegetables for themselves. Vegetables are bought from other farm workers who have small vegetable plots near their houses. These are irrigated with well water. The crop restrictions are being strictly enforced by the provincial health inspectorate.

- The maize is irrigated with effluent from the Cachiche ponds every 15 days in the dry season. It appears that when the river is flowing, river water is used for irrigation as it is available free of charge. However, during most of the year the pond effluent is used for which farmers have to pay.

Although the health risk to consumers through use of wastewater for irrigation is effectively dealt with at Cachiche by the practice of crop restriction, it is possible that there is a health risk to farm workers and their families. Since the families live on the agricultural land, the risk is probably not purely "occupational". For example, young children may be exposed to the wastewater while playing.

Parcona

A single waste stabilization pond of 2-3 ha in size which treats the sewage from Tinguiña was built at Parcona in 1979. The pond is operated by SENAPA. It is well built, maintained and fenced. The effluent from the pond is sold to farmers at the rate of 20 Intis/hr[1]. The effluent is discharged into an irrigation canal where it is diluted with surface water. A total of about 120 hectares of land is being irrigated in that area. The main crops grown are cotton and fruit trees. Since the effluent flow is small, the total effluent is used by these farmers.

Recently, the land adjacent to the pond has partly become built up by low-cost housing, and there are indications that housing development is going to compete with agriculture for the land now being irrigated downstream of the pond.

The river water seasonally available through the nearby irrigation canal is provided to farmers at Intis 100 per crop. It is thus available to them more cheaply than the wastewater. If farmers need to buy well water, they have to pay Intis 100/hr which in turn is more expensive than pond effluent. There are in fact more farmers who are demanding sewage but the flow is insufficient to satisfy these demands.

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[1] 1985: $ 1.00 = Soles 12,500 = Intis 12.50 (the monetary unit "Inti" was introduced in 1985)

Túpac Amaru

In this location, a "pueblo jóven" of Ica, raw sewage is pumped directly from a main sewer to 5 ha of farmland belonging to two farmers, one of them a town councellor, at the fringe of Ica town. Cotton and maize are planted there. The construction of the sewer line which supposedly was to drain into the main collector leading to the Cachiche ponds, remained uncompleted. The pump is operated by and at the expense of the town administration.

• Wastewater Reuse in Tacna

Tacna is the southern-most town in Perú located a few kilometres inland in the arid coastal belt and 20 km north of the Chilean border. The town is rather densely built up. It is clustered at the foot of sand and rock hills which are bare of any vegetation (Photo 5.8). The town is expanding to the south-west where residential housing areas are being developed. Beyond, there is flat desert land which offers a striking view of contrasting colours: there are two large oases, one about 2 km from the town center which is irrigated with wastewater, and one further away which is irrigated with river or ground water.

Tacna has grown from 85,000 inhabitants in 1974 to 135,000 in 1985. This has lead to deficits in the drinking water supply as well as to heavy overloading of the sewage treatment plant. The town is supplied with drinking water from two deep wells which are between 100 and 200 m deep and through three surface supplies from nearby rivers. More than 80% of houses have in-house water supply. The remainder of the population is served by 70 standpipes ("piletas") and by tanker trucks. The piped supply is intermittent: it is interrupted for eight hours at night. Daily per-capita supply is about 100 liters. 83% of the houses are sewered, others have septic tanks and a few houses are equipped with pour-flush latrines. There is no mechanical septic tank emptying service; reportedly, septic tanks are emptied "by hand".

The town wastewater is treated in a sewage treatment plant consisting of two parallel aerated primary and two parallel secondary ponds (Photo 5.9). The plant is operated by the town's water supply and sewerage authority, SEDATACNA. Its effluent is used to irrigate an area of 210 ha. The primary ponds, which are aerated by four aerators each have heavy sludge build-up, particularly so in the corners of the basin and near the effluent weir. The authority is faced with the pressing problems of frequent need for desludging as well as unsatisfactory bacteriological quality of the effluent caused by hydraulic overloading and short retention time. Influent and effluent faecal coliform contents have been found to amount to, respectively, 10^6-10^7/100 ml and 10^5-10^6/100 ml.

From the sewage treatment plant, the wastewater flows in a concrete gravity canal over a distance of 1.5 km to the irrigation area. There, it is distributed to the individual holdings through a system of concrete primary and secondary canals and unlined tertiary channels (Photo 5.10). Fig. 5.4 is a schematic illustration of the wastewater treatment and reuse scheme of Tacna. The transport and main canals were constructed and are maintained by the Ministry of Agriculture. The Ministry also controls adherence to the rules for crop restriction (see Chpt. 5.3).

During a visit to the irrigation area, Segundo Fernandez , one of the farmers, described the wastewater reuse practice: The irrigation scheme was established in the early 1980s[1]. Land was made available free of cost. The farmers who are owners of the land, are organized in the "Cooperativa Tûpac Amaro", a service cooperative which caters for wholesale purchasing of chemical fertilizer and farm implements. The land in the command area is owned by 47 families. The average holding is 4.5 ha. Segundo Fernandez owns 5.9 ha on which he cultivates mainly alfalfa and maize, but also banana and other fruit trees (Photo 5.11). Beans are planted for home consumption. Basically, the farmers are not allowed to plant vegetables. However, reportedly, other farmers do grow potatoes, sweet potatoes, chili and pumpkin to a limited extent. By 1985, S. Fernandez has been farming for 22 years. He became land owner in this area in 1981.

He mainly raises and markets cattle. His family comprises 27 persons, but only he and his wife (and two farm labourers in times of heavy work) are doing farm work. They have a simple one-storey farm house near their field. Drinking water for human and animal consumption is supplied through a standpipe. It appears that the S. Fernandez (like most other farm owners) live on their farm land only temporarily, and have their permanent residence in town. Most members of the family generate income through employment other than farming, i.e. as teachers, in military service or on banks, e.g. At the time of the visit, the area was inhabited by "peons" (watchmen, caretakers) only, as it was eve of the national holiday. There are no farm houses other than the simple brick buildings of the "peones".

Each farmer is allocated wastewater for irrigation once a week. S. Fernandez irrigated half of his land in the night prior to our visit. For this, he received wastewater for 3 h 15 min. A few days hence, he will be allocated wastewater again, which will allow him to irrigate the remainder of his land.

[1] Prior to this, there was, reportedly, uncontrolled use of wastewater.

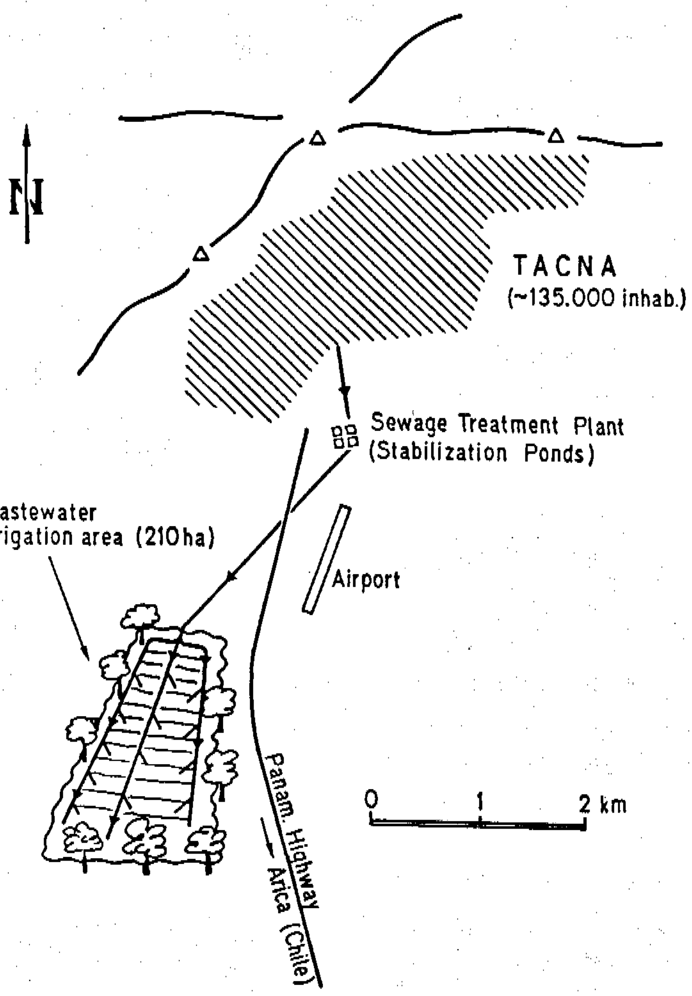

Fig.5.4 Wastewater Reuse in Tacna (schematic)

The management and control of wastewater irrigation in Tacna appear to function well, i.e. crop restrictions are largely adhered to. No larger-scale cultivations of vegetables could be observed. Some of the demand for vegetables by Tacna consumers is probably satisfied through cultivation in the second, freshwater-irrigated oasis. In addition, some produce is probably imported from other areas in the country. This may help to explain why crop restrictions are properly followed.

Irrigation infrastructures (canals, gates) are in good state of repair. Foam formation in the main wastewater channels is occurring rather frequently. S. Fernández reports about occasional damages to plants due to "burning" by the undecomposed detergents.

Over the past few years, an evaluation of wastewater reuse in Tacna has been conducted. The study, which was to be terminated end of 1985, has been commissioned by the Tacna Development Corporation. Two biologists, one chemist and one agronomist have been assessing, among others, wastewater quality and bacteriological contamination of crops irrigated.

5.3 Regulations, Permits and Authorities

The wastewater **quality and treatment standards** as well as **reuse regulations** are specified in the "Ley General de Aguas" (general water law) issued in 1970 and amended in 1983. The law stipulates that:

- Irrigation with raw or treated wastewater of crops growing close to the ground and root crops which may be eaten raw, is not permitted.
- Except for silviculture (forestry), where raw sewage irrigation is allowed, all other reuse in agriculture requires specified treatment (e.g. "primary" treatment for industrially processed food crops, cotton and maize; "secondary" treatment for fruit crops not grown near the ground, for root crops eaten cooked and for forage crops)
- Non-compliance shall be fined with an amount 5-50 times the minimum labour wage in industry
- Permits for wastewater reuse shall be issued only to members of registered (farmers) associations[1]
- Government control activities shall be financed by a fee based on hectarage irrigated
- Natural water used for crop irrigation shall not contain more than 10^3 TC/100 ml.

Government responsibilities related to water, wastewater, irrigation and health are divided up as follows:

- Natural water resources and their allocation - Ministry of Agriculture
- Wastewater management allocation for reuse - SENAPA or its subsidiary municipal water and sewerage departments
- Monitoring and enforcement of reuse and reuse regulations - Ministry of Health

Farmers have to get a **permit** from government authorities to use water or wastewater for irrigation. The permits specify types of crop and hectarage irrigated, the kind of water used and type of land tenancy. Permits are issued by the Ministries of Agriculture and Health, i.e. by their respective local subsidiary administrations. In some places, the responsibilities for wastewater allocation and for enforcing health regulations and crop restrictions have been shifted by delegation from one agency to the other, probably in response to local administrative and political structures and the local water resources and agricultural conditions.

[1] Whether this means that permits are issued only in the name of associations is not known

Administrative arrangements and enforcement practices in relation to wastewater reuse vary widely throughout the country. The following was observed:

- in Lima:

  - Actual use uncontrolled; regulations and permit specifications uninforced; authorities "close their eyes" vis-ã-vis raw sewage irrigation; reuse of sewage-like water from Rio Rimac officially rated as natural-water-irrigation
  - Failure or lack of will by SEDAPAL (Lima water & sewerage authority) to prevent breaking of sewer lines by the "campesinos" who are in search of irrigation water

- in Ica:

  - Authority for water supply and sewerage delegated by SENAPA to the town public works department
  - Permits by Ministry of Agriculture to individual farmers
  - Health inspectorate effectively controlling sewage irrigation, i.e. the crop restrictions to forage and non-edible crops (here: maize, alfalfa, cotton); irrigation of alfalfa with raw sewage permitted if the crop is left to dry for one week before feeding
  - Previously: raw sewage irrigation of vegetables, breaking of sewer line; practice stopped by health inspectorate.

- in Tacna:

  - SEDATACNA (Tacna Water & Sewerage Authority) in charge of sewerage and sewage treatment
  - Local agriculture department controlling treated wastewater distribution to farmers (construction and operation & maintenance of main irrigation structures; wastewater allocation)
  - Ministry of Health issueing user permits
  - Crop restriction to forage crops and vegetables eaten cooked effectively enforced.

5.4 Health and Epidemiological Aspects

- Important Components of the Endemic Disease Situation

As a background to this section, the reader is referred to Section 1.2, where the health risks associated with wastewater use have been summarized, and to Section 1.4, where the difficulties involved in evaluating the health effects of a specific reuse practice have been outlined. The data available do not allow an accurate assessment of the health risks to be made, so this section contains epidemiological judgements which should be considered as "informed speculation" rather than strict scientific analysis.

The coastal area of Peru, where most of the wastewater reuse occurs, is characterised by extreme dryness, and in places almost desert conditions. This influences the occurrence of some infections, particularly those where there is a life-cycle stage occurring in the environment, especially if it is not very resistant to dessication. Selected data from a series of studies on the prevalence of intestinal helminth and protozoan infections in different areas of Peru are presented in Table 5.2. For the helminth infections *Enterobius vermicularis* and *Hymelolepis nana* infections are the most common, probably since they involve direct transmission and the eggs are immediately infective. The soil-transmitted nematode infections, *Ascaris* and *Trichuris* have a very low prevalence, generally under 5%, and hookworm infections are very uncommon, since the larvae need moist conditions for survival. The situation contrasts with that found in the moister environment of the mountains (Sierra) and even more so with that in the forest, where the prevalence of *Ascaris, Trichuris* and hookworm reaches over 70%. The most common of the enteric protozoan infections appears to be *Giardia lamblia*, which reaches very high rates in Ica. The relevance of this to wastewater reuse in the area is discussed below in the section "Potential Impact of the Existing Use Practice".

Analysis of routine data from health centres in Lima (Campos, unpub. doc.) showed that acute diarrhoeal disease, typhoid fever and hepatitis A were the most common of the infectious diseases associated with water supplies and excreta disposal. The rate of diarrhoeal diseases (average 9.8 episodes per year per child under 5 years) in the new towns is particularly high. This is, however, more likely to be associated with poor domestic water supplies and sanitation (see below) and other factors, than with wastewater reuse. A study of risk factors for typhoid fever in Lima (Gotuzza, pers. comm.) indicated that eating food or ice cream sold by street vendors was an important risk factor for children whereas work involving handling garbage and lack of in-house latrines were important risk factors for adults. Discussion of the enteric disease pattern around Ica revealed that diarr-

Tab. 5.2 **Prevalence [%] of Intestinal Helminth and Protozoan Infections Determined by Peruvian Investigators in Several Areas of Perú**
(Source: Villanueva et al 1988)

Type of population	Helminths						Protozoa		Date	Author
	Hymenolepis nana	Enterobius vermicularis	Ascaris lumbricoides	Trichuris trichiura	Strongyloides stercoralis	Ancylostoma or Necator	Giardia lamblia	Entamoeba histolytica		
School families on the coast	14.1		0.5	1.4	0.1	0.1	25.5	23.7	1987a	Valdivia et al
School families in the Sierra	11.8		24.1	18.1	2.2	32.	19.0	37.2	1987b	Valdivia et al
School families in the forest	3.4		72.2	88.7	37.2	73.6	10.5	24.9	1987c	Valdivia et al
Adults and children in new towns in Ica (coast)	20.2	76.0[1]	10.6[2]	0.5	10.6[2]	0.5	57.4	4.3	1987	Villanueva et al
Children 1-15 years in new towns in Ica	22.3	2.8	0.4	1.1	1.46	-	56.5	10.1	1988	Villanueva et al
Children and adults in new towns in Ica	22.4	0.8	0.5	0.3	0.36	-	55.2	22.4	1988	Chavez et al
Children and adults in new towns in Ica	9.4	54.5[1]	16.4	1.5	-	-	49.1	4.8	1988	Huayanca et al
Children and adults in new towns in Trujillo (coast)	28.1	18.5[1]	-	6.0	1.0	0.5	27.1	-	1988	Atoche et al
Hospital Lima Metropolitana	3.1	5.5	2.1	3.2	0.4	0.7	10.9	0.3	1988	Beltram/Uyema

1. Using the method of Graham examining a series of 3 samples
2. The majority of cases were imported

hoeal disease, typhoid fever and intestinal parasitic disease were important, particularly for people coming from rural districts. The number of typhoid fever cases in the area was possibly greater than from some other towns on the coast. It is apparent that there are many possible transmission routes for these excreta-related infectious diseases and that use of wastewater may not be an important risk factor in this context.

• Water Supply, Sanitation and Hygiene Behaviour

The coverage of safe drinking water supplies and sanitary waste disposal (1983 figures) is not very high in urban areas compared with other countries in Latin America (73% and 35%, respectively) and appears to be extremely low in rural areas (18% and 2%, respectively). In Lima the influx of new residents over the past 20 years has increased the population, but this has been more rapid than the rate at which services can be supplied to them. Complications over land tenure have inhibited the provision of services further. Water is bought from water vendors in many of the new settlements.

In the areas where treated wastewater is used in agriculture, normally wells are used to supply water for dringing and washing purposes. Where the water table is high, e.g. in Ica, this supply is probably sufficient to satisfy needs. In many areas, however, the water table is low and the well water supply not as plentiful. Well water may be supplemented by use of river water, but this is not available for much of the year when there is little or no rainfall. So, in some areas, clean water is in short supply, and it is likely to be insufficient to support good hygiene behavious. Many farmers do not have tenure of the land they cultivate, or the land on which they live. Investment in their homes is therefore inhibited, and means that many houses have no excreta disposal facilities. It is apparent that conditions leading to increased transmission of excreta-related infections occur, quite apart from any consideration of use of wastewater in agriculture.

Irrigation occurs through use of flooding, or in some areas through use of furrow irrigation. The water is channelled in the required direction by constructing small earth dams. It appears that use is often made of bare hands, which come into contact with the wastewater. Working the soil is often done using bare feet, although boots may be worn. The use of boots is often for physical protection (e.g. from stones underfoot) and does not appear to be seen as a health protection measure.

- Potential Impact of the Existing Use Practice

Studies have been made on the waste stabilisation pond systems at San Juan de Miraflores (near Lima) where some families are using the treated effluent for irrigation, and other families are withdrawing the sewage before it enters the ponds, and using it for irrigation. Microbiological studies of the effectiveness of pathogen removal in waste stabilisation ponds have been carried out by researchers working at CEPIS (Pan American Center for Sanitary Engineering and Environmental Services). The exposed human population is too small, however, to be used in an epidemiological study of health impact, so no data is available on any health risks associated with these practices.

Some information is available from a descriptive parasitological survey of the inhabitants of San Juan de Miraflores, carried out by Lucas (1980). Stool specimens were taken from persons living by the waste stabilisation ponds and from students from a nearby school. A detailed comparison of the results from the two groups was not made, but the results indicated that the prevalence of some parasites, particularly *Trichuris* and *Ascaris* was higher in the group living near the ponds (67% compared with 14% for *Trichuris*, and 31% compared with 6% for *Ascaris*). The severe methodological limitations of the study mean that firm conclusions cannot be drawn from it, but the results are consistent with the model of increased risk of intestinal nematode infection from use of wastewater in agriculture. However, there may be an increased risk associated with irrigation with any type of water, since this could increase the survival of the eggs in the environmenht. So it has not been shown that use of wastewater itself causes a health risk. In addition, no information is available on any difference between the populations using treated wastewater from the ponds or untreated wastewater before it entered the ponds.

An evaluation of the health risks of the range of current practices in Peru can be attempted using the epidemiological model of health risk and the limited data available.

a) Use of raw wastewater

Farmers and their families withdrawing raw sewage before it is treated, are likely to be at increased risk from *Ascaris* and *Trichuris* infections, *Giardia* infection, diarrhoeal disease and possibly typhoid fever. Since vegetables eaten raw are grown and marketed, consumers buying these crops may also be at risk from these infections.

b) Use of partially treated wastewater

Farmers and their families using effluent from stabilization ponds with a short retention time are likely to avoid the risks described in (a) as long as the effluent is used on a restricted range of crops, as occurs at Ica, and not on those eaten raw. The partial waste treatment should remove any helminth eggs and the enforcement of crop restrictions is important to protect the health of consumers. The ability of the ponds set up in parallel to remove *Giardia* cysts in the time of retention is not clear, so some risk of *Giardia* infection could remain. Complete protozoa removal was achieved at San Juan when the two cell retention time was 15 days. Where there are situations where crop restrictions are not enforced and vegetable crops are grown with partially treated effluent, there may remain a risk of transmission of some bacterial infections. The risk of typhoid fever would be of concern particularly in areas where it is known to be endemic.

c) Use of fully treated wastewater

Farmers and their families using the effluent from the San Juan ponds (quality, below 1000 faecal coliforms per 100 ml) probably are at no increased risk compared with persons using fresh water for irrigation. The crops irrigated should also be 'safe', including vegetable crops eaten raw, so consumers would also have no increased risk.

- Implications for the Control of Health Risks

There are many situations where reuse is occurring in Peru where adequate health protection measures are in Place. This is mainly due to the use of waste stabilization ponds to treat the effluent before use, and in some cases due to the enforcement of crop restrictions. There are, howeever, several types of situations where further health protection measures are needed.

Raw wastewater is used to irrigate vegetable crops in situations where water is extremely scarce (e.g. in Huaral and in San Martín de Porras). In Huaral, the waste stabilization pond system which is currently in disuse could be reinstated to provide good quality effluent for reuse. If the current users of raw wastewater are not given access to the effluent, however, there could be a repeat of the past problem, with raw wastewater being diverted for use in irrigation. A way needs to be found to distribute the effluent over a wider area, and not simply to farmers downstream of the ponds, even if this necessitates the addition of a pumping system. In San Martín de Porras, it is more difficult to see an immediate solution. In the longer term, if the disposal of sewage at sea ceases and a greater volume is treated using pond systems, then more good quality effluent will be available for reuse. The distribution of this much-needed water to the places where it is needed may be problematical.

The design of any new waste stabilization ponds needs to be done carefully to ensure maximum pathogen removal efficiency, using the experience gained by CEPIS at San Juan de Miraflores. In comparison with some existing systems, new ponds should include more cells, which should be connected in series and not in parallel. The effluent can be used for unrestricted irrigation if the quality is below 1000 faecal coliforms per 100 ml, but crop restrictions should be enforced if the quality is not as good as this. The ability of health inspectors to enforce crop restrictions needs to be strengthened. It would be preferable in this situation of acute water shortage, however, to treat the wastewater to the quality necessary for unrestricted irrigation.

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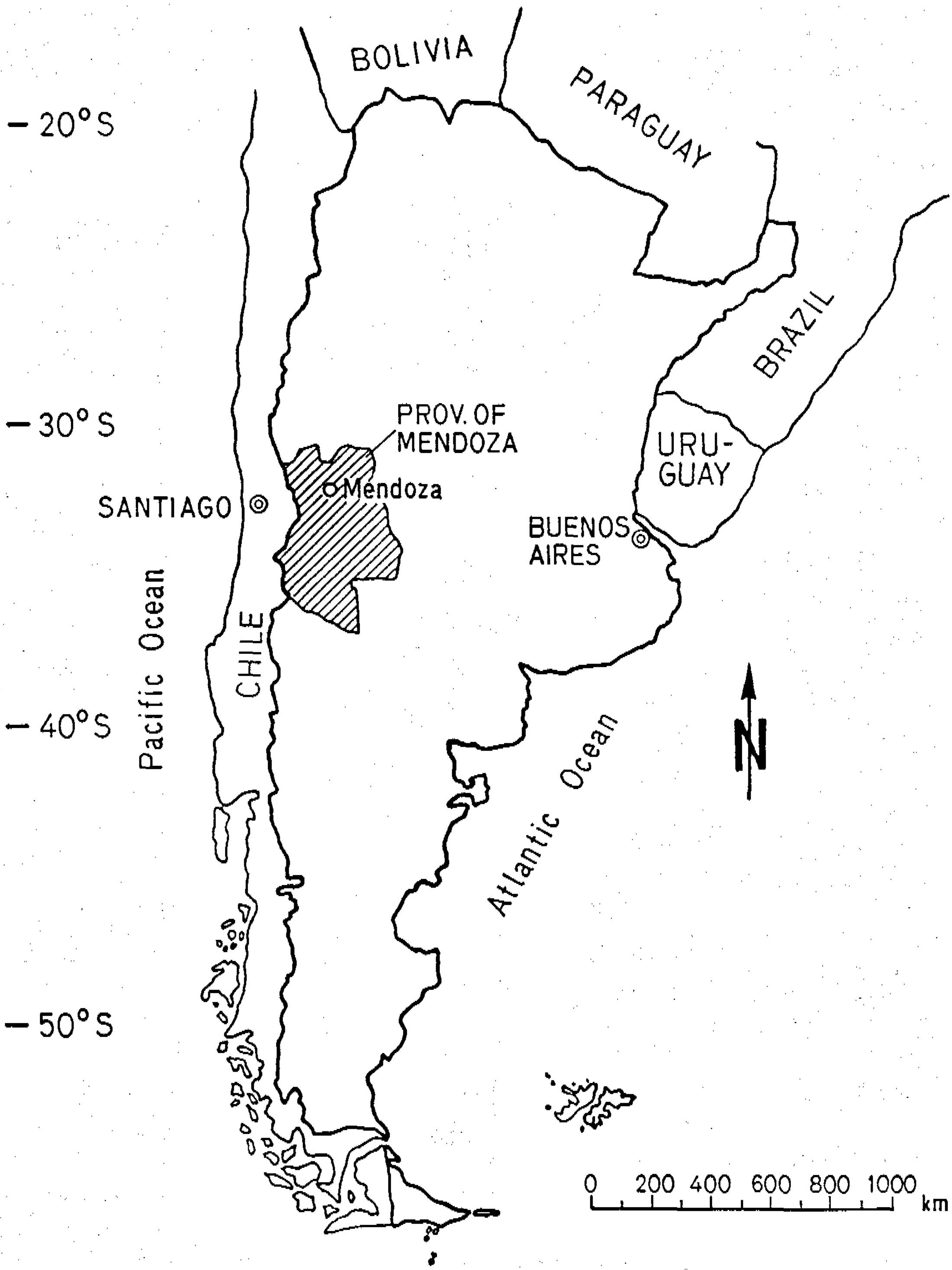
6 ARGENTINA

Acronyms

INCYTH	-	Instituto Nacional de Ciencia y Técnica Hídricas
INCYTH - CELA	-	Centro de Economía, Legislación y Administración del Agua (Mendoza)
INCYTH - CTUA	-	Centro de Tecnología del Uso del Agua (Buenos Aires)
INTA	-	Instituto Nacional de Tecnología Agropecuria

ARGENTINA


BOLIVIA
PARAGUAY
BRAZIL
URU-
GUAY
CHILE
PROV. OF
MENDOZA
Mendoza
SANTIAGO
BUENOS
AIRES
Pacific Ocean
Atlantic Ocean
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– 20°S
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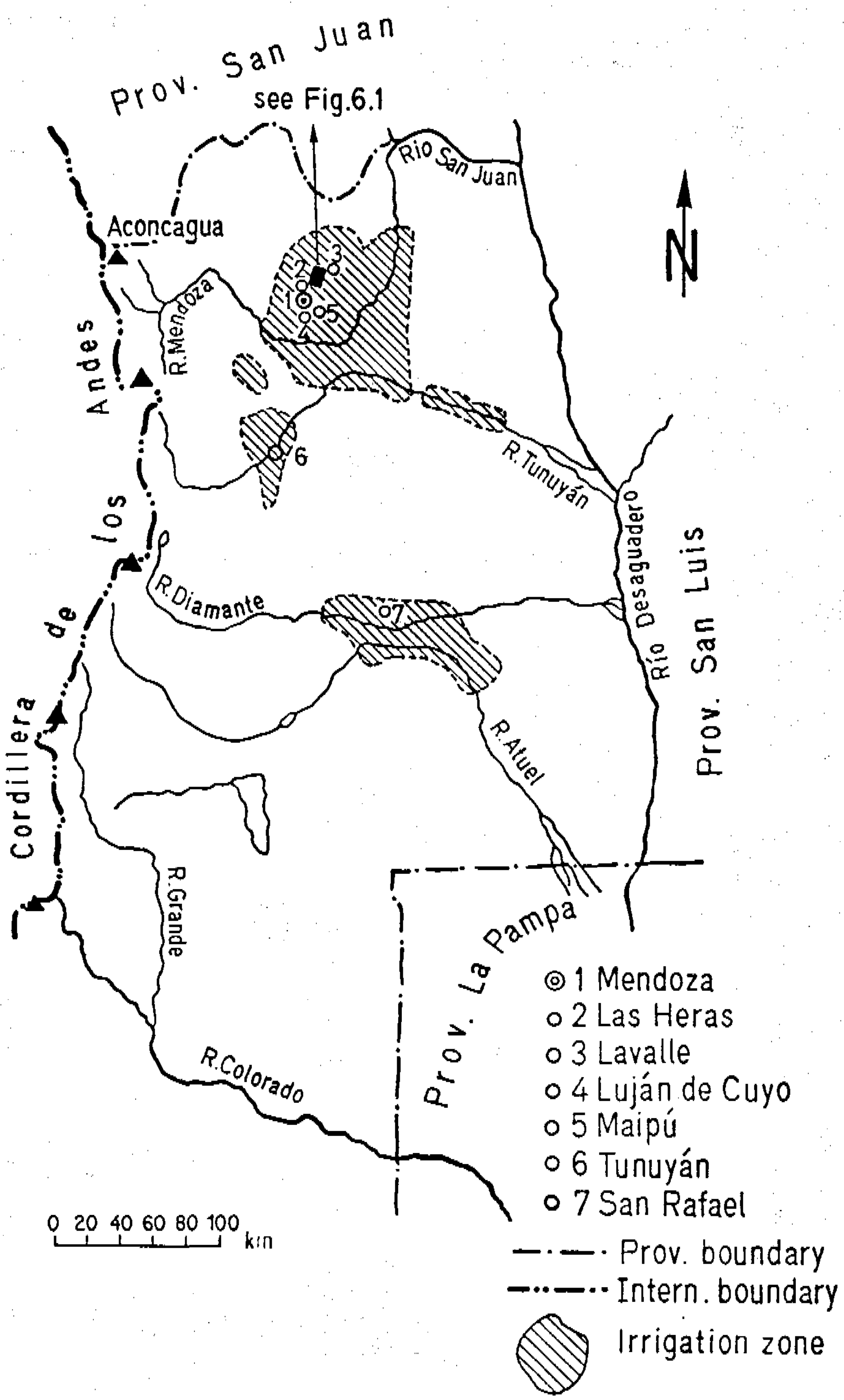
0 200 400 600 800 1000 km

PROVINCE OF MENDOZA
with Major Irrigation Zones



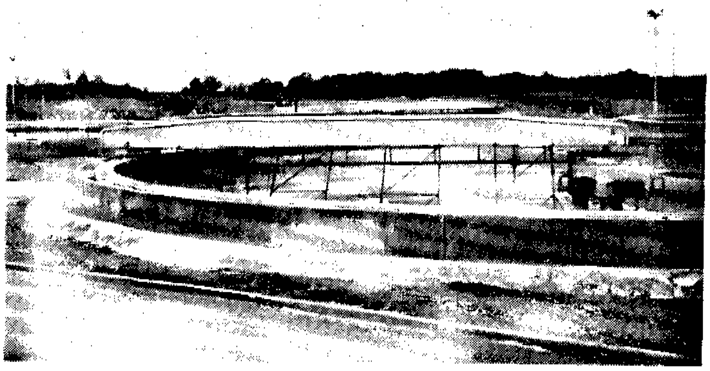


Photo 6.1

The Campo Espejo STP where most of the wastewater from the City of Mendoza is subjected to primary treatment prior to reuse mainly for vegetable cultivation

Photo 6.2

Sludge drying beds at the Campo Espejo STP. The dried sludge is sold to farmers

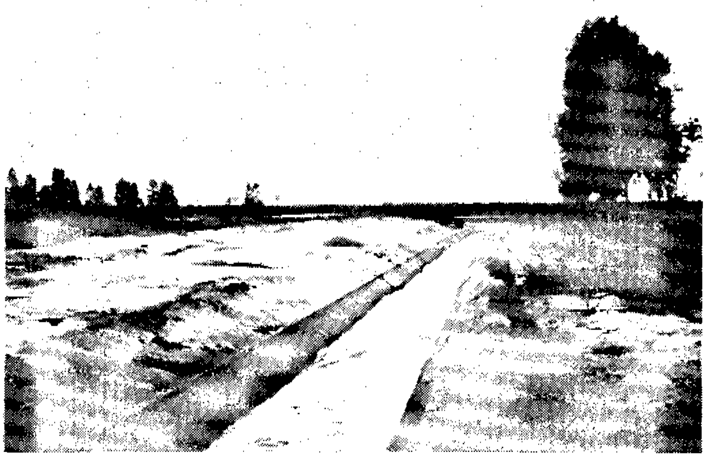


Photo 6.3

The Campo Espejo STP effluent channel transporting primary effluent to the irrigation area

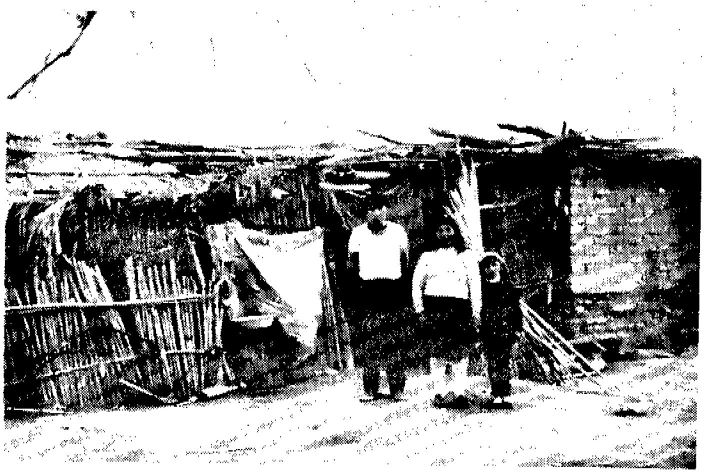


Photo 6.4

A farm labourer's family in front of their house near the irrigation sites

Photo 6.5

A salad field irrigated with primary effluent

6.1 Geographical Features and Water Resources of Mendoza Province

The visit to Argentina was restricted to the Mendoza Province, specifically to the city of Mendoza and the area where the city's wastewater is reused for irrigation.

Mendoza Province (see the maps on pages ii and iii), which comprises an area of 150,000 km^2, lies in the country's **arid zone** bordering the Andes. The average yearly precipitation amounts to only 190 mm, approximately, and falls from October to March, mainly. Average maximum temperatures are around 23°C and average minimum temperatures 9°C. A number of snow-fed, perennial rivers descend from the Andes and cross the Province in west-to-east direction. Their water is used in water supply and irrigation. Irrigation has been practised for many centuries since cultivation is not possible without it. In some catchment areas, the various uses have become increasingly competitive in recent years.

Soils are mostly alluvial, deep and rather fertile, but organic and nitrogen contents are low in some areas. In a number of places, soils are highly saline and alkaline due to the arid climate.

River water **irrigation** is practised in 5 major zones called "oasis", which comprise a total of about 360,000 ha (3600 km^2; see map on page ii). The Province government has issued irrigation rights for a total of 600,000 ha. Impounded river water is distributed through a total of 3,200 km of primary and secondary canals, and there are an estimated 600 km of drainage collector canals (Chambouleyron, 1984). 100,000 ha are irrigated exclusively with groundwater extracted from numerous wells.

The major **crops** cultivated in the Province are grapes for wine production, fruit trees and vegetables. Tomatoes, potatoes, lettuce, onions, garlic, and pepper are important vegetables grown there. Some of the produce is exported to other provinces and abroad.

Mendoza, the Province capital, numbered a population of about 700,000 in 1988 (including 5 suburban districts) out of 1.3 million which live in the whole Province. The city has developed near and around the irrigated land. Potable water for the Mendoza metropolitan area is supplied mainly from rivers through several treatment plants. Part of the impounded river water is used to irrigate the city's alleys and parks. About 65% of the buildings in Mendoza are connected to the city's sewerage scheme.

6.2 Wastewater Reuse in Mendoza Province

- The Current Reuse Practice

There exist in the outskirts of Mendoza city two major areas where wastewater is used (see Fig. 6.1), one situated northeast of the city in the Departementos Las Heras and Lavalle and one located east of the city in Guaymaltén. Fig. 6.1 shows that the areas south, east and northeast of the city are crisscrossed by a large number of irrigation and drainage canals. The canals transport water from the Río Mendoza to the rural irrigation perimeters and to the city for alley and park watering. The drainage canals carry varying proportions of excess irrigation water, urban storm runoff, agricultural drainage water and municipal or industrial wastewater depending on the location and the season.

There are two sites for the treatment of the wastewater from the city's urban and peri-urban areas: one is the **Campo Espejo** primary STP treating the main portion of Mendoza's wastewater flow, i.e. of its central and northern parts. The effluent from this STP is used for irrigation in the Districts of Lavalle and Las Heras. The other treatment site is the **Ortega** (or Coquinbital) WSP scheme, which treats the wastewater from some 35,000 inhabitants in the southern suburban districts of Luján and Maipú, and the effluent of which is used to irrigate the area of Guaymallén north of the treatment site. The **Paramillo** WSP scheme (see also Fig. 6.1) treats the wastewater from an outlying community. Its effluent discharges into Río Mendoza further to the east and upstream of irrigation water intakes.

The **Campo Espejo primary sewage treatment plant** (Photo 6.1) was treating 1,200 l/s in 1984. The plant provides mechanical treatment; sludge is anaerobically digested, dried and sold to farmers (Photo 6.2). The effluent of the plant (Photo 6.3) discharges into a major agricultural drainage canal, the Canal Moyano. The mixed water is reused for irrigation in an area covering approximately 2,000 ha in the Districts of Lavalle and Las Heras (see Fig. 6.1). Fig. 6.2 shows in more detail the distribution of the primary effluent through the Moyano drainage canal.

Theoretically, irrigation water used in the area close to the city N-NE of the airport (**"Zone II"** in Fig. 6.2) should hardly be contaminated, as the canal feeding the area ("Canal Desagüe Moyano") was built to convey excess irrigation water (and possibly surface drainage water) the city's green belt. The canal, however, appears to receive numerous wastewater discharges (Vélez et al. 1982). Irrigation water used further north ("Zone I" in Fig. 6.2) is composed of the primary effluent diluted by varying flows of channeled river and drainage water. BOD values of up to 100 mg/l

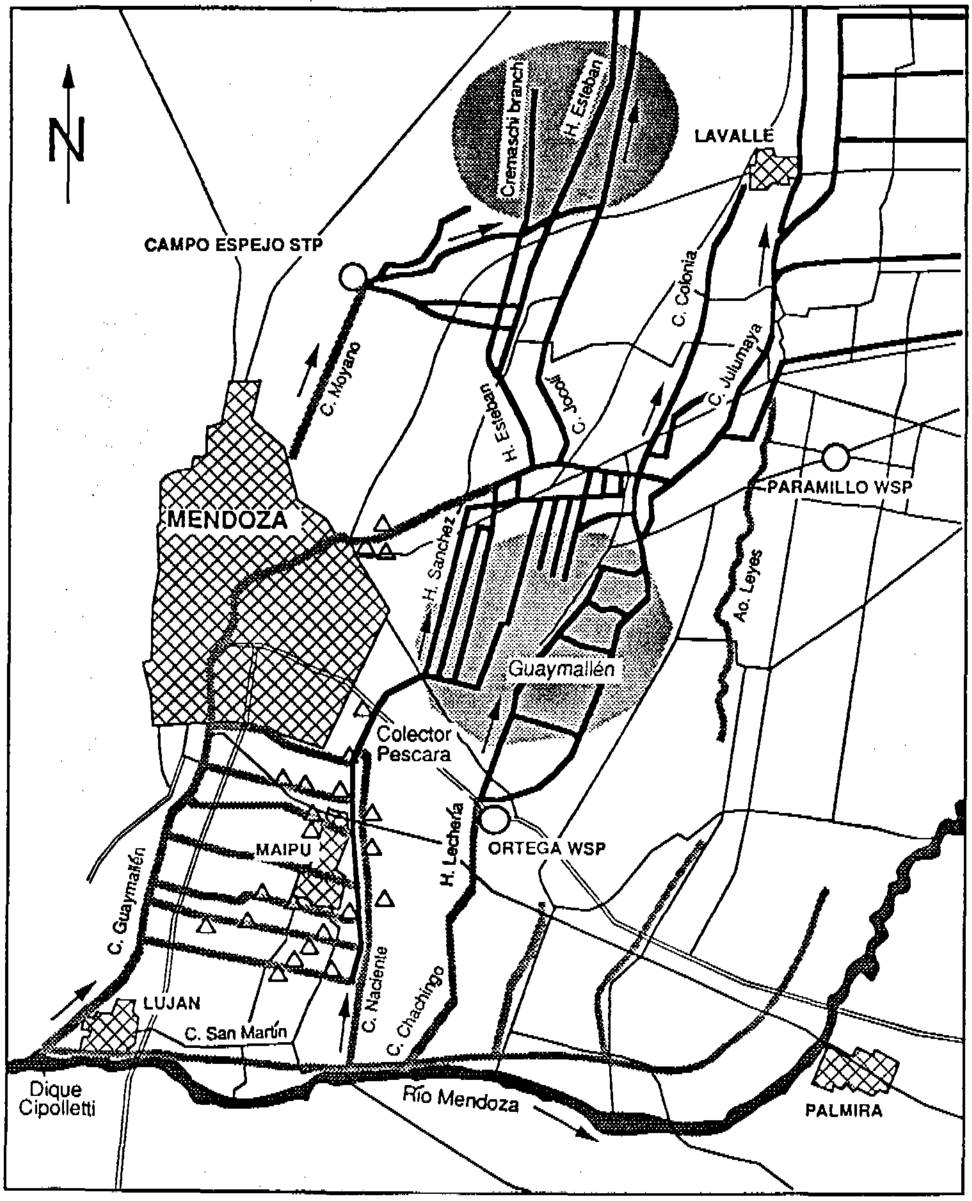


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Fig. 6.1 Irrigation and Wastewater Treatment in the Greater Mendoza Area
(*Source:* *INCYTH-Centro de Economía, Legislación y Administración del Agua;* INTA-Estación Agropecuaria Luján)

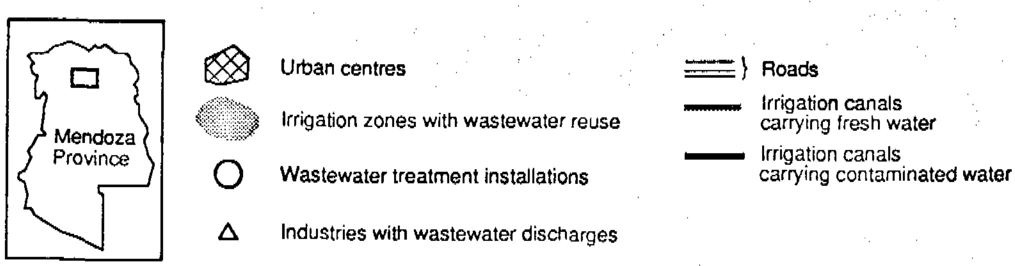
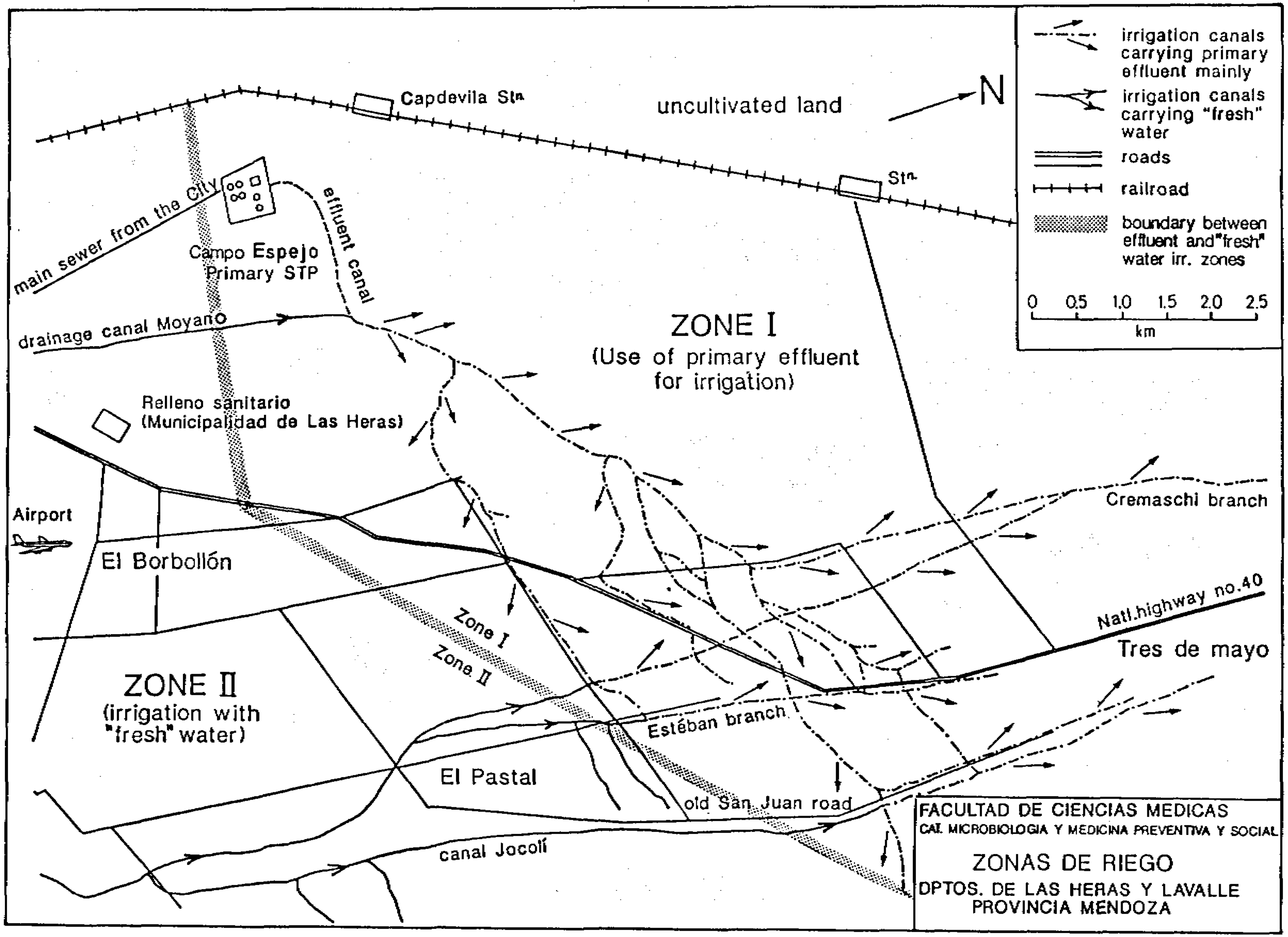


Fig. 6.2 **Reuse of Effluent from the Campo Espejo Primary STP, Mendoza** (after Montbrun et al. 1984)



have been measured. It is on this area, mainly, where studies regarding contamination of vegetables and potential excess disease incidence have focused so far (Bertranou et al. 1980; Montbrun et al. 1984).

"Zone I", where primary effluent is used for irrigation, was visited. The farming area is only sparsely populated. Most farmers are peasants who cultivate fractions (in the order of 4-20 ha) of holdings of up to several hundred hectares by sharecropping. The farmers which we met live in simple houses made of "adobe" (sun-dried bricks), mats or burnt bricks (Photo 6.4). For most peasants, water for domestic use is supplied through small brick-made yard water tanks which are periodically filled by tanker trucks owned and operated by the nearby municipal authorities, or owned by the landlords. Water from these storage tanks is used for drinking and cooking, mainly. Since tanker supply is reportedly infrequent and irregular, water from the irrigation canals is thereby presumably and frequently used for washing and bathing (INCYTH-CELA, 1980). The families live in difficult socioeconomic conditions, and the provided health service facilities are located quite far away from the farms.

On the farms visited, lettuce, onions, tomatoes, and artichokes are grown (Photo 6.5). Usually, the land is irrigated every 8 days for 8 hours, but this sequence varies according to cultivated crop and season. Wholesale entrepreneurs or the owners themselves transport the harvested produce by truck. Access to the farms is difficult as roads and paths are unpaved and inundated during the rainy season.

Families living in the cultivated area closer to the city ("Zone II" in Fig. 6.2) reportedly have higher standards of living, including in-house water supply and electricity. Income is partly derived also from non- farming activities.

In the irrigation area of **Guaymallén**, which receives effluent from the Ortega WSP scheme, the cultivation of vegetables appears to play an important role. The Ortega ponds are reportedly heavily overloaded (Fasciolo, pers. communication). At the time of the microbiological investigation carried out by the Province Department of Environmental Sanitation (Dpto. Saneamiento Ambiental) in 1984, the 5 facultative ponds were operated in parallel and provided a detention time of 8 days (Gabrielli and Rodriguez, 1985). The following total coliform concentrations were measured:

• Irrigation canal upstream of WSP	$\sim 10^4$	TC/100 ml
• Raw sewage	$\sim 10^8$	"
• Treated sewage (8 days WSP)	$\sim 10^8$	"
• Irrigation canal upon mixing with WSP effluent	10^6-10^7	"

It is interesting to note that after 8 days of pond retention, the TC concentration was still at the same level as in the raw sewage. Possibly, the 8 days correspond to the design retention period whereas the true retention time under the reported conditions of overloading might be considerably shorter.

The Guaymallén command area is reportedly larger than the irrigation area in the Departamentos Lavalle and Las Heras which are supplied with primary effluent from the Campo Espejo STP. The quality of the irrigation water used in Guaymaltén is likely to vary depending on the proportion of river water and WSP effluent which may fluctuate seasonally. Overall, however, the treated wastewater fraction is probably small relative to the fresh water diverted from Río Mendoza and transported to the Guaymaltén area. Even though, it might be important to assess the hygienic potential health risks associated with the use of partially treated wastewater in this area by monitoring the quality of the irrigation water as it reaches the field and assessing the quality of the irrigated vegetables. The risks may include both consumer risks, because bacteria removal in the overloaded WSP scheme is likely to be negligible, and worker risks, because egg and cyst removal in the Ortega ponds is probably incomplete. Both cooked and raw-eaten vegetables are cultivated in the Guaymaltén area and include lettuce, beet root, garlic, onion, cabbage and artichockes. Fruit trees and flowers are also grown.

The investigators suggested changing the WSP operation from parallel to series.

• Problems, Plans and Proposals

Concern has been raised among authorities and researchers regarding the present pattern of reuse of wastewater from the City of Mendoza: (1), the **use** of irrigation water **is unrestricted**, i.e. the microbiological quality of the water and the selection of crops irrigated are neither regulated nor controlled by the authorities. (2), irrigation **water rights** are or were issued on a permanent basis and by individual command hectarage. This renders controls over actual draw-offs difficult. Downstream users often face shortages. Similarly, introduction of crop restrictions is difficult if permanent rights are issued instead of renewable permits. (3), sewage treated at the Campo de Espejo treatment plant is subjected to **primary treatment only.** Its effluent certainly contains the bacterial and viral pathogens that cause the diseases endemic in the area. (4), many peasant farmers and farm labourers have a low **socio-economic status.** In some of the "oasis", the domestic water supply situation is rather critical, mainly as regards available quantities. These are important factors which contribute to the transmission of excreta and water-related infections.

The Province Department of Irrigation (Departamento General de Irrigación) has developed plans to create a **zone** of about 7,000 ha for **restricted irrigation** in the area N of the existing sewage treatment plant. Crops to be permitted in this zone would, among others, include trees and vineyards. A suitable legal basis, as well as an adequate monitoring and control organisation, would have to be created to make such a scheme function as planned. Also, the economic interests of the area as a whole and of the landowners will have to be considered and suitably integrated into respective strategies. Farmers might be unwilling to cooperate unless the new irrigation regime would be more advantageous to them than the present one.

The upgrading of the Campo Espejo primary sewage treatment plant to a mechanical-biological plant has repeatedly been proposed. Implementation has been postponed mainly for economic reasons. Biological treatment by activated sludge or trickling filters would certainly improve the environmental situation downstream of the plant. It would also increase the removal of helminth eggs through the secondary clarification step, however, it would have only little effect on the removal or inactivation of pathogenic bacteria and of viruses. With the present state of knowledge regarding health risks of wastewater reuse, the effluent from a conventional mechanical-biological (secondary) STP would require further treatment by polishing ponds or rapid sand filtration-cum-chlorination for bacteria removal if the wastewater is to be used for unrestricted irrigation, i.e. for crops eaten raw. Effluent from secondary STP might be practically free from helminth eggs if the STP is well-designed and operated and iflthe raw wastewater concentration is not excessively high. It might be used for restricted irrigation with only minimal risks for farmers and consumers (see also Chpt. 1.3). An alternative to activated sludge or trickling filter treatment would be the addition of one or more polishing ponds to the primary STP. The number of ponds required depends on the degree of pathogen removal desired. For helminth removal, one pond of 5 days retention time would be adequate. The effluent could be used for restricted irrigation. For bacteria removal, ponds with an overall retention of 3-4 weeks would be required.

There is probably a great need to introduce treatment of municipal and industrial wastewaters in many urban areas of the country in the years to come. However, difficult economic conditions may often preclude the construction of treatment works at the desired or required pace.

INCYTH, through its centres for applied research in Buenos Aires (CTUA) and Mendoza (CELA), is investigating land and lagoon treatment of industrial and municipal wastewaters. A pilot WSP scheme was put in operation by CTUA in 1985 to study the suitability and optimum operation of anaerobic ponds. It can therefore be concluded that waste stabilization ponds might start playing an increasingly important role as treatment technology option in the near future. In the vicinity of Mendoza City, WSP are used in two relatively small sewage systems (Tunuyán and Coquimbito). At Paramillos, 35 km E of Mendoza, a scheme is being implemented which comprises WSP treatment designed for 250,000 inhabitants. The pond effluent shall be used on a 700-ha irrigation command area.

Another important suggestion was the improvement of the health status of sewage farmers not only through wastewater treatment but also through the achievement of a better standard of their housing conditions and domestic water supply.

6.3 Institutional and Regulatory Framework

The following institutions play a role in wastewater reuse:

Institution	Known or presumed role/ activities
• Provincial Government	Granting water rights to the land property
• Dirección General de Irrigación (Dept. of Irrigation, Province of Mendoza)	Construction and administration of large irrigation infrastructural works; delivery of the irrigation water to the user associations (see below)
• Dpto. de Obras Sanitarias (Dept. of Sewage Works, Prov. of Mendoza)	Implementation and operation of sewerage and sewage treatment works
• Dpto. de Saneamiento Ambiental (Dept. of Environm. Sanitation, Ministry of Social Welfare, Prov. of Mendoza)	Health aspects of wastewater management, including reuse; monitoring and control; enforcement
• Inspecciones de Cauce - User (farmer) associations (regulated by law)	Construction and management of secondary and tertiary canals; delivery of the irrigation water to the lands with water rights
• INCYTH (under the National Ministry of Public Works and Services)	Research, training and advisory work in water resources
- INCYTH-CELA (Mendoza)	Research in technical and socio-economic aspects of freshwater and sewage irrigation
- INCYTH-CTUA (B. Aires)	Research in wastewater treatment and use
• Universidad Nacional de Cuyo (Mendoza), Faculty of Medicine, Dep. of Microbiology, Dep. of Prev. Medicine and Public Health	Research in microbiological aspects of wastewater use; training in epidemiology, hygiene and sanitary engineering

The capture and distribution of irrigation water within the Province, i.e. construction of canals, their operation and administration, is regulated constitutionally and by laws. **Canal associations** play an important role in the construction and management of all canals except the primary canals. The canal or user associations receive the irrigation water, both the effluent-laden and the fresh one, from the Directorate of Irrigation and deliver it to the associates who own land with a water right. There is, reportedly, no control over the kinds of crops irrigated by contaminated water. Water shortages affecting those at the downstream end of the canals and periods of low yearly river flows are some of the reported difficulties of the established system.

Reportedly, a legal framework for health safeguards in wastewater reuse in agriculture did not exist in 1985. Microbiological quality standards for water or wastewater used in irrigation (e.g. permissible levels of faecal coliforms) were therefore lacking. Similarly, there were no regulations governing restrictions on crop cultivation as a function of the microbiological quality of the irrigation water.

6.4 Investigations Regarding Wastewater Reuse in the Mendoza Area

A team of the Faculty of Medicine of the Universidad Nacional de Cuyo in Mendoza investigated the occurrence of excreted pathogens and related potential health risks in the area N of Mendoza where the city's wastewater is used in agriculture (Montbrun et al., 1984). *Salmonellae*, parasites and coliforms were analyzed in the irrigation water and lettuce, in the drinking water and in excreta. The area designated as "Zone I" in Fig. 6.1) served as a test area, whereas "Zone II" was used as a control. The socio-economic level of the population living in the test area is very low. It is distinctly higher in the control zone. For all types of samples, the investigators found higher levels of pathogens and indicators on samples coming from the test zone than those from the control zone. The stools of 115 persons (62 in Zone I, 53 in Zone II) were examined for parasites and *Salmonella*. 63% of Zone-I-samples and 36% of Zone-II-samples were parasite-positive. 60% of the positive samples from Zone I contained *Giardia intestinalis*[1]. The researchers stated that the high percentage of *Giardia*-positive samples tends to be congruent with the fact that a high percentage of persons who report to Mendoza Hospital exhibit Giardia symptoms. For *Salmonella*, the examinations yielded 23% of

[1] *G. intestinalis* is now commonly referred to as *G. lamblia*

the stool samples positive in Zone I and 4% positive in Zone II. The number of samples analyzed in the investigation was too small to render the observed differences statistically significant. Also, the distinct difference in socioeconomic level between the test and control zone, means that any difference in infection rates found cannot be attributed to the wastewater use practice, but may be due to other factors that differ between the two areas.

The same *Salmonella* serotypes were found in samples from human faeces, reused wastewater, surface water, and lettuce in the test zone. The researchers concluded that the city's wastewater used for irrigation serves as the common source. They also concluded that the socioeconomic conditions, such as standard of housing and sanitary installations, are a determining factor "regulating" the level of contamination with excreted pathogens in the environment and in humans. Control measures proposed are the prohibition of vegetable irrigation with untreated wastewater, interventions against uncontrolled sewage discharge and use, and (conventional?) biological treatment of all wastewater used in agriculture.

In a different study, a team of INCYTH-CELA (Bertranou et al. 1980) attempted to determine the relative importance of domestic water supply and treatment of wastewater used for irrigation in order to bring about health improvements. This was achieved by comparing the health status of the inhabitants of two rural areas, one using "contaminated" wastewater for irrigation and the other "uncontaminated" water, i.e. where relatively clean water is used for irrigation. The two areas are similar with regard to the socioeconomic status and occupation of the test population (mainly agricultural). The "contaminated" zone is nearly identical with "Zone I" shown in Fig. 6.1. The "uncontaminated" area is located about 20 km to the east bordering Río Mendoza. 179 families were investigated (103 out of 600 households in the "contaminated" and 76 out of 500 households in the "uncontaminated" zone). The investigators concluded from the results obtained that there was no difference between the two areas as regards the diarrhoeal and parasitic diseases. Irrespective of the zone observed, major differences in health status were found when comparing inhabitants with and without proper domestic water supply. Diarrhoea incidence was significantly higher among people without an adequate domestic water supply than with an adequate supply. Based on these findings, the researchers recommended to concentrate efforts on water supply improvements rather than wastewater treatment, given the tight economic situation and based on the assumption that water supply improvements would require less investments than improved wastewater management.

This study demonstrates an important point, that the inadequacy of domestic water supplies in this situation may play a greater role in the transmission of diarrhoea and intestinal parasite infection (through poor hygiene habits) than does the use of wastewater in irrigation. However, it does not show that there is no risk related to wastewater use; just that none was detected. The size of sample needed to detect a difference of public-health significance in any given situation needs to be calculated carefully. For each infection being studied, the investigator needs to have an estimate of the proportion infected in the control group, and the possible proportion infected in the exposed group (or the size of the difference the investigator wishes to detect) as well as defining the required significance level and power of the study (details given in Kirkwood 1988). It is likely that the sample size in this study was inadequate to detect the difference that existed at the required significance level.

6.5 Implications for the Control of Health Risks

The only health protection measure which exists at present for the reuse of effluent from the Campo Espejo STP in Mendoza, is the primary treatment of the sewage. The effect of this treatment for health protection is uncertain: Theoretically, the process does allow for some removal of helminth eggs and cysts by the sedimentation process. A well-designed and operated sedimentation tank may in fact remove 90% or more of the eggs and up to 90% of the cysts. However, the process is sensitive to hydraulic shock loads or continuous hydraulic overloading. Egg and cyst removal in STP clarifiers is therefore not a reliable process. The removal of helminth eggs is likely to vary substantially, and the removal of bacteria, viruses and cysts during primary treatment is probably marginal. Consequently, the protection of the agricultural workers is insufficient.

The effluent of the Ortega WSP scheme may also be of an unsatisfactory quality with respect to pathogen removal, due to the reported overloading of the ponds. The use of this effluent therefore poses a relatively high risk if it is used indiluted or only little diluted with fresh irrigation water. At increasing dilution ratios, the risk is getting more and more reduced.

Neither in Argentina at the national level nor in the Mendoza Province do regulations exist governing crop restriction. Thus, consumers of raw-eaten vegetables are likely to be at risk, too. The question is, how best the risks of both the workers and the consumers could be reduced.

Irrigation water rights are intrinsically linked with the property rights (see Sect. 6.4 above). The Irrigation Directorate delivers the irrigation water to the users' associations through which it is distributed to the lands with water rights. The Directorate does therefore not have direct contracts with the irrigation water users and therefore, control of crop restrictions, would probably be difficult to enforce if such would be introduced.

In the absence of crop restriction regulations and effective ways of enforcing them, **further treatment** of both the Campo Espejo primary effluent and the Ortega pond effluent would probably be the most appropriate health protection measure. It would allow to distribute to the farms effluent of a specified quality. Depending on the crops grown and the degree of health protection envisaged, the primary effluent would have to be further treated either partially, i.e. helminth and protozoa removal only, or fully, i.e. for the removal of bacterial pathogens and viruses. Partially treated effluent would be safe for restricted irrigation, whereas fully treated effluent could be used for unrestricted irrigation. For effective pathogen removal, the installation of **ponds** would be most appropriate, as WSP schemes operate more reliably than conventional STP with short retention times. The disadvantage of WSP is their large land requirement.

Efforts should, however, not concentrate exclusively on health risk reduction in reuse. Similar efforts are required for **improving domestic water supply** for the farm works in the irrigation areas, as was suggested by the INCYTH-CELA team on the basis of one of their investigations (Bertranou et al. 1980). Our own observations in "Zone I" confirmed the urgent need to upgrade the water supply, i.e. to improve its reliability and increase the quantities supplied. Such improvements are likely to substantially contribute to reducing the transmission of bacterial and viral enteric infections, in particular diarrhoeal diseases.

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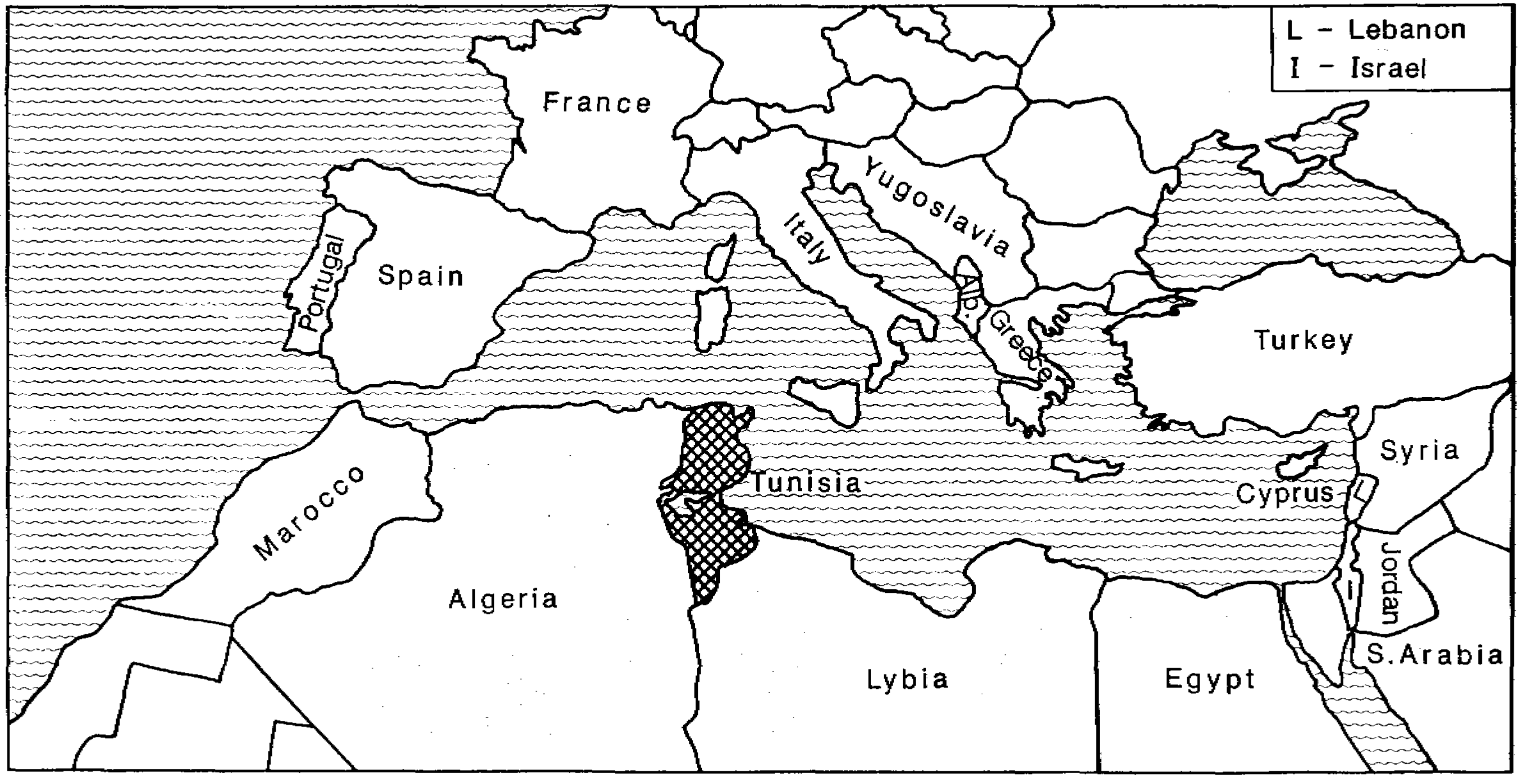
7 TUNISIA

page

Acronyms

CRGR	Centre de Recherche du Génie Rural
OMVPI	Office pour la Mise en Valeur du Périmètre d'Irrigation Nabeul (Development Authority for the Nabeul Irrigation Area)
OMVVM	Office pour la Mise en Valeur de la Vallée Medjerda (Medjerda Valley Development Authority)
ONAS	Office National de l'Assainissement (National Sanitation Authority)
SONEDE	Société Nationale d'Exploitation et de Distribution des Eaux (National Water Supply Agency)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France
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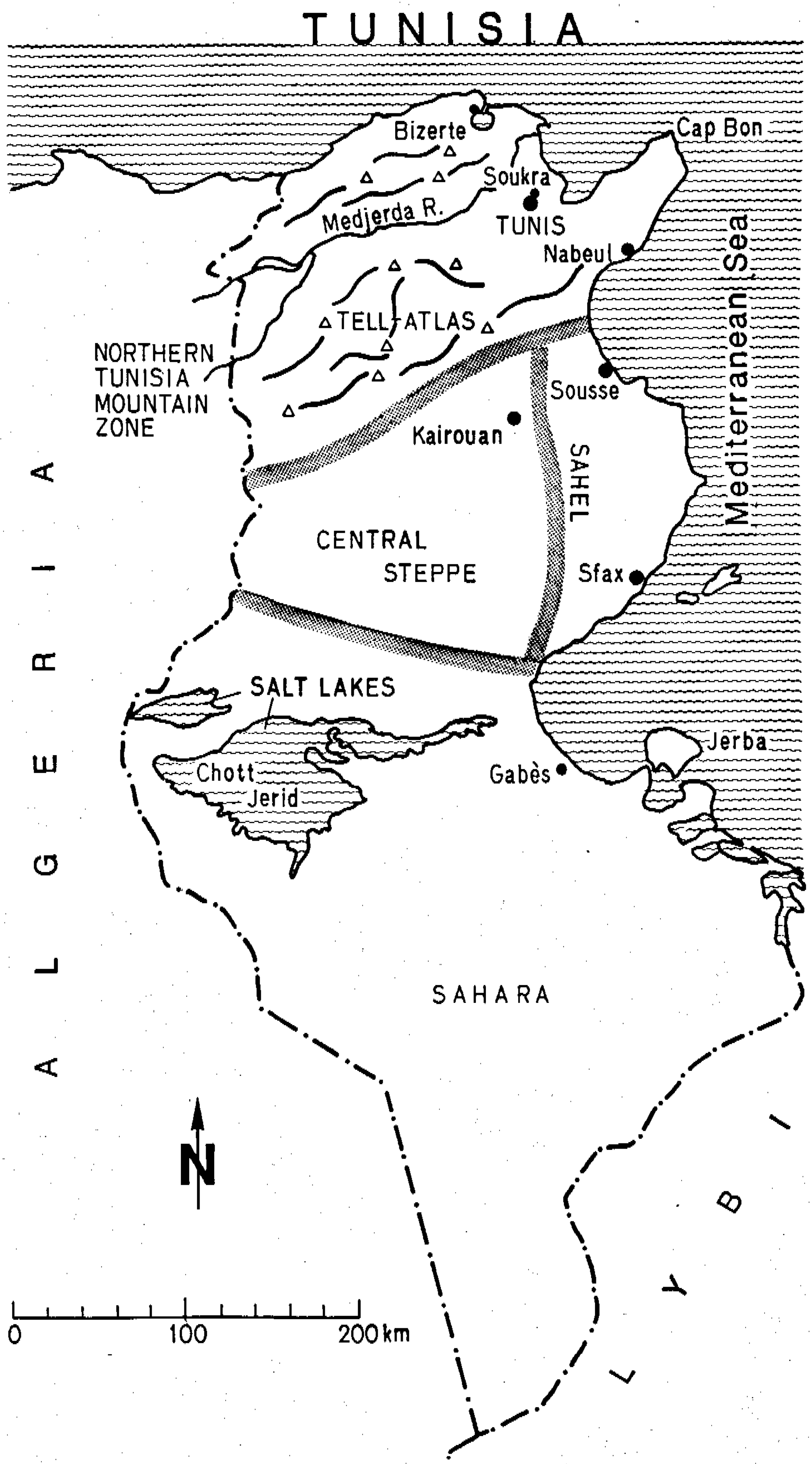
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Bizerte
Cap Bon
Soukra
Medjerda R.
TUNIS
Nabeul
Mediterranean Sea
TELL ATLAS
NORTHERN
TUNISIA
MOUNTAIN
ZONE
Sousse
Kairouan
SAHEL
CENTRAL
STEPPE
Sfax
A L G E R I A
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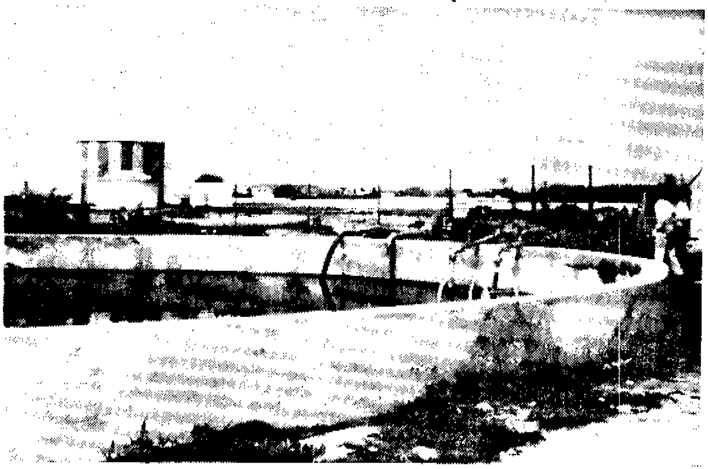

Photo 7.1

Background: the Nabeul STP (activated sludge) operated by ONAS

Foreground: the effluent pump sump from which wastewater is transported to the irrigation command area; operated by OMVPI

Photo 7.2

A pomegranate orchard at Soukra irrigated with treated wastewater

Photo 7.3

Soukra farm plot: Valve ("vanne") on the underground pipe network through which treated wastewater is distributed

V

Photo 7.4

Discharge of secondary effluent on a Soukra fruit tree farm

Photo 7.5

In-line strainers for drip irrigation of secondary effluent to the Min. of Agriculture experimental farm at Nabeul

7.1 Wastewater and Nightsoil Use: Rationale and Overview

- Demography, Climate and Groundwater

Tunisia totals a population of 7 million with an annual growth rate of 2.3%. About 50% of the population is rural and 25% live in the metropolitan area of Tunis. The country is basically agricultural; i.e. of the total area of 160,000 km^2, 90,000 km^2 are cultivated. The main agricultural products are wheat, barley, citrus fruits, dates and wine.

The northern part of the country (see map on p. iii) (between the Algerian border, the Gulf of Bizerte and Tunis) is characterized by the mountainous formations of the easternmost part of the Atlas range. There, the climate is influenced mainly by the Mediterranean. The climate is warm and temperate with > 600 mm rainfall, which is thus more abundant than in the rest of the country. The area is fertile and represents the country's corn belt. The water resources of the valley of the **Medjerda river**, which runs from west to east and discharges into the Mediterranean 30 km north of Tunis, have been continuously developed by impoundments and irrigation schemes. Rainfall decreases towards the central plateaus and the south (Tunis: 400 mm/a, Sfax: 200 mm/a). Rainfall varies according to the season with the main rains during winter and little during the summer months.

The main produce around Tunis and on the Cape Bon Peninsula are **citrus fruits**, while in the Sahelian zone, in the eastern part of the country between Nabeul and Sfax, olive plantations prevail. Both citrus fruits and olives are important **cash crops** which are exported.

Much of the intensively cultivated agricultural land is structured in large holdings, either privately-owned or state-owned ("terres domaniales"). Therefore, there is an important labour force of seasonal and casual farm workers.

The urban centres have developed mainly along the north-eastern and eastern coast (Bizerte, Tunis, Nabeul, Sousse, Sfax, Gabes). These zones also harbour the **touristic centres** which have grown into an important industry and source of foreign exchange.

Under the aforementioned climatic conditions, **groundwater** plays an important role, both as an irrigation and drinking water source. In discussions with officials and farmers we learnt that in recent years the use of groundwater for irrigation had to be abandoned in a number of zones due to increasing water **salinity**. This has apparently occurred in some coastal areas for the following reasons: the continuous and intensified extraction of groundwater has led to the intrusion of saline groundwater from the sea.

Another possible reason for the increase in salinity is the intense evaporation of groundwater whose level has been rising through irrigation. Whether and to what extent this is really the case, was not discussed. Such possible effects should be given due consideration when wastewater irrigation is introduced or propagated in arid or semi-arid areas where no irrigation has been practised before.

- Overview of Wastewater Reuse Practices in Tunisia

In 1984, about 60% of the population living in urban and semi-urban areas was being served with domestic water through piped systems, the majority thereof having in-house supply and a smaller portion drawing water from public standpipes. 40% were fetching water "at the source", i.e., from wells and rainwater cisterns, or from seasonal rivers (wadi, oued) and springs (Atallah 1984).

The housings of approx. 30% of the inhabitants were connected to sewerage schemes, while 23 sewage treatment plants were in operation and six plants under planning (Labonté 1984, Atallah 1984).

Given the climatic conditions, the potential and need for increased agricultural production through irrigated cultivation, as well as the growing quantities of wastewater produced in expanding urban areas, it is not surprising to learn that wastewater reuse is practised in Tunisia since several decades. Reuse is seasonal, i.e. during the dry months in spring and summer, mainly. The pattern of reuse varies according to region. In a number of areas where controlled reuse is practised, treated sewage is distributed through government-owned subsidiary services (e.g. OMVVM, OMVPI-Nabeul). The use of raw wastewater was observed in a number of sites in 1984. The quantities of wastewater used in the sites listed under "raw sewage" are likely to be small compared to those applied in the schemes using treated wastewater. The use of raw wastewater is probably clandestine to a large extent, as the authorities appear to effectively control and enforce the regulations. These stipulate that all wastewater earmaked for reuse must be treated and may not be applied to crops which can be eaten raw (see also Chpt. 7.5).

Raw sewage sludge is used in some places (6 sites listed in 1984). Irrigation with fresh water mixed with untreated wastewater has been reported in one area.

The following crops are irrigated with wastewater: fruit and olive trees, forage crops, chillies, potatoes, tomatoes, onions, and other vegetables.

The water law, enacted in 1975, stipulates that water be used to its maximum value[1]. Thus, treated wastewater reuse is part of a purposeful economical management of water resources, and fully legalized, provided the specified regulations and precautions are adhered to (see Chpt. 7.5). The national sanitation commission has stipulated that the reuse of all treated wastewater be one of the objectives of the Water and Sanitation Decade.

Table 7.1 provides an overview of current (1984) and planned wastewater reuse practices in Tunisia.

The discussions with officials of the Ministries of Public Health and Agriculture revealed that **reuse of treated wastewater** is an integral **part of the national water resources strategy**, and that many new reuse schemes will be established in the years to come. ONAS, the national sanitation agency, has carried out studies for 20 new schemes.

Most of the sewage treatment plants are found in the populated coastal areas where prevention of coastal pollution is important, particularly in tourist areas. Out of the 23 sewage treatment plants, 17 are listed as activated sludge plants, 2 with trickling filters, 3 comprising of oxidation ponds and 1 with oxidation channels. Photo 7.1 shows the Nabeul STP (activated sludge), the effluent of which is used for irrigation. Chlorination of effluents is not practised. According to ONAS's recent evaluation of the long-term feasibility of sewage treatment methods, priorities should be given to activated sludge plants and waste stabilization ponds. It also indicated that ponds will quite likely gain popularity, particularly so where land is available at reasonable cost. The country's relatively tight economic situation calls for low-cost sewage treatment solutions.

ONAS and sewage treatment plant operators monitor regularly effluent quality by analyzing parameters such as BOD, COD, pH, Cl^-, and suspended solids. Reportedly, bacteriological analyses are occasionally carried out on demand on samples sent by ONAS to the Institut Pasteur (the research and monitoring institution of the Ministry of Public Health). However, treatment quality standards to date clearly relate to the environmental quality of receiving waters (i.e. to the removal of organic contaminants), mainly, and not to reuse objectives (i.e. to the removal of pathogenic organisms).

In Sousse, treated wastewater from the Sousse Nord STP is used at the rate of 500 m^3/d to irrigate the golf course of approx. 50 ha at El Kantaoui. In addition, 117 ha of hotel lawns were projected to be irrigated with effluent from the same STP. For this, specific terms of reference ("Cahier de Charges") have been worked out, which outline the responsibilities of the

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[1] "La programmation de l'utilisation des ressources en eau doit .... procéder du principe de la valorisation maximale du mètre cube d'eau....".

Table 7.1 Current and Planned Wastewater Reuse (as per 1985)[1]

Town location	Area (ha)	Type of waste	Crops (among others)
Existing			
Tunis-Soukra	620	Charguia STP (act. sludge) effluent	Citrus fruits mainly
Nabeul	330[2]	Nabeul-SE$_4$ STP (act. sludge) effluent and treated sludge	Citrus fruits, olive trees
Sousse Nord	50	Sousse-Nord STP (act. sludge) effluent	Golf course
Kairouan	200	STP effluent	Cotton, forage crops
Bizerte area (3 locations)		Raw sewage	Tomatoes,chile, maize
Zaghouan		Raw sewage	Fruit trees, misc. vegetables
Bèja area (3 locations)		Raw sewage and sludge mixed with fresh (river?) water	Tomatoes, chilli, celery, parsley
Sousse area (3 locations)		Raw sewage, raw sludge	Potatoes, onions, maize, forage crops
Monastir area (5 locations)		Raw sewage	Tomatoes, chilli,maize, onions, fruit trees, melons
Jerba Island (2 locations)		Raw sludge	Misc. vegetables, fruit trees
Gafsa		Raw sewage	Fennel, onions, salad, potatoes
Tozeur area (3 locations)		Raw sludge	Parsley, onions, fennel salad, chilli
Under implementation			
Tunis-Soukra	+200	Charguia STP effluent	Citrus fruits
Tunis-Henchir Tobias - Cébala[3]	2670	Charguia STP effluent Côtière Nord (ponds) Choutrana STP effl.	Cereals, forage crops
Tunis-Mornagh	940	Sud Miliane STP effl.	Fruit trees
Planned			
Chiba	320		
Hamman Sousse	400		
Sousse Sud	500		
Dekhila Monastir	300		
Sfax[4]	800		

[1] after Atallah (1984) and Labonté (1984); schemes listed as using "raw sewage" or "raw sludge" are not officially authorized

[2] Unclear whether this is the existing or future extension of the perimeter, whether wastewater irrigation has already been extended from the 10 ha indicated in some documents to the whole command area (as indicated by the local irrigation authority), and as to the proportion groundwater:wastewater.

[3] This scheme is put in operation in 1989

[4] This scheme was put in operation in 1988

hotel management, the government public health administration and of the national sewerage and sanitation agency (ONAS) (see also Chpt. 7.5)

Beside the reuse of wastewater, **nightsoil** also appears to be used particularly in the areas of Gabes and Cap Bon, where there are farmers who collect nightsoil, mix it with cattle dung and apply it to their fields as soil conditioner. Possible excess health risks through this practice have not been investigated. Reportedly, there is a relatively high prevalence of parasitic diseases in the Gabes area, but it is not known whether this is due to nightsoil use.

- Current and Planned Wastewater Reuse Infrastructure for the Metropolian Area of Tunis

In Tunisia, approx. 1000 ha are at present irrigated with treated wastewater in a controlled manner. Thereof, approx. 600 ha receive wastewater from Tunis which totals a 1.7 million population. Prior to the reuse of wastewater from the City of Tunis, sewage was discharged into the "Lac de Tunis", a shallow brackish water lake adjacent to the city. Prevention of pollution in the lake was reportedly one of the main reasons for diverting from the receiving water body the wastewater which is now used in agriculture.

The **Soukra** municipality is the reuse area in question which lies north of the city. There, before wastewater irrigation was started in 1964, irrigation was exclusively carried out with groundwater. The reused wastewater originates from the Charguia STP which is located in the vicinity of Tunis airport. From there, it is transported over 10 kilometres to the Soukra irrigation area as shown in Fig. 7.1.

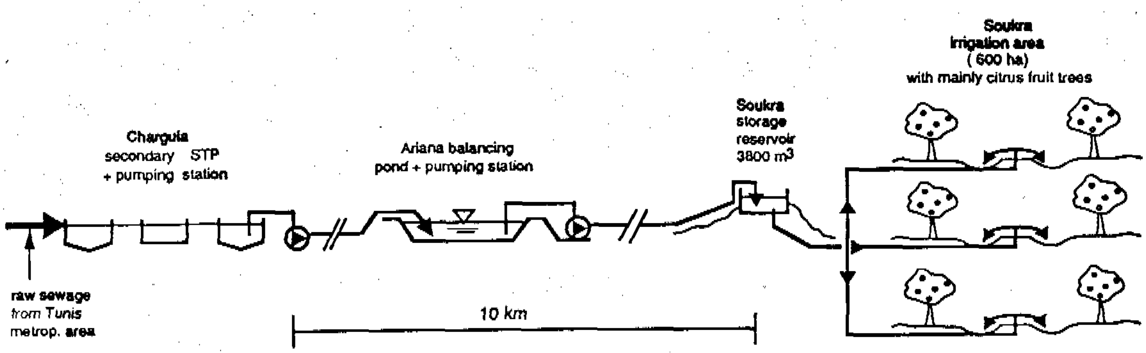


Fig. 7.1 Treated Wastewater Conveyance Scheme Tunis - Soukra

In recent years, the wastewater-irrigated area around Tunis has continuously been expanded and shall eventually encompass a total of 4450 ha. The project includes expansion of the existing command area at Soukra, creation of a new, large irrigation zone (Henchir Tobias-Cêbala, taken into operation in 1989) further north of Tunis and of a new command area (Mornagh) 20 km south of the city. Within the Ministry of Agriculture, the hydraulic works section ("Direction des Etudes et des Grands Travaux Hydrauliques") is the agency responsible for executing the project in particular for the construction of the conduits from the STP to the new irrigation areas and for the distribution works to the farm boundaries. Table 7.2 and Fig. 7.2 provide an overview of the current (1990) and future wastewater irrigation schemes in the Tunis area.

Table 7.2 **Data on the Current (1990) and Future Reuse of Wastewater from the Tunis Metropolitan Area**

Irrigation scheme	Actual/proposed cultivation	Sewage Treatment Plant: Name of station supplying irrigation water	System	Present plant capacity[1] m^3/day	Effluent quality[2] E.coli/100 ml (geom. mean)
Existing					
Soukra 600 ha	Citrus fruits	Charguia	Activated sludge	60,000	$2 \cdot 10^5$
Henchir Tobias-Cébala 2670 ha [3]	Cereals, forage	Charguia expanded	Stabil. ponds	16,000	600
		Côtière Nord (existing) Choutrana	Activated sludge	40,000 ?	$2 \cdot 10^5$
Future (under planning or Implementation)					
Soukra + 200 ha	Fruit trees	Charguia expanded	Activated sludge	100,000	
Mornagh 940 ha	Fruit trees	Sud Miliane	Oxidation channel	40,000	

[1] Projected dry-weather-flow of all 4 STP (1987): 250,000 m^3/d
Expected demand for irrigation of all perimeters (4450 ha): 187,000 m^3/d
[2] Data collected during 1987/89 (Trad-Raïs 1989, personal communication)
[3] Put under irrigation in 1989

Mornagh is a state-owned irrigation area ("terres domaniales") on which fruit trees have already been planted. **Henchir Tobias-Cêbala** is an area where, until today, cultivation was dependent exclusively on seasonal rain water. There are, reportedly, both rich and poor farmers, as well as large and small holdings. A monitoring programme of the development of this area after the introduction of irrigation could furnish interesting and important information. How will the situation of the farmers be changed socio-economically? Will all present land owners switch to irrigation farming, or will land be purchased by rich outsiders as land values go up? Will the

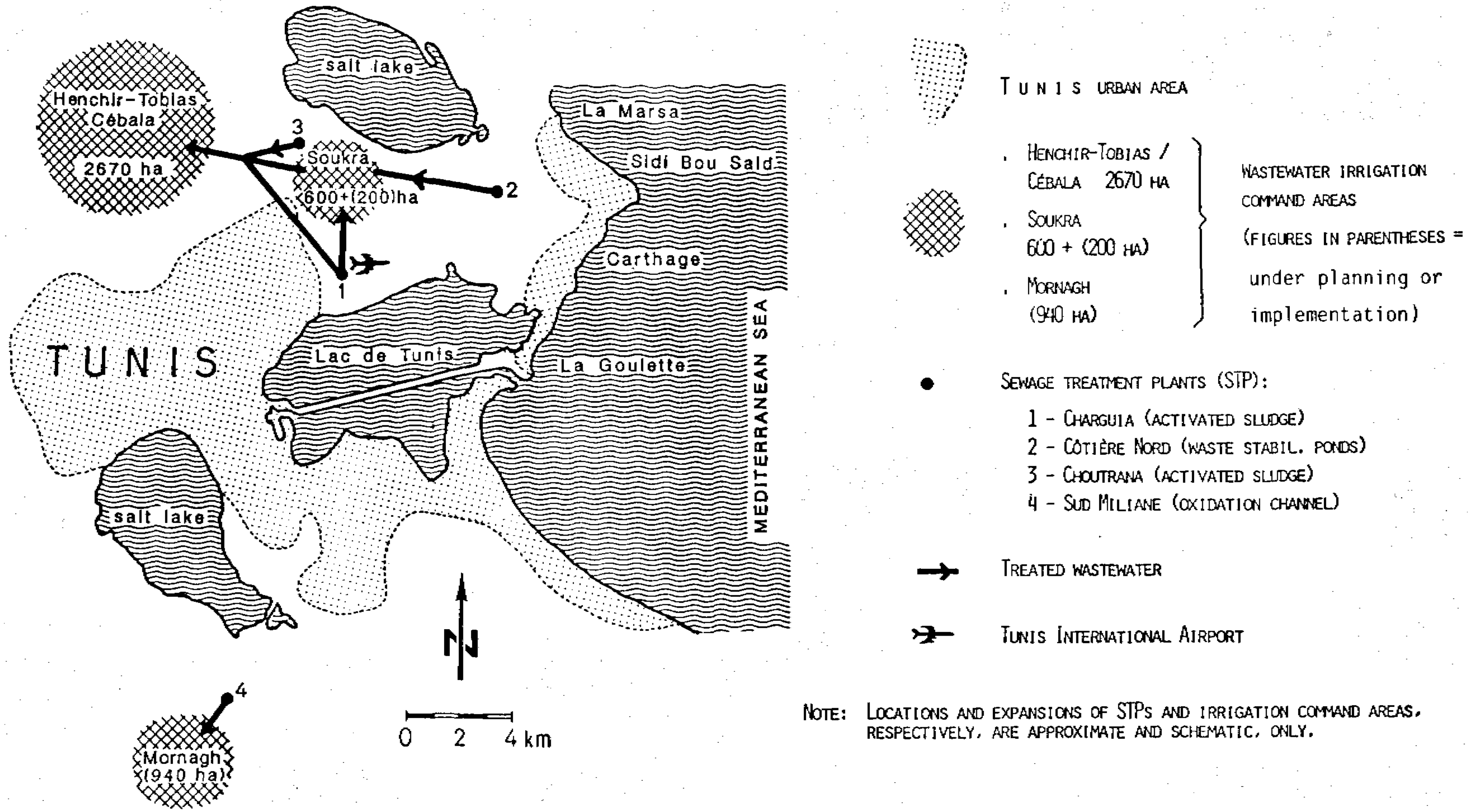


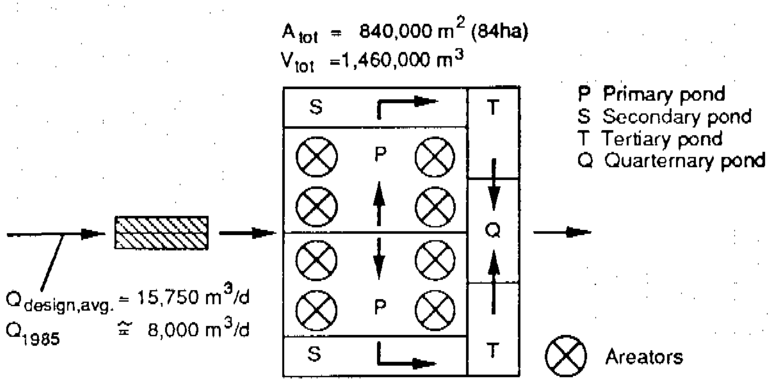
Fig.7.2 Current (1990) and Future Irrigation with Treated Wastewater in the Tunis Metropolitan Area

health status of farmers and farm workers be affected - positively or negatively - by the introduction of wastewater irrigation? What are the expected nutritional changes?

In the **Soukra** command area, mainly citrus fruits are cultivated, both for local sale as well as for export. Chpt. 7.3 gives a more detailed description of wastewater distribution and reuse practices based on a visit to this area and from discussions with farmers.

In 1981, a large **waste stabilization pond scheme** was put in operation at Côtière Nord. It consists of two series of aerated primary, secondary and tertiary ponds operating in parallel as well as one common quaternary pond. Wastewater mainly of domestic origin from La Marsa and La Goulette is treated in this plant. The pond system is schematised in Fig. 7.3.

The scheme is located at the site of an ancient lake on cheaply available land.



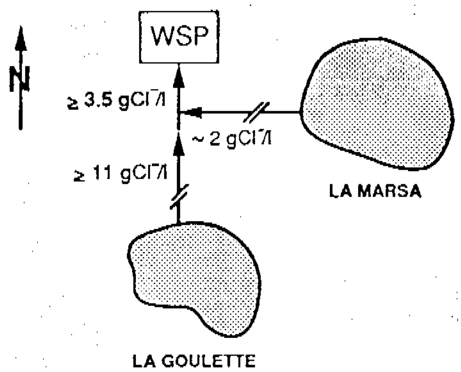


Fig. 7.3 Côtière Nord Waste Stabilization Ponds (WSP) - Layout and Influent Salinity

The theoretical hydraulic detention time at average design flow is 93 days, at maximum design flow it would still be 58 days. With the current average flow of 8,000 m^3/d, the calculated retention time is in the order of 180 days. From these figures, the plant can be expected to produce under any condition, an effluent of excellent hygienic quality as indicated by the figure of 600 E.coli/100 ml in Table 7.2. The effluent of this plant would indeed be excellent water for unrestricted irrigation. Furthermore, given the long hydraulic retention period, the system may achieve satisfactory BOD removal without mechanical aeration. Sludge accumulation rates of about 40 cm/4 years were observed in the aerated primary ponds.

A major problem of the WSP scheme of the Côtière Nord is the extremely high salinity of the inflowing sewage. The influent is a mixture of wastewater collected in the suburban areas of La Marsa and La Goulette. The effluent, although of very good hygienic quality, may not directly be used for irrigation because of its high salinity content (EC ≥ 7 mS/cm)[1].

The reason for this high salinity was found in the old and leaking sewerage system of La Goulette: there, salty groundwater finds its way into sewers. Reconstruction of the La Goulette sewers has reportedly been considered, but not proven feasible. Instead, the effluent of the Côtière Nord ponds will be mixed with the less saline effluents of the Charguia and Choutrana STPs for reuse in the new irrigation area at Henchir Tobias-Cébala (see Fig. 7.2). By mixing these effluents, the hygienically high-quality effluent of Côtière Nord - which would allow even unrestricted vegetable irrigation - and the relatively high investments for this plant might be largely foregone. The mixed sewage to be reused at Henchir Tobias-Cébala will be of relatively poor hygienic quality, unless the effluents of the Charguia and Choutrana activated sludge plants are treated for pathogen removal (e.g. by complementing them with maturation ponds).

[1] mS/cm (millisiemens/cm) is the unit of measure for electrical conductance (s) which itself is a measure of the dissolved solids (salts, hardness) content of a liquid. FAO (1985) formulated the following guidelines regarding the suitability of irrigation water for crop cultivation and plant sensitivity: at EC < 0.7: no restriction regarding crop selection; EC = 0.7-3.0: moderate restriction; EC > 3.0: severe restriction.

7.2 Wastewater Reuse Practice: A Field Visit

The wastewater irrigation practice described below is based on the example of the Soukra-Ariana irrigation area. Treated wastewater from the City of Tunis is used there. This information was obtained from half a day visit to the area which included discussions with irrigation network operators and farmers.

Ariana is a suburban area north-east of Tunis. It is located in the Soukra municipality which is partly residential partly agricultural. An underground **pipe system** distributes the effluent from the Charguia activated sludge STP to the farmers' plots. A schematic layout of the scheme is shown in Fig. 7.1 above. Citrus fruit trees are mainly grown there.

The sewage is distributed by OMVVM, the Medjerda Valley Development Authority. A similar organisation exists in Nabeul and possibly also in other irrigation areas. These authorities which are dependent on the Ministry of Agriculture, have three major tasks:

- To construct and cater for the infrastructure required to distribute the sewage (pumping stations, transport mains, balancing reservoirs, distribution piping and appurtenances)
- to operate the system according to delivery schedules
- To collect revenues.

OMVVM's responsibility is thus to deliver the treated wastewater to the farmer's plots. The authority also controls the farmers' observance of **crop restrictions**, i.e. the non-use of wastewater on vegetables which may be eaten raw.

The wastewater is metered at the branch off at the owner's plot. In 1985, OMVVM was selling the sewage for TD .025/m^3 [1]. The subscriber is billed every three months. Operators/controllers call on the farmers regularly to collect the fees and check on the proper functioning of the system. Thus, the OMVVM personnel and farmers appear to be in rather close contact.

The farm owner arranges and pays himself for the distribution of the treated wastewater on his plots. The farm owner subscribes to the wastewater delivery service and by this he agrees to adhere to the crop restrictions. OMVVM can fine offenders or may even stop service.

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[1] TD 0.800 = US $ 1.00 (1985)

A visit to two farms in Ariana (Soukra) enabled us to gain some insight into actual wastewater use and to meet two of the more than hundred farmers or farm owners in the Soukra wastewater irrigation district. The size of the two farms is 1-2 ha. Other farms in the irrigation area may be up to 20 ha. Intensive fruit tree cultivation apparently allows good income generation. Both farms are walled off against the road along which there are also recently constructed residential buildings. The farms are plantations of orange and pomegranate trees cultivated in sandy soil (Photo 7.2). The family of the first farmer settled in the area ten years ago. It also lives and works on the farm. This contrasts with many other farm owners in the Soukra area who employ peasant farmers or farm workers to cultivate their land. At the time of harvest, up to ten workers are contracted to pick the oranges which are harvested once a year in December and January. The fruit is transported to a wholesale market by the farmer. Alternatively, a wholesale entrepreneur may directly arrange for the picking of the fruit with his own labourers and vehicles. The fruit is partly sold on local markets and partly exported. The produce determined for exportation are washed with hot water and waxed.

The farm receives treated wastewater 3-4 times/week during the dry season. Delivery is twice a day for a total of 7 hours, i.e. 3.5 hours in the morning and 3.5 hours in the evening. On the farm, wastewater is distributed through an underground pipe system and delivered through outlets ("vannes") which are opened and closed by a simple valve (Photo 7.3). The system is depicted in Fig. 7.4. The pressure at the outlet is rather low. The water is channeled from the outlets to the nearby trees (Photo 7.4). The farmer opens and closes himself the furrows with a shovel to irrigate the trees in turns. Most farmers or farm workers reportedly work barefoot or wear sandals; boots are rarely worn.

The farmer has also told us that prior to the delivery of wastewater, irrigation had steadily diminished as groundwater resources were dwindling. Increasing stretches of land also had to be abandoned due to high soil and groundwater salinity. Some farmers in the Soukra area whose homes are connected to SONEDE's piped water supply, reportedly used such water for irrigation when it was still relatively cheap.

The farmer purchases cattle manure for soil fertilization and conditioning. He does not use mineral fertilizer.

On the second farm, also oranges and pomogranates are being cultivated. The farmer irrigates his land with both OMVVM-supplied wastewater and with own well water. The well water is pumped to an overhead tank from where it is supplied into the farm distribution system. The same underground distribution system is used for both the treated wastewater and the well water. There are 60 outlets, each irrigating 4-5 trees.

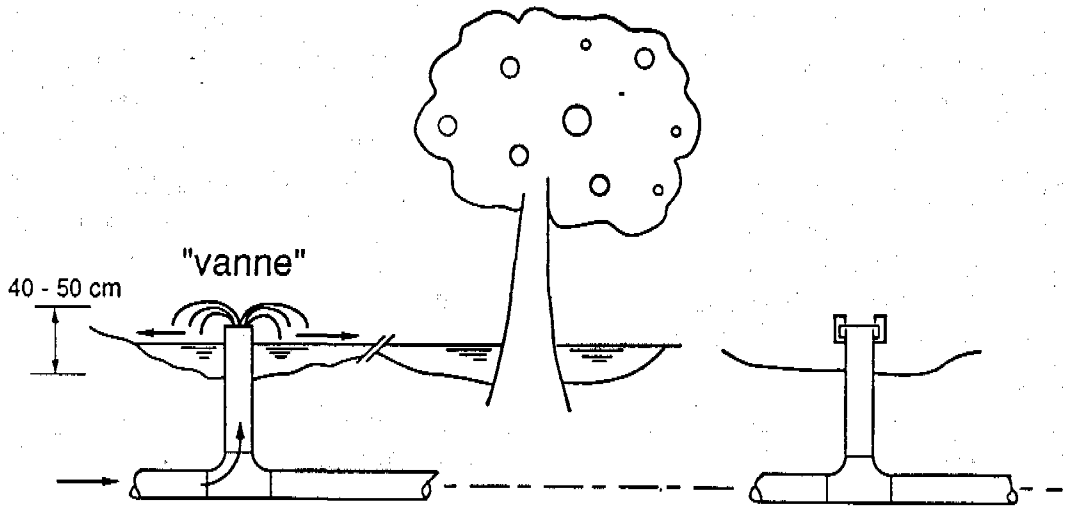

Fig. 7.4 Farm Distribution of Treated Wastewater
(schematic; see also Photos 7.3 and 7.4)

Photos 7.2, 7.3 and 7.4 show the plantation on one of the visited farms, and the above-ground valves ("vannes") by which the wastewater is fed into the furrows.

7.3 Institutional and Regulatory Framework

- Institutions

In large municipalities, **wastewater collection, treatment and disposal** into receiving waters fall under the jurisdiction of ONAS ("Office National de l'Assainissement"), the national sewerage and sanitation agency, which was set up in 1974. Previously, responsibility remained with the respective municipal authorities. ONAS is a subsidiary body of the "Ministère de l'Equipement", which is equivalent to a Ministry of Public Works. The agency caters for the construction as well as for the operation, maintenance and replacement of sanitation infrastructures.

Where **treated wastewater** is used for irrigation, the **Ministry of Agriculture** acquires the wastewater from ONAS through its subsidiary agencies for land development and irrigation. These agencies, such as OMVVM and OMVPI Nabeul, cater for the transmission and **distribution of irrigation wastewater** used for irrigation to the farmers. This is garanteed by the installation and operation of pumping stations, transmission lines, reservoirs and distribution mains. The agencies also check whether farmers adhere to the **crop restrictions** postulated by the "Code des Eaux" (Water Code) if wastewater is used for irrigation (see "Regulations" below).

CRGR, the Rural Engineering Research Division of the Ministry of Agriculture, has recently set up a laboratory for microbiological analyses with the support of UNDP (see also Chpt. 7.4).

Domestic water supply - both piped and unpiped - is under the jurisdiction of the Ministry of Agriculture. Piped supplies for urban and rural communities exceeding 500 inhabitants are constructed and operated by SONEDE (Société Nationale d'Exploitation et de Distribution des Eaux"), the National Water Supply Authority. Water supply to smaller communities are dealt with by the Rural Development Division ("Direction du Génie Rural") of the Ministry of Agriculture. Both ONAS and SONEDE carry out in their own laboratories, routine analysis of wastewater and drinking water respectively. To date, wastewater quality control appears to be based exclusively on receiving water quality standards, and less so or not on health requirements for irrigation of crops. Reportedly, ONAS occasionally sends wastewater samples to the Pasteur Institute (Ministry of Public Health) for bacteriological analysis.

The **Ministry of Public Health** is responsible for the control of the hygienic **quality of wastewater reused for irrigation purposes** and of marketed crops. Health services in Tunisia operate through "Régions Sanitaires" (Regional Health authorities), which are subsidiaries of the Ministry. The basic health services, hospitals and regional public health laboratories are grouped under these authorities. We visited the Nabeul regional public health laboratory which performs clinical microbiological tests, food hygiene controls and sanitary microbiological analyses. The latter includes the testing of ground and supplied water as well as of wastewater reused in agriculture or discharged otherwise. Reportedly, such monitoring is carried out periodically, and particularly so when confined outbreaks or individual cases of notifiable diseases occur (e.g. hepatitis A, cholera) to localize the transmission foci. For non-routine analyses, samples are sent to the Pasteur Institute, which is the Ministry's reference and research laboratory.

The **Ministry of Public Health** is the agency responsible for water pollution monitoring and pollution control enforcement. It plays an important part in the formulation of **pollution control and reuse regulations** and in the clearing of wastewater reuse permissions issued by the Ministry of Agriculture.

- Regulations

The principal regulatory act which provides the legal framework for the wastewater reuse practices is the **"Code des Eaux"**, the National Water Law. The law stipulates that wastewater earmarked for irrigation shall be of a quality which may not lead to the transmission of diseases.

An important complementary document to the Water Code will be the **ordinance** regulating more specifically the reuse of wastewater in agriculture. The ordinance which is about to be enacted, stipulates, among other things, the following:

- Wastewater reuse is authorized only if the wastewater has been adequately treated.
- Treated wastewater to be reused in agriculture must satisfy the standard of $\leqslant$ 1 helminth egg/ℓ as arithmetic mean.
- The effluent may be used to only irrigate crops which are not directly consumable. No other crops may be cultivated in the particular irrigation command area.
- The Ministry of Agriculture, after consultation with the Ministry of Public Health, lists the crops which may be irrigated with the treated wastewater.
- Vegetables, whether eaten raw or cooked, may not be irrigated with treated wastewater.
- Cattle may not be grazed on pastures irrigated with treated wastewater.
- Effluent reuse must be authorized by the Ministry of Agriculture after clearance by the Ministry of Public Health and after consultation with the National Environmental Protection Agency (Agence Nationale de Protection de l'Environnement). A "cahier des charges" (terms of reference) is issued for each reuse authorization.
- The effluents must be analyzed for helminth eggs every 2 weeks on 24-hours composite samples.
- The agencies distributing the treated wastewater are responsible for the regular analysis of the effluent. The Ministry of Public Health and the National Environmental Protection Agency are the controlling authorities. The Ministry of Public Health is to take the necessary measures to safeguard the health of the agricultural workers and of the consumers.

In Sousse, the Ministry of Agriculture authorized in 1983 irrigation of a large tourist area, including a golf course, with treated wastewater from the Sousse Nord STP[1]. In another scheme, hotel grounds were to be irrigated with effluent from the same STP. Reuse is restricted to lawns, ornamental plants and non- fruit trees. Included in the authorization is a "Cahier des Charges" (terms of references) stipulating the rights and duties of the users (the hotel), the Ministry of Agriculture, the Ministry of Public Health and ONAS, the National Sanitation Agency.

7.4 Health and Epidemiological Aspects

In this section, discussion will not be limited to water and excreta-related infections but these will be discussed in the wider context of the most important causes of morbidity and mortality in the country. This will allow the reader to assess the importance of the water and excreta-related infections that might be associated with the waste reuse practice in comparison with the predominant diseases in the area. The reader is also referred to section 1.2, where the health risks associated with wastewater use have been summarized, and to section 1.4, where the difficulties involved in evaluating the health effects of a specific reuse practice have been outlined. The data available do not allow an accurate assessment of the health risks to be made, so the following sections contain epidemiological judgements which should be considered as "informed speculation" rather than strict scientific analysis.

- Important Components of the Endemic Disease Situation

In Tunisia, the most important of the major notifiable diseases include viral hepatitis, tuberculosis, measles and typhoid fever (Table 3). The increasing incidence of some diseases over the period 1980-84 could be explained partly by an increase in reporting, stemming from the growing improvement in medical services throughout the country. The incidence of the major notifiable diseases varies greatly between different regions in the country (Table 7.3). The incidence of typhoid and paratyphoid fever was notifiably higher in 5 regions of the country in 1984, whereas rates of tuberculosis are more similar in all the regions. In 4 regions, epidemics of typhoid fever were responsible for the high figures.

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[1] The type of treatment used is not known. It possibly consists of activated sludge.

Table 7.3 Incidence of principal notifiable disease in Tunisia from 1980 to 1984 (per 100,000 persons)

(from Bulletin Epidemiologique Trimestriel, 4/84)

Year	1980	1981	1982	1983	1984
Measles	3.5	45.6	27.0	21.1	35.6
Viral hepatitis	19.3	24.1	29.1	39.3	50.8
Typhoid and paratyphoid fever	10.3	9.5	9.6	10.6	13.8
Tuberculosis	39.6	35.1	37.8	44.2	35.9
Meningitis C.S.	2.1	2.3	4.6	10.4	9.0
Hydatidosis	4.8	5.0	4.4	4.3	6.8

Considering the major diseases related to water and sanitation conditions, the trends over the last 10 years differ between diseases. The incidence of cholera has been progressively reduced, and no cases were seen between 1981 and 1984. Through the use of specific campaigns schistosomiasis was reduced to 20 cases in 1984 and malaria to 3 cases. However, the incidence of viral hepatitis rose sharply between 1980 and 1984 (Fig. 7.5). The incidence of typhoid fever has remained relatively steady, but with a tendency towards an increase in the number of cases (Fig. 7.6). In 1984, epidemics in Kebili, Tozeur, Gafsa and Zaghouan accounted for 51% of the total cases of typhoid fever (Table 7.4). Following these epidemics, the Ministry of Public Health suggested that efforts to improve the state of hygiene and sanitation in these regions should be made urgently. In Zaghouan, the source of the epidemic was traced to a slow-moving water source that was highly polluted; the epidemic stopped when this source was condemned. In other areas, the epidemics were thought to be related to factors of environmental hygiene (although the link was not firmly established); firstly, the use of traditional latrines which are emptied from outside through a door and secondly, the use of irrigation water contaminated with human excreta. The high incidence of typhoid fever in Gabes is a more stable feature of the epidemiological situation, and it is thought that this could be linked with excreta use practices (see the section below on studies and impact).

Cases of infection with intestinal helminths are not notifiable, so there are no national figures available. An impression of their status in some

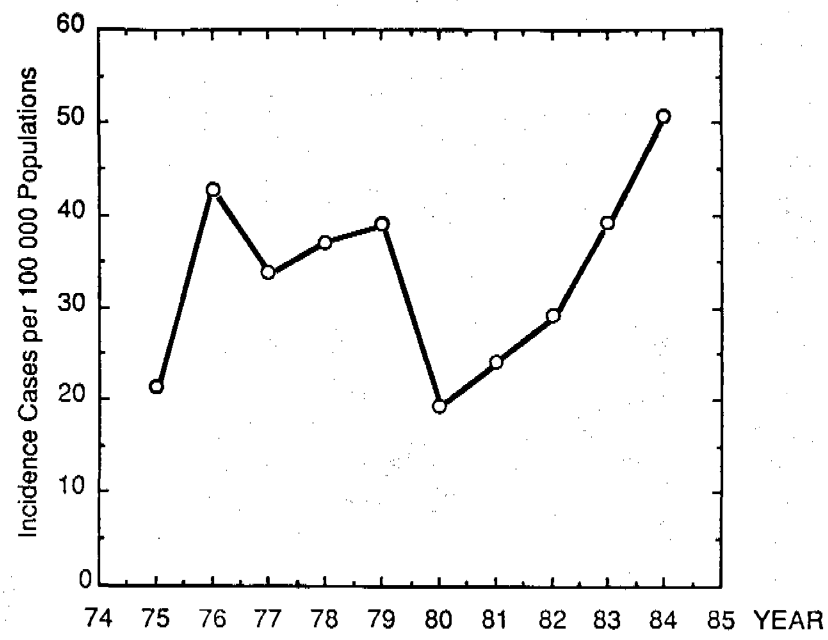


Fig.7.5 Annual reported incidence rates of viral hepatitis from 1975 to 1984 (per 100 000 inhabitants)

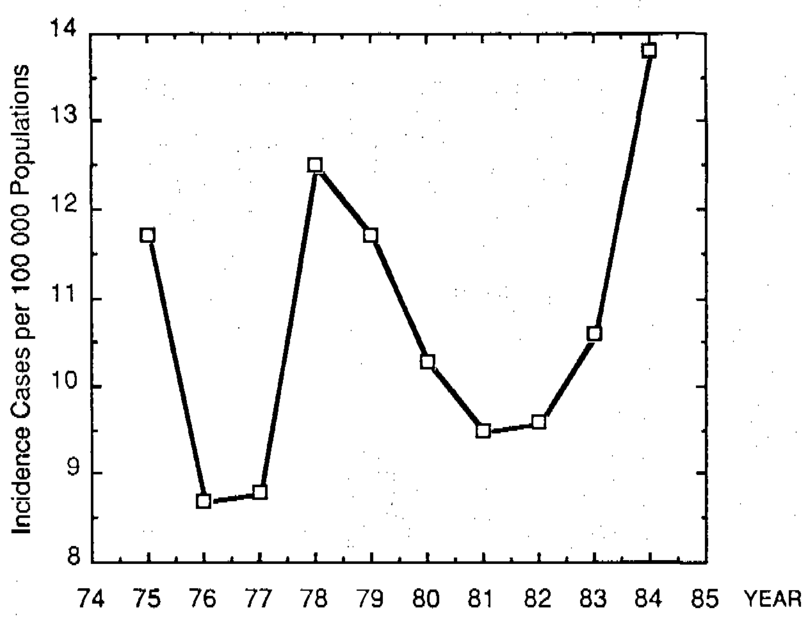


Fig. 7. 6 Annual reported incidence rates of typhoid fever from 1975 to 1984 (per 100 000 inhabitants)

Table 7.4 Incidence of the principal notifiable diseases by region in 1984 (per 100,000 persons)

	Typhoid and paratyphoid	Infectious hepatitis	Tuberculosis	Measles
Kebili	*189.5	76.8	35.8	5.3
Gafsa	* 80.1	22.9	68.2	5.9
Tozeur	* 77.9	26.5	36.8	29.4
Zaghouan	* 58.0	41.2	42.9	31.9
Gabes	48.8	127.5	44.2	121.3
Beja	18.9	22.2	29.0	46.5
Bizerte	15.1	48.1	28.4	33.4
Nabeul	8.7	81.8	18.4	67.5
Sousse	7.8	44.7	51.9	87.0
Mahdia	7.0	64.8	14.8	49.3
Sidi Bouzid	5.9	25.3	68.9	11.8
Jendouba	5.8	22.6	31.5	4.7
Monastir	5.4	95.0	19.4	42.1
Kasserine	5.4	24.2	62.0	8.1
Medenine	4.7	72.3	54.0	40.2
Tataouine	4.0	508.0	55.0	136.0
Sfax	2.9	29.9	21.5	2.2
Kairouan	2.8	71.6	32.2	16.1
Tunis	2.6	18.7	33.1	32.5
Siliana	1.8	15.8	32.0	12.6
Le Kef	0.8	44.0	32.7	48.4
Total 1984	13.8	50.8	35.9	35.6
(1983)	10.6	39.3	44.2	21.1

* Regions where epidemics occurred.

areas can be gathered from the results of a survey done in the Cap Bon area (comprising 14 districts) by personnel from the Regional Laboratory of Public Health (Gharbi 1985). In a survey of primary school children coming from both rural and urban areas, children in the first and sixth year of school were tested for the presence of helminth eggs. 5650 out of 17335 samples (32.6%) were positive for one or more helminth parasites. The prevalence of particular parasitic infections was as follows: *Enterobius* 28.7%, *Hymenolepis nana* 12.1%, *Ascaris* 2.9%, *Trichuris* 2.4% and hookworm 0.9%. The survey indicated that significant reductions had occurred over the previous decade, due to the application of various control measures. The major reductions shown from 1974 to 1984 were for *Ascaris* infection, that is, from 12.5% to 2.9% (overall) and 71.1% to 10.5% in the focus with the highest prevalence. The predominance of *Enterobius* and *Hymenolepis* infection with localised foci of *Ascaris* infection (most probably in the less dry areas) is fairly typical for a semi-arid area.

- Water Supply and Excreta Disposal

Around 90% of the population is now served by piped water by SONEDE, the national water authority. The provision of piped water has had an effect in reducing water-borne disease. However, less than half of the population are served by sewerage systems. 50% of the country is rural, and here only 30% of the population have sanitary waste disposal. A variety of traditional latrines are generally in use. In some areas, nightsoil is used as a fertiliser in the fields. In 1985, this practice was reportedly still rather common in the region of Gabes; in this area the prevalence of parasite infections and incidence of typhoid fever is also high.

- Studies Undertaken and Potential Impact of the Existing Practice

From 1983-1986, the Ministries of Agriculture and Public Health jointly undertook research into the health risks of wastewater reuse. The project (PNUD/OPE-RAB 80/011), which was co-financed by UNDP, aimed at evaluating the effects of using treated wastewater and dried, digested sludge on crop productivity, and on the hygienic quality of crops and soil. In addition, groundwater quality in the experimental area has been monitored. The experiments have been conducted at experimental stations of the Ministry of Agriculture in Soukra near Tunis (1.5 ha) and near Nabeul (2.5 ha). The treated wastewater originates from the nearby activated sludge STP at Charguia (Tunis) and Nabeul, respectively. In Soukra, sorgho (millet), a forage crop, and green pepper were cultivated. Wastewater was applied by furrow irrigation and groundwater was used for control experiments. In Nabeul, where also drip irrigation tests were made, orange trees were used as experimental crops. Photo 7.5 shows in-line filtration equipment for the drip irrigation supply of treated wastewater.

The field stations were managed by the "Centre de Recherche du Génie Rural" (CRGR), the rural engineering research division of the Ministry of Agriculture. CRGR has established a microbiology laboratory with the assistance of UNDP, where routine testing for indicator organisms can be made. The investigations included regular sampling of STP effluents, crops, soil and of groundwater in the irrigated area for analyses for faecal coliforms and faecal streptococci with periodical examination for the presence of *V. cholerae* and *Salmonella* sp. The results of the irrigation with treated wastewater were compared with those of the irrigation with groundwater. In addition, experiments of one week duration with daily observations were made to assess the die-off kinetics of the indicator organisms between two consecutive irrigations.

Faecal coliform (FC) concentrations in the influent to and in the effluent from the Charguia activated sludge STP and at the entrance to the agricultural research station in Soukra were as shown in Table 7.5.

Table 7.5 Ranges of FC Concentrations in the Wastewater at the Charguia STP (Tunis) and of the Treated Wastewater Entering the Soukra Agricultural Station (Trad-Rais and Saillet 1986)

Wastewater/water analyzed	Range of FC/100 ml[1] (mean concentrations)
• Charguia activated sludge STP:	
- influent	$4x10^6$ .... 10^8
- effluent[2]	$2x10^4$ .... $2x10^7$
• Treated wastewater as received at the Soukra agricultural station	$2.5x10^4$ .... $1.6x10^6$
• Groundwater in the irrigation command area	$3x10^1$ ...... $1.6x10^3$

[1] range indicates seasonal variation (highest STP influent and effluent concentration in September)

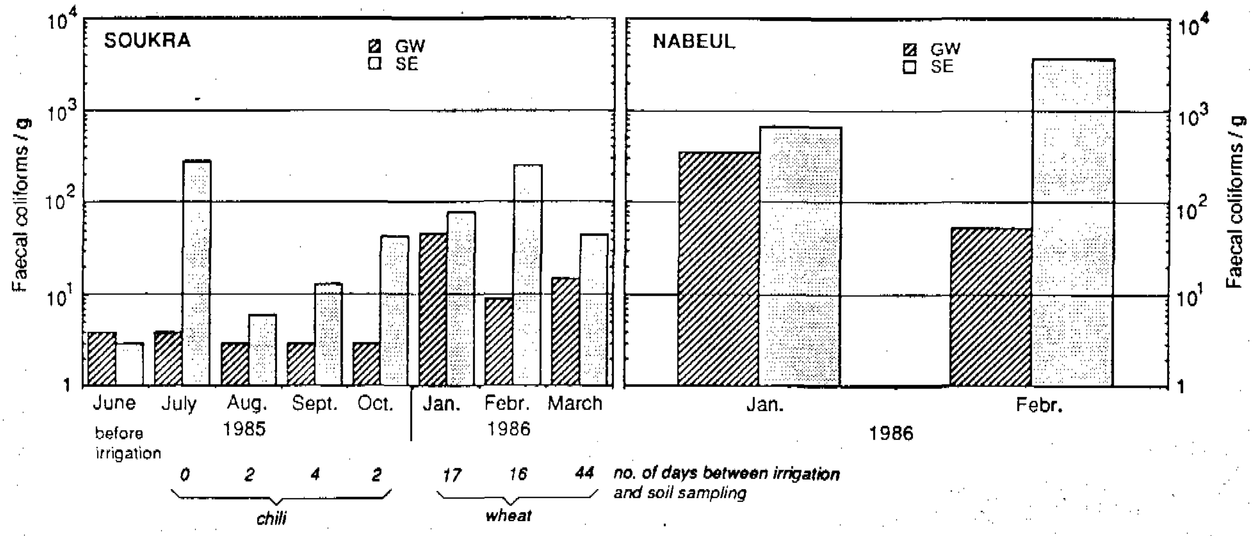
[2] total retention time 6 hours; non-chlorinated

While the range of FC-levels in the wastewater can be considered as normal, the FC concentrations in the groundwater are considerably higher than expected. The authors explain this by the shallow depth of the groundwater. It is not protected by an impermeable layer. Also, the soil is rather permeable, possibly enabling irrigation water to mix with the shallow groundwater.

Fig. 7.7 shows a comparative assessment of the bacterial contamination of soil irrigated with groundwater and of soil irrigated with secondary effluent at the agricultural stations of Soukra and Nabeul.

The results indicate that the level of contamination due to groundwater and wastewater irrigation as measured by the FC concentrations is, in general, not significantly different. However, a distinct difference occurred in the July '85 campaign: The FC concentration on wastewater-irrigated soil was two orders of magnitude larger than on groundwater-irrigated soil. A possible explanation for this is that the soil sampling was done on the day of irrigation. Again in the February '86 campaign, the same difference in the levels of contamination occurred, although the soil was sampled only 16 days after irrigation. This difference might be explained by the fact that

Fig. 7.7 Faecal Coliform Concentrations in Soils Irrigated with Groundwater and Treated Wastewater in Soukra and Nabeul [1,2]
(Trad - Rais and Saillet, 1986)



GW = Irrigation with groundwater
SE = Irrigation with secondary effluent

Soil types: Soukra, plot no. 1 : sandy
Nabeul : calcareous brown soil

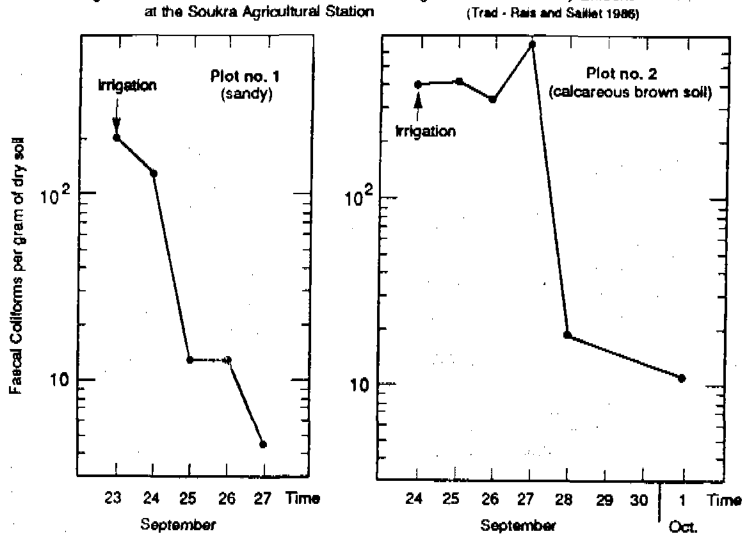
[1] Not reported here but also investigated were the effects of irrigating with groundwater + sludge and with treated wastewater + sludge

[2] The figures are averages of 5 samples taken at a depth of 5 cm on the particular plot at a time interval of 4 weeks

soil drying is much slower in cool than in hot weather. Also, the soil may have been wetted by rainfall after the irrigation campaign, creating a soil microclimate favouring bacterial survival. The investigators concluded that longer lasting experiments with a larger number of samplings are required in order to enable a more definite conclusion regarding the relative levels of contamination.

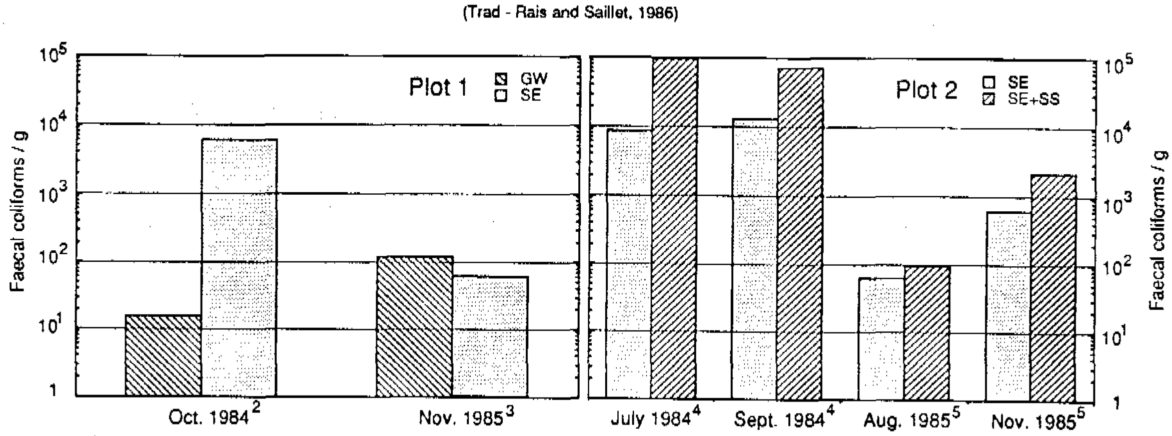
Fig. 7.8 illustrates the **FC die-off on two types of soil** irrigated with secondary effluent. On sandy soil, FC died off by two orders of magnitude within approx. 2 days. On calcareous brown soil, which has a finer texture than sandy soils, the level of contamination remained high (even increased somewhat) during the four days after irrigation. It then dropped by more than one order of magnitude within 1 day. In this one experiment, die-off on the brown soil tended to be slower than in the sandy soil. This is not unexpected as the dessication process which leads to accelerated pathogen die-off is greater in the sandy than in the calcareous brown soil.

Fig. 7.8 Faecal Coliform Die - Off in Soil after Irrigation with Secondary Effluent at the Soukra Agricultural Station (Trad - Rais and Saillet 1986)



Faecal coliform concentrations on sorgho (millet), a forage crop, were also investigated. Fig. 7.9 shows the results for sorgho irrigated with **groundwater, secondary effluent** and **secondary effluent amended by sewage sludge.** A major difference of more than 2 orders of magnitude in FC concentration resulted for the campaign in the authumn of 1984 during which groundwater and secondary effluent were used. This might be explained by climatic factors favouring longer survival of pathogens in the cooler and more humid month of October than in the hot, dry month of July. Levels of contamination due to secondary effluent and secondary effluent amended by sludge were not significantly different.

Fig. 7.9 Faecal Coliform Concentrations on Sorgho [1] (Millet) Irrigated with Groundwater, Secondary Effluent and Sewage Sludge in Soukra (Trad - Rais and Saillet, 1986)



GW = Irrigation with groundwater
SE = Irrigation with secondary effluent
SE+SS = Irrigation with secondary effluent and sewage sludge

1 a fodder crop; plants were cut a few centimeters above the ground
2 8 samples per treatment taken a few days after irrigation
3 1 sample per treatment taken 5 weeks after irrigation
4 18 samples per treatment
5 6 samples per treatment

Table 7.6 contains results of investigations during which the levels of bacteriological contamination of **groundwater-irrigated** and **effluent-**

Table 7.6 Faecal Contamination of Chili Irrigated with Groundwater and of Chili Irrigated with Secondary Effluent in Soukra (Trad-Rais and Saillet 1986)

	FC/100 g 1984[a]	FC/100 g 1985[b]
• Chili irrigated with groundwater	1.8×10^1	0
• Chili irrigated with secondary effluent	2.2×10^1	1.1×10^1

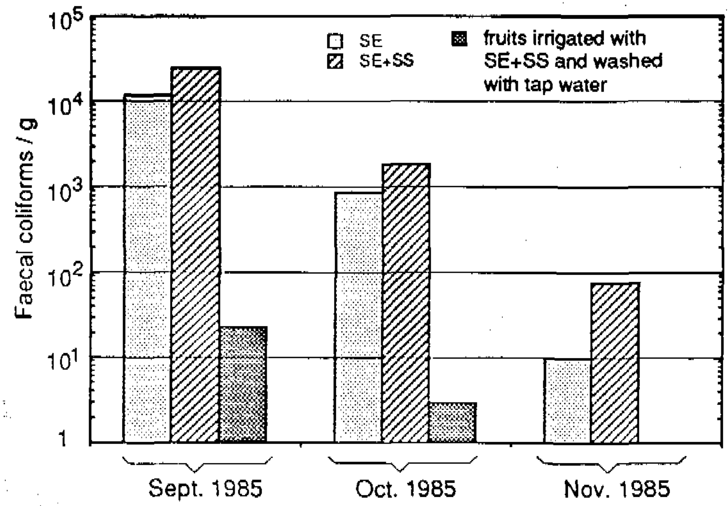
a average of 24 samples (taken from 24 fruits)
b results pertain to a sample consisting of 10 fruits

irrigated chili were compared. Fruits were sampled just before harvest. With the last irrigation having taken place a few days before harvest, substantial die-off occurred prior to the sampling. According the the data in Table 7.6, there was no significant difference in the level of contamination between the groundwater and the effluent-irrigated chili.

Fig. 7.10 shows the bacteria levels on chili after irrigation with secondary effluent and with secondary effluent amended by sewage sludge, as well as the effect of washing the crops with tap water. Irrigation took place before the first sampling in September. FC die-off was more rapid and to lower residual concentrations for plants irrigated with secondary effluent than for those irrigated with the mixture of effluent and sludge. The effect of washing the crops with tap water was rather pronounced as faecal coliform concentrations dropped by about 3 orders of magnitude.

Fig. 7.10 Feacal Coliform Concentrations on Chili Irrigated with Secondary Effluent and Sewage Sludge in Soukra, and after Washing with Tap Water

(Trad - Rais and Saillet, 1986)[1]



SE = Irrigation with secondary effluent
SE+SS = Irrigation with secondary effluent and sewage sludge

[1] Figures are based on 6 samples each

The investigators also examined the quality of vegetables sold on public markets, most of which were, most probably, cultivated on land irrigated with fresh water or with only little polluted water. Results are presented in Table 7.7 and reveal that the levels of FC are of the same order of magnitude as for effluent-irrigated crops.

Table 7.7 Faecal Coliform (MPN) Concentrations on Chili Sold in Public Markets (Trad-Rais and Saillet 1986)

Sampling campaign	FC/100 g	no. of samples
1984	3.9×10^3	15
1985	1.6×10^5	13

The results of the various investigations confirm previous findings on excreted bacteria survival that:

- Pathogen die-off both on soil and crops is slower in cool and humid periods than during hot and dry periods.

- Bacterial die-off in soil and on crops is exponential, i.e. it is fast in the hours and days after irrigation and slow down later. Differences in the level of bacterial contamination between fresh water and effluent-irrigated soil and crops therefore tend to be significant right after irrigation but are evened out as the period after irrigation increases.

- The fact that vegetables sold on markets showed rather high levels of faecal coliforms is not surprising, as numerous pathways of faecal contamination beside irrigation with wastewater exist.

Reportedly, the overall project was influenced by several logistic difficulties such as periodic shortages of wastewater at the experimental stations and shortage of laboratory personnel. Irrigation and sampling campaigns were therefore curtailed and the data collected did in most cases not allow a statistically significant interpretation of the results. It was, nevertheless, possible to make important qualitative observations and to establish in a trendwise manner the effect of secondary effluent use on the bacterial contamination of soils and crops.

The **Ministry of Public Health** through its Directorate of Environmental Health and Protection conducted an **epidemiological study** of health risks of treated wastewater irrigation in 1985 as part of the above UNDP-supported investigation. The objective was to find out whether farmers and their families who use wastewater for irrigation have higher incidence rates of enteric diseases than families who use well water for irrigation.

The experimental group consisted of 50 families in the Soukra area who irrigate with effluent from the Charguia (Tunis) activated sludge plant. The control group consisted of 50 farming families living in Borj Touil, an area 30 km north of Tunis. The inquiries were made in summer 1985 after irrigation started. The families' disease status was assessed by enquiring about symptoms experienced since onset of irrigation and symptoms experienced over a longer time period. Information, data and attitudes regarding socioeconomic, behavioural, hygiene, agricultural and social aspects were also collected. Data analysis and evaluation was about to start at the time of our visit in the autumn of 1985. The team was testing the hypothesis that farmers and their families using wastewater would have an excess risk of gastro-intestinal infection over those using fresh water. However, the risk would have to be very high to be detectable in a study of this size, so it is possible that a further study may be needed, using a larger sample population.

The likely **impact of the current situation** can be summarised as follows:

a. Use of sewage effluent from activated sludge plants to irrigate orange trees is unlikely to lead to any adverse health effects, especially if workers wear protective footwear and no effluent contacts fruit on branches of the trees reaching near the ground. The use of this effluent is particularly safe where drip irrigation is used to deliver the water directly to the tree and is probably still safe where furrow irrigation is used. The latter needs to be confirmed by the results of the epidemiological study (extended to include a larger sample size).

b. Use of effluent from activated sludge plants appears to be safe for use on vegetable crops growing above the ground, e.g. peppers, but when used on crops coming into more contact with the effluent, further precautionary measures may be needed.

c. Use of raw sewage or nightsoil to fertilize/irrigate vegetables is likely to lead to a higher level of some parasitic infections, e.g. *Ascaris*, than found in other areas of Tunisia. However, since the level of infection with intestinal parasites in the general population appears to be relatively low (in comparison with less arid and poorer countries), this may not lead to as large an excess risk as may occur in some other situations.

d. Use of raw sewage or nightsoil to fertilize vegetables may also lead to a higher incidence of bacterial infections, in particular, typhoid fever, and may contribute to the spread of epidemics.

- Implications for the Control of Health Risks

The Ministries of Health and Agriculture are trying to stop the use of raw wastewater and promote the use of treated effluent, with additional use of crop restrictions or localised application techniques. The demand for water and the demand to grow vegetable crops is high, so that it is both hard to prevent the use of raw wastewater and hard to restrict the use of treated effluent to exclude irrigation of vegetable crops. In this case, the low-cost production of effluent treated to the level required for unrestricted irrigation would be preferable. The decision of ONAS, the agency responsible for wastewater treatment, to use waste stabilization ponds as their first-choice treatment technology is therefore compatible with the needs for effluent reuse; effluent from an appropriate series of ponds could be used in irrigation of vegetable crops without further protection measures being needed. Current crop restrictions could be relaxed, if effluent of less than 1000 faecal coliforms/100 ml were produced.

Several existing treatment plants use conventional methods, such as activated sludge. Effluent from such plants is generally used in restricted irrigation, to avoid the risk to consumers, especially from bacterial infections. The risk to workers from helminth infections is likely to be low, but precautions for workers to avoid exposure to the wastewater are advisable, since, in the absence of chlorination, some pathogenic organisms will be present. The upgrading of these treatment plants by the addition of maturation ponds would produce a better quality effluent which could then be used on a less restricted range of crops.

The most suitable **health protection measures** to be adopted will therefore depend on which crop the farmers want to grow in a certain area:

(a) Where there is a demand to grow vegetables and if special permission[1] to irrigate them with treated wastewater would be granted, the wastewater would have to be treated in waste stabilization ponds, or secondary treatment plants upgraded by ponds to attain WHO microbiological guideline levels for unrestricted irrigation.

[1] The regulations which are about to be enacted, do not allow the use of treated wastewater for vegetable irrigation (see also sect. 7.3).

(b) Where the demand is to grow citrus or olive trees, a lower quality effluent could be used, providing that workers' exposure to the effluent is low and fruit is not picked off the ground. A reduction in exposure of the workers can be achieved by two main methods: (i) the wearing of protective clothing, (ii) the distribution of the wastewater through drip irrigation systems. The latter is more expensive, but may be suitable for commercial systems and where the water gain from decreased evaporation is also a benefit.

7.5 References

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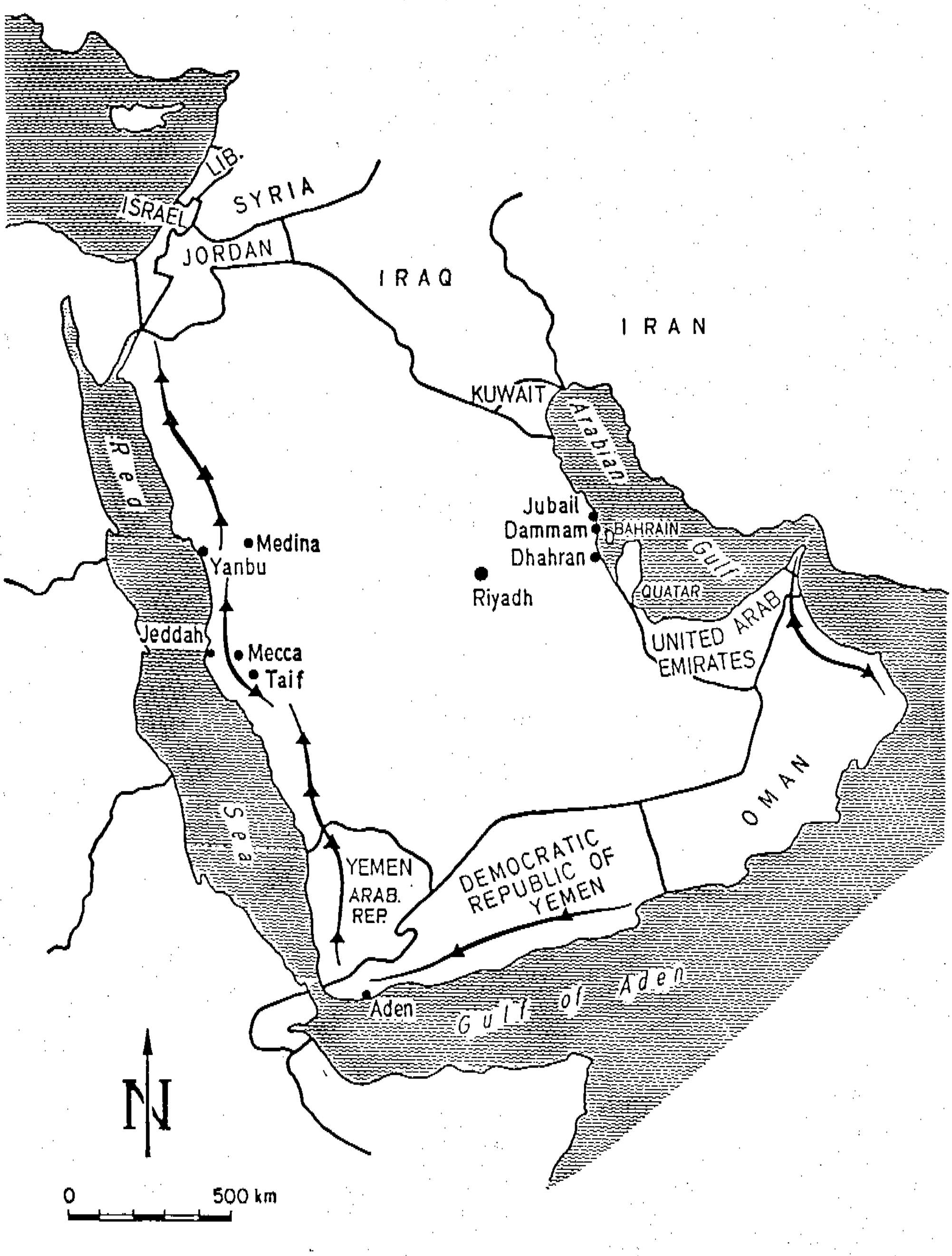
8 SAUDI ARABIA

Acronyms

ECWA	Economic Commission for Western Asia
MAW	Ministry of Agriculture and Water
MEPA	Meteorology and Environmental Protection Administration
MOH	Ministry of Health
MOMRA	Ministry of Municipal and Rural Affairs
WASA	Water and Sewage Authorities (municipal)

KINGDOM OF SAUDI ARABIA



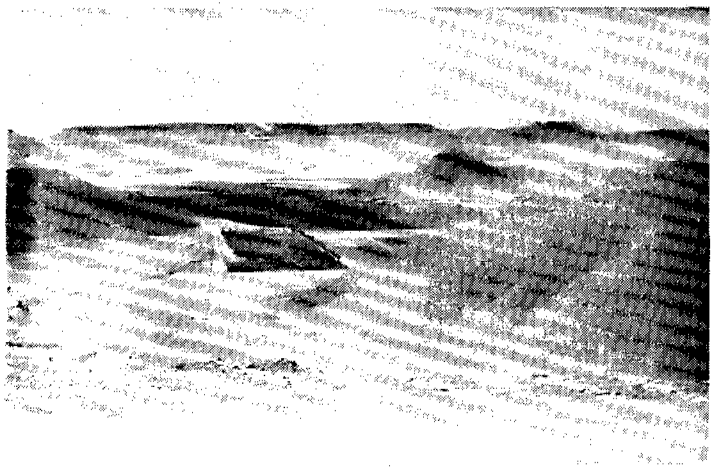


Photo 8.1

Dirab (Riyadh): wheat and fodder cultivation through tertiary effluent irrigation

Photo 8.2

Unreclaimed land near the Dirab irrigation area

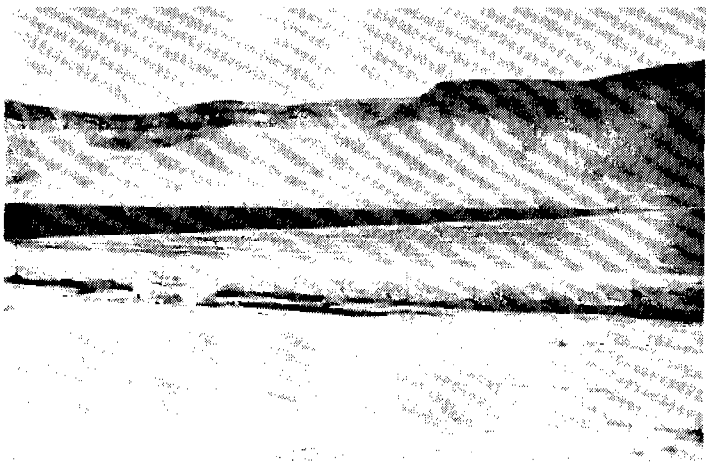


Photo 8.3

Moveable spray irrigator at Dirab

8.1 Geography, Economic Development and Water Resources Situation

The Kingdom of Saudi Arabia covers an area of approx. 2,200,000 km^2, making up most of the Arabian Peninsula. The total population numbered about 11 million in 1986 of which the non-national labour force amounted to approx. 2 million (1984). Due to the desert nature of the country and the rapid industrial development over the past 10 years, as much as half of the population lives in urban areas. Riyadh (population approx. 1 million), Jeddah (1,000,000), Mecca (500,000), Medina (500,000), and Dammam (300,000) are the main cities.

Geologically, the Arabian Peninsula forms part of the continental mass of Africa. The two parts are separated by the Red Sea which is a continuation of the East African Rift Valley. A mountain range, which extends from the Gulf of Aqaba to the Gulf of Aden, rises from the Red Sea coastal plains to over 1000 m. From this high western range, there is a gradual decline across the Peninsula to the inner Highlands and the Arabian Gulf in the East. The highland region consists mainly of crystalline and young lava formations. Lime formations and sand deserts are found in the eastern part of the Peninsula.

The climate of Saudi Arabia is characterised by extremely low rainfall and high evaporation. The mean annual rainfall totals 48 mm in Jeddah (Red Sea Coast), 150 mm in Riyadh (Central Plateau) and 95 mm in Dhahran (Arabian Gulf coast). Most precipitation occurs in the months of December through April. Large parts of the Central Plateau receives at times no rain at all over a number of years. Agriculture which is dependent on rain is only possible in the southwestern mountain ranges (Province of Asir) which receive a mean annual rainfall of up to 600 mm. Evaporation rates amount to 2200-2500 mm per year.

About 0.5% of the Kingdom's area is under cultivation. While formerly, agriculture was limited to oases and the rain-fed areas of the Asir Highland in the southwest, large investments have been made over the past two decades to reclaim desert land, to install irrigation schemes and to control surface runoff in order to expand agricultural production. Undeveloped land has been distributed to farmers. Private investment has focused on meat, poultry and dairy production including the cultivation of fodder crops. Wheat, dates, water melons, tomatoes, milk, poultry, and cattle meat are the major agricultural products.

Saudi Arabia is one of the world's largest oil producers. Income from oil exports have brought rapid economic growth and great wealth to the country. Industrial development concentrated on the setting up of hydrocarbon-based and energy-intensive industries to convert the crude oil and gas into high-level manufactured or processed products (refineries, cement, petrochemical, steel, aluminium factories). Two large industrial cities have been set up, Jubail on the Gulf and Yanbu on the Red Sea. Major financial resources are also invested into the development of the transport infrastructure (roads, harbours, air traffic) and social works (education and health services, development funds).

In order to satisfy the rapidly increasing water demands of urban, industrial and agricultural developments, available water resources have been increasingly exploited over the past two decades. Ground and sea water are the main sources of water supply. An exception are the large springs near Mecca, Jeddah and Taif, which provide in the order of 0.3 x 10^9 m^3 of water and cover much of the water demands in the cities on the western escarpment (Pescod 1984). The country lacks perennial rivers. Therefore, a large number of dams have been built in recent years in order to reduce water losses from flood runoff in "wadis". Geologically, the greater part of western Saudi Arabia consists of igneous rocks which contain little groundwater. The other parts of the country consists of sedimentary rocks containing sandstone and limestone aquifers (Pescod, 1984). Annual groundwater extraction amounted to 2.3 x 10^9 m^3 in 1983 (Khan et al. 1983, cited in Pescod 1984), thereby providing 70% of the Kingdom's water supplies. Annual aquifer recharge through rainfall has been estimated at 0.9 x 10^9 m^3. This might increase somewhat in future, as more dams are being constructed to impound seasonal rivers.

According to one report (Flottau 1988), agriculture has become the largest employer in Saudi Arabia. Through the tapping of deep aquifers with cheaply available energy which includes the "mining" of fossil, non-renewable groundwater, huge wheat and dairy farms have been developed at several locations in the country. The Safi farm, 100 km SE of Riyadh, is claimed to be the largest dairy farm in the Middle East (if not of the world): it comprises 16,000 ha of irrigated land, most of which are used to grow fodder crops as well as 18,000 heads of cattle. Saudi Arabia is an exporter of wheat as it produces about three times its own subsistence requirements. The strategy behind the intensive agricultural development is to diversify the economic basis of the country. Non-renewable groundwater is being tapped for this. Groundwater levels are receeding as recharge of deep aquifers is insignificant. Also in some coastal areas, like in many other countries, salinity intrusion has become a problem because of over-utilization of the sweet water aquifers near the coast.

In 1969, the first sea water desalination plants came into operation on the Red Sea coast. Since then, the desalinated water production capacity has been steadily expanded and amounted to 2.2 x 10^6 m^3/d (0.8 x 10^9 m^3/yr) in 1983 (Khan et al. 1983, cited in Pescod 1984), making Saudi Arabia the world's largest desalinated potable water producer. It now covers about 20% of the Kingdom's water demands. About 50% of the potable water distributed in Riyadh, the capital city, are desalinated sea water produced at Jubail on the Gulf coast and conveyed 460 km inland. This water is blended with groundwater before distribution.

In order to meet the country's increasing water demands for agriculture, landscape irrigation and industrial purposes, use of reclaimed wastewater was started in the early eighties. Although at present it constitutes only just a minor fraction of the overall water production, it is gaining importance. It is now a declared policy of the Kingdom to utilize all available treated municipal wastewater for various purposes, among which agriculture is given top priority (Kalthem and Jamaan 1985). Chpt.8.2 outlines the present and planned wastewater reuse practice in the Kingdom.

8.2 Existing and Planned Wastewater Reuse

- Overview

In 1981/82 the first wastewater reuse pilot projects came into operation near Riyadh, using treated wastewater of the Masani (South Riyadh) wastewater treatment plant. Since then, several other reuse schemes have come into operation and many more are planned. In future, all municipal wastewater is to be utilized, upon suitable treatment to meet the effluent standards.

Table 8.1 shows the country's overall water demands along with the expected production of usable wastewater (Kalthem and Jamaan 1985). According to these figures, while wastewater could satisfy only just a negligible fraction of the Kingdom's water demand some ten years ago, it is estimated to supply about 10% of the agricultural water demand by 1990 and 13% by the year 2000.

Table 8.1 The Country's Water Requirements in the Years 1978, 1990 and 2000

	demand, million m^3/year		
	1978	1990	2000
• Urban water supplies	198	1,028	1,807
• Agriculture	3,171	3,684	5,119
• Others	131	163	315
Total	3,500	4,875	7,241
• Usable, reclaimed wastewater	35	368	674
• Quantity of available wastewater as percentage of the agricultural demand	1.1%	10%	13,1%

Table 8.2 **Present (1985) and Planned Wastewater Reuse**[1]

City and irrigation area	Available or used waste-water flow [m^3/d]	Irrigated area [ha]	Treatment provided	Major crops cultivated	Remarks
A. Existing					
. Riyadh (expanded South Riyadh treatment plant)	200,000 (plant capacity)		Secondary + aerated lagoons + chlorination/Tertiary (incl. filtration + chlorination)		
- Dirab (30 km SW of the city)	~ 57,000 (av.) - 120,000 (max.)	2,000		Wheat, fodder crops (alfalfa, millet, sorghum, barley), vegetables	Complementary irrigation with groundwater
- Dariyah (10 km NW of the city)	~ 53,000 (av.) - 80,000 (max.)	800		Date palms, vegetables, fodder crops, fruit trees	___"___
- Amariyah	~ 80,000	1,200		n.a.	
- Riyadh Refinery	~ 20,000	-		-	used as boiler and cooling water
. Medina (North Medina treatment plant)	120,000 (plant capacity)		Activated sludge + filtration + chlorination		
	~ 23,000 (1984)	400		n.a.	wastewater irrig. was suspended in May 1985 because of (non-cholera) vibrio bacteria found on some vegetable crops; reuse planned to be resumed
B. Planned					
. Riyadh (new treatment plant SE of the city)	200,000 (plant capacity)	n.a.			all effluents planned to be reused if quality standards are met
. Medina	54,000 (expected flow available for irrigation in 1990)				
	141,000 (2000)	3,100 (area req'd. in 2000)			
. Qassim Province[2] (towns of Buraydah, Unaizah, Ar Rass, Bukayriah, Riyad Al Khabra	Expected flow availability: 1990: 59,000 2000: 99,000	820 (area req'd in 2000)	Waste stabilization ponds or extended aeration, mainly		
. Jubail Industrial city (Gulf coast)	115,000 (plant capacity)			municipal (green belt) irrigation	

[1]Sources: Information collected during writer's mission, Pescod (1984), Kalthem and Jamaan (1988), Economic Commission for Western Asia (1985), Schertenleib (1982). Figures given by the various sources are partly contradictory for some of the items.

[2]north-central Saudi Arabia

n.a.: no information available

Table 8.2 provides an overview of the present and planned major wastewater reuse schemes in the Kingdom as per 1985. Given the policy that all municipal wastewater must be reused, many more reuse schemes will be planned and implemented in the near future.

Wastewater is partly collected and disposed of in centralized sewerage systems and partly in septic tanks which are emptied by vacuum tankers. Septage is being disposed of into main sewers or directly into the wastewater treatment plants. In the cities of Riyadh and Medina e.g., whose reuse schemes are described below in more detail, approx. 70% and 50% of the houses, respectively, are sewered, while 30% and 50%, respectively, are serviced by septic tanks.

In the Kingdom, until a few years ago, sewage mainly underwent conventional secondary treatment through trickling filters. The range of processes was later enlarged to include oxidation ditches, extended aeration and activated sludge. In Qassim and Eastern Provinces, waste stabilization ponds were recently put into operation. They reportedly produce effluents containing as little as 200 faecal coliform/100 ml. In future, all plants may be upgraded by sand filtration and disinfection. MAW stipulates very strict effluent standards for wastewater to be reused in agriculture (see also Chpt. 8.3).

Operation and maintenance of sewage treatment plants is in some cases carried out by the local authorities themselves, in other cases these tasks are contracted out to private enterprises.

- Riyadh and Medina Reuse Schemes

In the **Riyadh** reuse schemes at **Dariyah** and **Dirab**, the arable soil is alluvial. In Dariyah, the soil consist of deep, homogeneous, fine sandy loam. In Dirab, the alluvium is composed of alternating coarse and fine textured soil. In both areas, cultivation has been existing prior to the introduction of reclaimed wastewater in the early eighties. Irrigation water was (and partly still is nowadays) extracted from aquifers at various depths. In the Dariyah area, irrigation water for vegetable cultivation is reportedly extracted from a 1000-m deep aquifer. Wastewater is used there to irrigate fodder crops and fruit trees only.

In both irrigation areas, but particularly so in Dirab, irrigation had to be constantly reduced over the past 15 years and prior to the introduction of reclaimed wastewater to as little as 10-15% of the previous rate. Groundwater levels have been receding due to overpumping and long drought periods over the years 1976 to 83. Some of the groundwater exhibits also very high total dissolved solids content (3-6000 mg TDS/l) consisting mainly of calcium and magnesium salts from the limestone aquifers[1]. Reclaimed wastewater has a TDS level of only about 1200 mg/l, and can therefore be blended with high-TDS groundwater. The blended water is suitable for a greater range of crops than the groundwater itself.

At Dariyah, which counts 145 farms, most of the owners are landlords who live in the nearby city. The farming pattern is rather traditional with date palms as the prevailing crop. The area which also serves as a recreation zone, does not lend itself for mechanized cultivation. This is different from the Dirab irrigation area where individual farms are much larger (13 farms of an average of 65 ha each) and operated as production farms. The Dirab command area has been greatly expanded over the past few years. At Amariyah, individual holdings are also rather small (approx. 13 ha).

In Dariyah, mainly basin, furrow and border irrigation is practised. At Dirab, where farming is more mechanized, quite some use is made of sprinkler, spray and drip irrigation methods. Farmers are free to use the method they prefer. At Dirab, also furrow irrigation is used.

Fig. 8.1 is a map of the Riyadh irrigation sites, and Fig. 8.2 is a sectional diagram of Dirab's wastewater conveyance and irrigation scheme.

The secondary treated, chlorinated effluent is pumped from the wastewater treatment plant over 25 km to the escarpment ridge above Wadi Sha'ib Luha, where the irrigation scheme is located. From the look out point near the sewage tank one has an impressive view onto the Dirab irrigation area: the lush green fields surrounded by greyish-brown rock formations, offer a surprising sight (Photo 8.1)! As a contrast, Photo 8.2 shows unreclaimed land in the Wadi Sha'ib Luha at Dirab. Circular plots extending over one to two kilometers in diameter on which wheat or fodder crops are grown, form part of the cultivated area. (Such plots are a common sight in Saudi Arabia: they are set up to accommodate mobile spray irrigators which are supplied with ground or wastewater and are engine-driven at a central pivoting point.) The wastewater flows by gravity from the escarpment ridge to a pressure-reducing station at the bottom of the wadi and is then transported to the individual farms by an underground and piped distribution system. There is a branch-off valve and meter at each farm from where the farmer can supply his irrigation scheme. Fig. 8.3 shows such a plot connection. During the first years of operation, the Municipality did not charge the farmers for the wastewater supplied.

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[1] According to FAO (1985), the growth of crops is, with a few exceptions, severely impaired at TDS levels above 2000 mg/l.

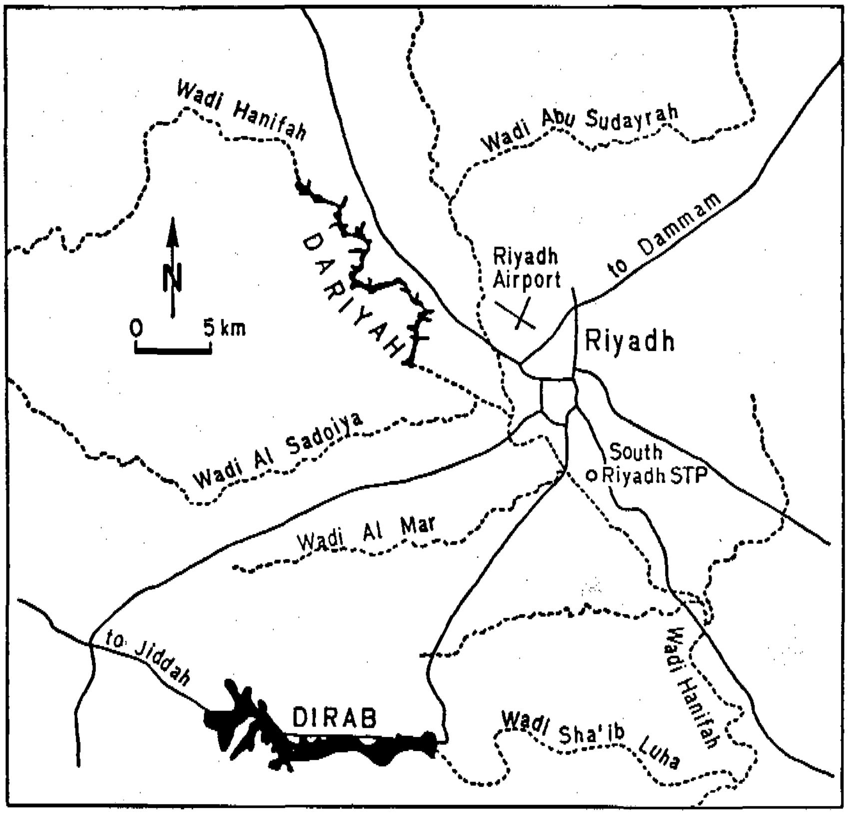

Fig. 8.1 Location of Riyadh's Irrigation Schemes at Dariyah and Dirab

The wastewater distribution scheme is operated and maintained by the MAW. Among other things, the operators also have to check whether the farmers follow the crop restrictions (see Chpt. 8.3). Through their routine work in operating the distribution system, operators are in close contact with the personnel working on the farms.

During a short visit and talk with some workers on a farm in Dirab, the following information was obtained:

> At this one farm, wastewater is used for alfalfa (a fodder crop) production, whereas groundwater, which is extracted from a depth of 500 m is used to irrigate cucumbers and other vegetables. The farm, which covers an area of 200 'Douam' (1 Douam = 0.1 ha) is run by four workers (Yemenis and Egyptians) who operate the farm as 50% share-croppers. (Apparently, quite a few of the agricultural workers are Yemenis). On this heavily mechanized farm, groundwater irrigation is practised by furrows and wastewater irrigation by spray irrigators. Photo 8.3 shows a spray irrigation device at a farm in Dirab.

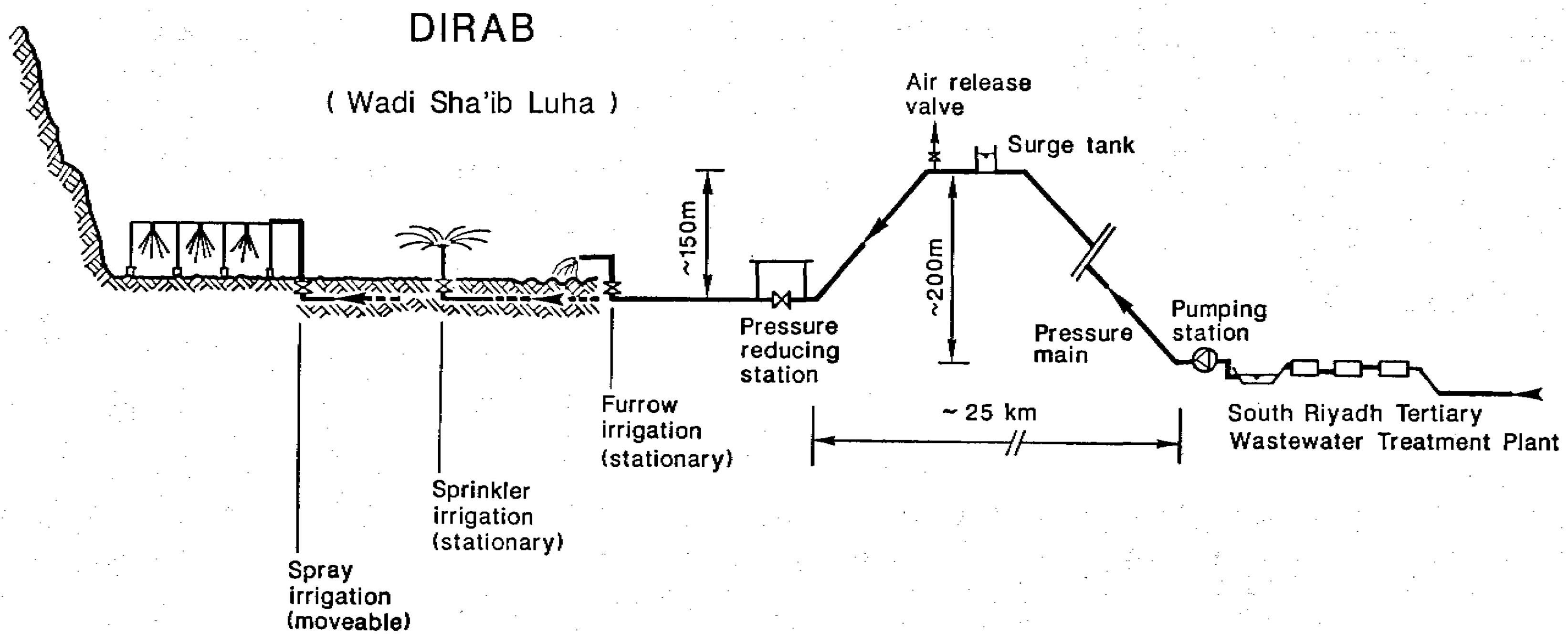

Fig.8.2 Cross Section of Dirab's (Riyadh) Treated Wastewater Conveyance and Irrigation Scheme

[Farmers use four types of irrigation: furrow, sprinkler, spray, or drip (not shown)]

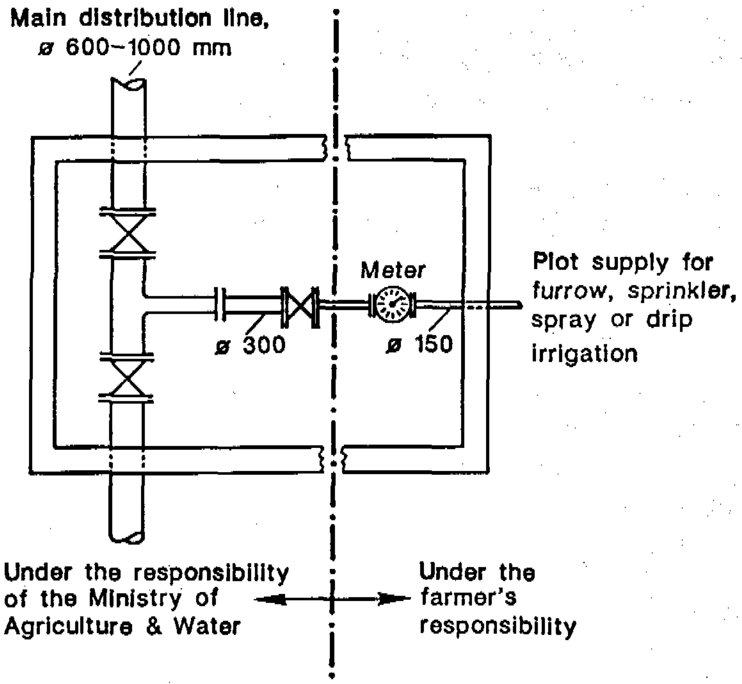

Fig. 8.3 Plot Connection in the Dirab (Riyadh) Wastewater Irrigation Scheme

In Medina, which is one of the holy Muslim cities, irrigation with reclaimed wastewater has been practised for a number of years before it was stopped in May 1985 by request of the Ministry of Health to the Ministry of Municipal and Rural Affairs, i.e. the authority in charge of sewage treatment plants. Farmers were extracting with pumps the secondarily treated, chlorinated effluent from the wadi into which it was discharged from the treatment plant. The farms are located on either side of the wadi, which is impounded further downstream for seasonal storage. The 140 farms with the 214 boreholes tap the groundwater at a depth of 40-60 m. The reclaimed wastewater was apparently favoured as a resource due to its nutrient content and because it needed to be pumped only over a few meters. Moreover, its salinity is lower than in the groundwater. Most farms belong to landowners who employ farm workers to cultivate them.

While visiting one of the farms of 2 ha, the mission team met three workers from Pakistan who live and work on the farm, one of them together with his family. The drinking water is supplied to the farm through roadside reservoirs which are regularly refilled by tanker trucks. The farmhouse is equipped with a pour-flush toilet. Date palms, maize, alfalfa, grapes, citrus fruits, and some vegetables are the crops grown and a few sheep are also kept. Well water is used for irrigation, and dried sewage sludge with a water content of 30-40% is used for soil conditioning and fertilization.

The holy cities of **Mecca** and **Medina** receive millions of Muslim pilgrims during 'hajj', the main month of pilgrimage. Health authorities have a justified fear of epidemic outbreaks as many of the pilgrims are carriers of excreted infections. Authorities therefore take great pains both in disease prevention and curative measures. There is intensive monitoring of water, treated effluents, crops and food. In a large vegetable monitoring campaign undertaken in Medina in 1985, 7 out of 2,200 samples of wastewater-irrigated vegetables were positive for Vibrio bacteria. However, there were no acute cholera cases in town. Farm labourers were also screened but were found not to be carriers. As authorities wanted to exclude any risk of disease transmission through vegetables irrigated with reclaimed wastewater, the practice was banned. The decree was police-enforced and crops were destroyed by burning and herbicides. Now, vegetable cultivation is totally prohibited, though only groundwater is used for irrigation.

In 1985, in Medina, sewage was being treated by secondary treatment (trickling filters) and chlorination. The new plant, which was built since includes activated sludge treatment, filtration and chlorination and has been in operation since 1988. Along with the upgrading of the sewage treatment, the MAW is also preparing a wastewater reuse project. Fig. 8.4 shows the previous and future wastewater irrigation sites of Medina.

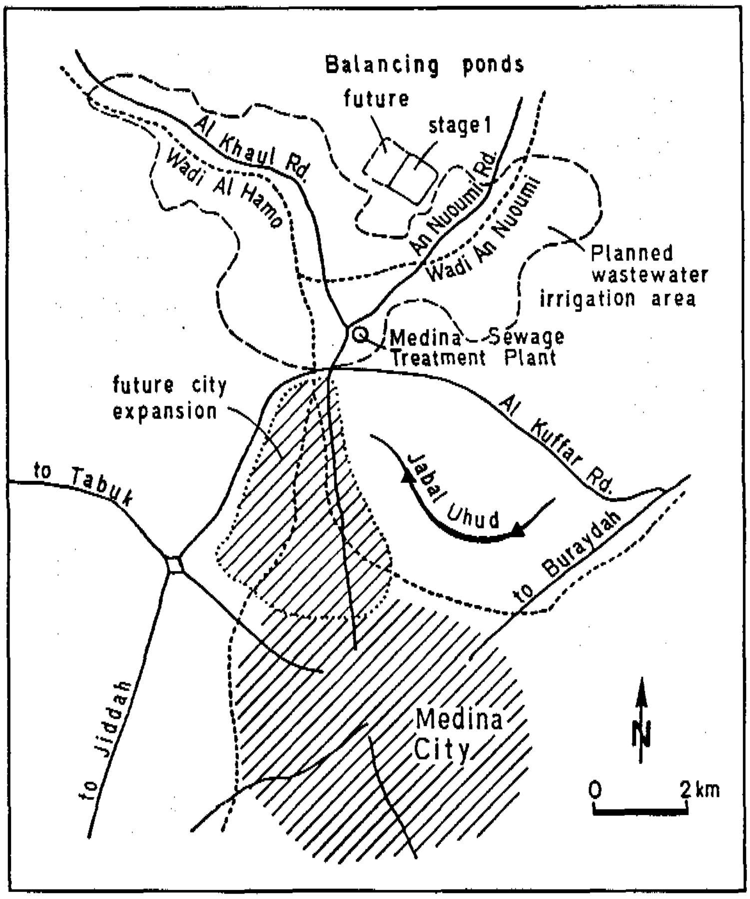

Fig. 8.4 Location of Medina's Wastewater Irrigation Scheme

8.3 Institutional and Regulatory Framework

- Regulations

Overall, wastewater management in Saudi Arabia is guided by the following basic policy and regulation:

- All treated municipal wastewater and sewage treatment plant sludge must be utilized. Agricultural use is given highest priority.
- Wastewater may not be discharged into the sea or any surface water body or course, except upon special permission to be granted by the Ministry of Agriculture and Water.

"National Wastewater Regulations" were drafted in 1984. They were reviewed in 1986-87 and come into force upon acceptance by the Council of Ministers and the issuance of a royal decree.

Wastewater intended for reuse in agriculture must receive secondary or tertiary treatment depending on the planned reuse practice. Effluents of secondary treatment plants must meet the following quality standards:

• FC, geom. mean over one month[1]:	≤ 100/100 ml
• TC[1]:	
- geom. mean over one week	≤ 23/100 ml
- in any two consecutive samples	≤ 240/100 ml
• BOD_5, one month average	≤ 20 mg/l
• Suspended solids, one month average	≤ 20 mg/l

Tertiary treated wastewater must not exceed the maximum concentrations listed below:

• Faecal coliform (FC) geom. mean over one month	≤ 50/100 ml
• Total coliform (TC):	
- geom. mean over one week	≤ 2.2/100 ml
- in any sample	≤ 23/100 ml
• BOD_5, one month average	≤ 10 mg/l
• Suspended solids, one month average	≤ 10 mg/l
• Nitrate (NO_3) as N	≤ 10 mg/l

[1] Usually, faecal coliform concentrations in excreta or wastewater are lower than total coliform levels. Effluent standards should therefore reflect this phenomenon.

These effluent quality standards are very strict, both with respect to the physico-chemical as well as to the bacteriological parameters. To achieve such an effluent quality, tertiary treatment including sand filtration, denitrification and chlorination is normally required. Also, STPs must be well designed, operated and maintained if the required effluent quality is to be continuously attained. The authors are of the opinion that the standards are overly strict, particularly as they stipulate high degrees of treatment both to prevent receiving water pollution (BOD:SS:NO_3-N = 10:10:10 mg/l) and to reduce disease transmission risks (FC $\leq$ 2.2/100 ml). The regulations tend to impede the reuse of treated wastewater, as effluent standards may not always be met which in turn may lead health authorities to deny permission for reuse. Reuse of **all** wastewater, however, has been stipulated as one of the objectives of the Kingdom's water resources policy.

Possibly, all sewage treatment plants in the country will be upgraded gradually to include tertiary treatment, i.e. sand filtration and chlorination. The MAW stipulates that effluents earmarked for reuse shall comply with the above quality standards.

Table 8.3 shows the use and disposal categories as specified by the Draft Regulations along with the restrictions governing the various categories.

The draft of the **National Wastewater Regulations** stipulates that a technical committee which comprises deputy ministers of the Ministries of Agriculture and Water, Health, Industries, and Municipal & Road Affairs shall review the regulations biannually. The committee shall be chaired by the deputy minister of MAW.

• Institutions

The major authorities involved in wastewater management and use are:

- The Ministry of Agriculture and Water (MAW)
- the Ministry of Municipal and Rural Affairs (MOMRA), and
- the Ministry of Health (MOH).
- the Water and Sewerage Authorities (WASAs)
- the Meteorology and Environmental Protection Administration (MEPA) (Ministry of Defense)

The **Ministry of Municipal and Rural Affairs** and the respective municipal **Water and Sewage Authorities** are the agencies responsible for wastewater collection and treatment. The Ministry operates its own water and sew- age quality laboratory, both for chemical and bacteriological (coliform) analyses. Some sewage treatment plants are also equipped for

Table 8.3 **Draft Regulations for Wastewater Reuse in Saudi Arabia**

Reuse category	Permitted crops or activity	Effluent standards and other regulations
1- "Restricted" use	. Legumes, forage, field crops or vegetables that are mechanically processed; pastures;	. FC ≤ 100/100 ml, TC ≤ 23/100 ml on average (secondary treatment including chlorination) . Cultivation of raw-eaten vegetables prohibited . Pastures not to be grazed for 24 h after irrigation
	. landscape irrigation	. Control of public access to sprayed areas
2- "Unrestricted" irrigation		. FC ≤ 50/100 ml, TC ≤ 2.2/100 ml on average ("tertiary treatment")
	. Raw-eaten crops and fish	. Additional treatment by using a suitable selection of the following processes: sand filtration, disinfection, carbon adsorption, phosphorus removal
3- Recreational use	. Recreational areas with only occasional human contact (e.g. green belts along streets and highways)	. TC ≤ 23/100 ml on average; ≤ 240/100 ml on two consec. days (secondary treatment + filtration + disinfection)
	. Recreational areas with unrestricted public accress (e.g. public parks, schoolyards, recreational lakes and ponds)	. TC ≤ 2.2/100 ml on average; ≤ 23/100 ml in any sample (secondary treatment + add'l oxidation + coagulation + filtration + disinfection)
4- Stock watering		. ——— " ———
5- Afforestation	. "Productive" or "unproductive" forestry	. Secondary treatment (including chlorination) . Irrigation sites at ≥ 25 km outside the city limits
8- Open land disposal	. Disposal on land, into water courses or wadis with potential groundwater recharge	. Effluent specification ambiguous; (probably FC ≤ 200/100 ml or possibly stricter)
7- Direct injection	. Groundwater recharge directly into aquifer	. Upon issuing of written permit by Min. of Agriculture and Water which will specify the effluent quality required

chemical and coliform analysis. The **reuse** of wastewater is under the authority of the **Ministry of Agriculture and Water.** Under the auspices of this Ministry, reclaimed wastewater distribution schemes are being planned and implemented. Its task is also to control the reuse practices and to enforce restrictions where such are required. MAW appears to be the leading agency as regards wastewater reuse and probably played an important role in promulgating the wastewater regulations, particularly the strict effluent quality standards. Matters related to public health, such as the microbiological monitoring of effluents and effluent-irrigated crops, as well as the screening of agricultural workers are under the jurisdiction of the **Ministry of Health.** This Ministry operates a large central laboratory in Riyadh which is well equipped and staffed to do microbiological analyses for both clinical and ecological purposes (parasites and bacteria). The Ministry or its subsidiary provincial health departments monitor sewage treatment plant effluents, particularly and most frequently in pilgrim areas (Mecca and Medina) and over pilgrimage periods. Health authorities undertake every possible effort to avoid communicable disease (e.g. cholera) outbreaks during the months when millions of pilgrims concentrate in the holy cities. MoIt as well as MOMRA carry out regular and comprehensive screenings of foreign workers, especially of food handlers and persons working in food establishments. Medina, as one of the holy pilgrimage cities, counts 22 health centres specialized in diarrheal diseases, as well as 5 hospitals. MEPA's prime responsibility is the control of environmental pollution.

8.4 Health and Epidemiological Aspects

In this section, discussion will not be limited to water and excreta-related infections but these will be discussed in the wider context of the most important causes of morbidity and mortality in the country. This will allow the reader to assess the importance of the water and excreta-related infections that might be associated with the waste reuse practice in comparison with the predominant diseases in the area. The reader is also referred to section 1.2, where the health risks associated with wastewater use have been summarised, and to section 1.4, where the difficulties involved in evaluating the health effects of a specific reuse practice have been outlined. The data available do not allow an accurate assessment of the health risks to be made, so the following sections contain epidemiological judgements which should be considered as "informed speculation" rather than strict scientific analysis.

- Important Components of the Endemic Disease Situation

Saudi Arabia is different from many of the countries visited in three major aspects. Firstly, the development of the country has been extremely rapid over the last 10 years (due to oil revenue) and some of the new income has been used to raise health standards, without taxation of the people. Secondly, there is a large immigrant or expatriate working population in the country. Among them are carriers of excreta-related infections, so that imported diseases are a major concern in wastewater reuse. Thirdly, every year for more than one month, the population is swollen by an influx of pilgrims going to Mecca and Medina for the Haj festival. This both diverts resources and services to the area and increases the rate of imported disease and the likelihood of epidemics. These three factors appear to influence the provision and distribution of health services as well as the regulations regarding the reuse of treated wastewater.

Table 8.4 Incidence of Principal Notifiable Diseases In Saudi Arabia in 1983 and 1987

Disease	Incidence rate per 100,000 persons 1983	1987
Amoebic dysentery	432.0	155.7
Bilharzia	187.0[1]	93.0
Hepatitis (all types)	55.3	64.5
Typhoid and paratyphoid	4.7	8.5
Malaria	517.0	188.0
Tuberculosis	79.0	34.0
Pertussis	12.5	n.a.
Diphteria	1.3[2]	0.2
Polio	1.9[2]	0.04
Measles	464.0	n.a.
Mumps	284.0	n.n.
Chicken pox	240.0	n.a.
Influenza	532.0	n.a.
Venereal disease	44.1	18.5

1. 1984
2. 1981
n.a. not available

In the initial stages of development, health systems concentrated on curative services from central facilities, and now an increasing emphasis is also placed on preventive services, delivered through a primary health care system. 75% of the kingdom is now covered by PHC centres. The incidence of the most frequently reported notifiable diseases can be seen in Table 8.4. Infectious diseases of childhood, respiratory disease and malaria all figure prominently. In addition, diarrhoeal disease, malnutrition, road accidents, cardio-vascular disease, intestinal parasites, schistosomiasis, venereal disease and metabolic disease are also considered important causes of morbidity and mortality (taken from a country review on evaluation of strategies for HFA/2000). A programme is now in existence to try to improve both the quality and use of surveillance data on 35 communicable diseases.

A variety of health programmes have been used for further a reduction in communicable disease. Vaccination programmes have succeeded in almost eradicating polio and tetanus; control programmmes are concerned with specific diseases, e.g. schistosomiasis; improvement in supplies of clear water and provision of sewerage system have reduced the number of cholera outbreaks and brought about a decline in some other water and sanitation related infections in the Saudi community. Specific surveillance and treatment of food handlers occurs, and a certificate of good health is required every 6 months. For example, since 1980, tests for tuberculosis have been included. It is intended to extend this programme to all foreigners.

The change in the number of reported cases of "amoebic dysentery" (Table 5) is an example of an infection having been reduced over the last decade, possibly as a result of improvements in environmental sanitation. However, the number of reported cases of typhoid fever have not reduced and in the case of infectious hepatitis the numbers have increased (Table 8.5). It is thought that the latter is not transmitted in water since drinking water supplies are well controlled but it may due to food hygiene or personal hygiene, and be spread by person to person contact.

Surveillance is most active in the summer season (June to October) before the Haj festival, when many foreigners visit the country. Surveillance is particularly strong for diarrhoeal disease, and every case is screened for cholerae, to try and detect any case early.

- Potential Impact of the Existing Practice

Although there is a national policy to reuse all wastewater, at present relatively little is being used, since the quality requirements before reuse can occur are very strict (see section 8.3). Also, at present the irrigation of raw-eaten vegetables is prohibited.

The use of effluent from Riyadh STP in Dirab and Dariyah to irrigate wheat, fodder crops, date palms and fruit trees is unlikely to involve any health risk. The use of crop restrictions following secondary treatment, lagooning or filtration plus chlorination (high chlorine dose) means there is very little chance of any consumers or agricultural workers becoming infected. The coliform levels are typically very low when the effluent has been chlorinated. A high level of safety is achieved by using this combination of health protection measures, i.e. tertiary wastewater treatment and crop restrictions.

Table 8.5 **Change in Reported Cases of Diseases Related to Water and Sanitation in Saudi Arabia from 1975 to 1983**

	Typhoid and paratyphoid	Infectious hepatitis	Amoebic dysentery
1975	535	3.383	165,371
1976	373	2,291	152,550
1977	193	2,172	171,319
1978	174	2,521	105,602
1979	474	3,062	82,979
1980	446	3,448	77,138
1981	490	4,015	65,251
1982	284	4,412	52,453
1983	452	5,317	41,489
1984	538	6,215	32,016
incidence rate per 100,000 in 1984	5.4	62.4	321.4

In Medina, the treatment plant could not perform to the standard required to produce an effluent that was safe for use in irrigating vegetables that would be eaten raw. The reduction in bacterial pathogens achieved was probably not sufficient, so that there was a risk to consumers of such vegetable crops. This was eliminated when the growing of vegetables with this effluent was stopped.

- Implications for the Control of the Health Risks

The authorities have understandably adopted a very cautious approach to wastewater use, mainly because of the fear of spreading imported disease via this route. Here, it is not the "endemic" disease level that is of most concern, but the possibility of "epidemic" disease from this route. The existence of the very large expatriate population, of whom many are coming from areas where intestinal infections are endemic, has a large influence on the policy for wastewater reuse permitting, as does the influx of pilgrims each year. However, there is a danger that the adoption of both advanced wastewater treatment and crop restrictions may prevent the use of a much needed resource, that of wastewater for use in agriculture.

A balance needs to be found between wastewater treatment efficiency and cost, appropriate microbiological quality standards and the need to reuse the water.

The efficiency of a domestic wastewater treatment plant in pathogen removal is the main criteria needed to judge if the effluent will not cause health risks if used in irrigation. The main indicators of this efficiency are faecal coliform levels and nematode egg levels. The upgrading of existing treatment plants to improve pathogen removal is useful, but the improvement of other parameters, e.g. BOD removal, is not normally necessary when effluent will be used in irrigation. Where crop restrictions are in operation, it is not necessary to upgrade all existing STPs in Saudi Arabia beyond current levels, to safeguard health. The further upgrading of STPs to produce higher quality effluents would, however, allow some relaxation of crop restrictions in future.

The cost of upgrading treatment plants to achieve the standards for wastewater quality for reuse (section 8.3) is high and financial constraints may prevent this occurring. A revised strategy for wastewater reuse may be necessary of this cannot occur.

8.5 Religious and Cultural Aspects[1]

In Islamic religion, cleanliness plays a primordial role. Muslihms have to ritually wash themselves with pure water before their five daily prayers. Islamic rules require that water used for ablution must be colourless, visually acceptable, odourless, and palatable.

Verdict (fatwah) no. 64, dated 25-10-1398 Hijra (1978) which was enacted by religious leaders[2] in the Kingdom of Saudi Arabia, regulates and gives guidance regarding the use of wastewater for ablution and drinking. It reads as follows:

> "Treated wastewater may be used for ablution and drinking after making sure that it does not harm its user. According to the Fatwah of Religious Scholars in the Kingdom, impure water can be purified in many ways, the best of which are the modern technical methods. After complete purification, such water becomes tasteless, colourless and odourless, and may therefore be used for washing, bathing, removal of impurities, and for drinking purposes if no health hazards are resulting thereof. **However**[3], the religious Scholars think it is better not to use such water for drinking to safeguard health and to avoid harm."

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1 after Farooq and Ansari (1983), and Mullick (1988)
2 The Organization of the Eminent Scholars of Saudi Arabia
3 put in bold by the authors of this report.

It might be inferred from this verdict, that Islamic laws do permit the use of wastewater in agriculture provided it is adequately treated and the necessary precautions are taken to avoid the transmission of diseases. According to the verdict, wastewater may be reused, at least theoretically, even for drinking, if it is treated to an extent that it meets the above-cited criteria. However, it appeares that the Scholars themselves may have been in doubt whether such a practice would be acceptable from a cultural and aesthetical viewpoint.

8.6 References

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A - WASTEWATER USE IN AGRICULTURE

Ac - SUMMARY and DISCUSSION

Ac SUMMARY AND DISCUSSION

In order to summarize and discuss the reports on the agricultural use of wastewater in Mexico, Chile, India, Peru, Argentina, Tunisia and Saudi Arabia, the information herewith provided is viewed from the following angles:

- The rationale for reusing wastewater
- The regulations and their enforcement
- The institutions and farmers, and
- The health impact and protection measures.

Rationale for Reusing Wastewater

Only a few decades ago, the raw or mechanically treated wastewater of many European cities was disposed of on nearby agricultural land. The rationale for this practice was mainly based on the fact that it presented then the most appropriate and cheapest method of wastewater treatment and disposal. In most of these countries, the climate is temperate and rainfall sufficient to enable agricultural production. Wastewater use in agriculture was therefore not associated with climatic conditions, i.e. wastewater did not have to replace or complement scarce water resources.

However, **in the countries** described in Chpts 2-8, the **use of wastewater** is very **closely linked with climatic conditions:** the climate is either **arid** or **semi-arid**, i.e. evaporation is greater than rainfall all year round or during part of the year. Rain-fed, direct cultivation is impossible under these climates, except during the rainy season.

The countries covered by our mission receive the following mean annual rainfall:

- Mexico (Mezq. Valley): 490 mm
- Chile (Santiago) : 340 mm
- India (New Delhi) : 670 mm
- Peru (coast) : 0...15 mm
- Argentina (Mendoza) : 200-350 mm
- Tunisia (Tunis) : 400 mm
- Saudi Arabia (Riyadh): 150 mm

Agricultural production is largely dependent on artificial irrigation. Thus, wastewater, both treated or untreated, constitutes a very precious water resource. Its use enables cultivation of the land which would otherwise not be possible due to a lack of freshwater sources, or excessive groundwater salinity. High **groundwater salinity** is found in coastal areas where aquifers have been overpumped and sea water is permeating into the aquifer (Tunisia, e.g.).

Urban **consumer demand for vegetables** and **staple food** crops is another important rationale for the use of wastewater on agricultural land located adjacent to large cities, particularly so in e.g. **Lima** (Peru), **Santiago** (Chile), **Mexico**, and **India**. Vegetable crops, in particular, often yield high prices and, moreover, allow for a regular cash income. Cereal crops, however, tend to yield lower prices and provide less regular cash income as they are harvested only once or twice a year. In **Tunisia**, much of the treated wastewater is used to irrigate **citrus fruit trees**. Citrus fruits are mainly exported. Wastewater reuse therefore helps to yield foreign exchange. In **Saudi Arabia**, most fodder crops and wheat which is an export product, are grown on wastewater-irrigated land. To conclude it can be said that farmers tend to select the crops to be cultivated with wastewater in this order of priority: (1) vegetables and fruit trees, (2) cereal and fodder crops, and (3), any other staple food which might be in high demand. This order is determined by the sales prices farmers tend to achieve.

Regulations and Their Enforcement

The regulations adopted in the various countries include either **wastewater quality standards** or **crop restrictions** or a combination of both. Table Ac.1 below provides an overview of the current (1985) regulations governing wastewater reuse in Mexico, Chile, India, Peru, Tunisia, and Saudi Arabia. In Argentina, no reuse regulations reportedly existed at the time of the team's visit in 1985. Information is also provided about adherence to or enforcement of the regulations. It is based on the writers' own observations during their field visits and information received through communication with officials, farmers and farm workers.

Table Ac.1 shows that both wastewater quality standards and crop restrictions vary rather widely. While unrestricted wastewater irrigation, i.e. irrigation of any crop including raw-eaten vegetables, is prohibited in Peru and Tunisia even if the wastewater is adequately treated, it is allowed in Mexico, Chile, and Saudi Arabia if the required wastewater quality is or would be reached. Saudi Arabia is the only of the illustrated countries where attempts are made to treat the wastewater to the stipulated quality standards.

It appears that the existing regulations were developed exclusively with the consumers' health risks in mind. The risks to which farm workers are exposed were probably not considered. Theoretically, this is of no serious consequence where regulations require all reused wastewaters to contain

Table Ac.1 Wastewater Reuse Regulations and Their Enforcement

Country	Regulations: Microbiol. wastewater quality standards	Regulations: Crop restrictions	Enforcement
MEXICO	≤1000 TC/100 ml for raw-eaten crops	• Set by the Irrigation Districts • in I.D. 03: prohibiton to cultivate lettuce, cabbage, carrots , and spinach, e.g.; fresh water to be used for these crops	• Restrictions appear to be well enforced in e.g.I.D. 03
CHILE	≤ 1000 FC/100 ml for unrestricted irrigation	• Metrop. Health Service prohibits cultivation of e.g. lettuce, chicory, radish and carrot as the wastewater is untreated	• Limited enforcement and adherence
INDIA	——	• Prohibition to irrigate vegetables eaten uncooked	• Limited enforcement and adherence
PERU	• ≤ 1000 TC/100 ml in "natural irrigation water"	• Prohibition to irrigate with raw or treated wastewater crops growing close to the ground or root crops eaten uncooked	• Enforcement variably strict; depends on availability of freshwater for vegetable irrigation and on the strictness of local administration
ARGENTINA	No regulations	No regulations	
TUNISIA	• Absence of *Vibrio cholerae and Salmonella* • ≤ 1 nematode egg/l for restricted irrigation • All wastewater used for irrigation must be adequately treated	• The use of even treated wastewater to irrigate raw-eaten vegetables, is prohibited	• Adherence, particularly by fruit tree farmers, must comply with strict trade hygiene laws • Irrigation authority may cut off supply if regulations are not adhered to
SAUDI ARABIA	Proposed regulations: • Unrestricted irrigation (= irrigation of raw-eaten crops): ≤ 50 FC/100 ml • Restricted irrigation (= irrigation of vegetables eaten cooked; forage; crops to be processed) ≤ 100 FC/100 ml		• Regulations well-enforced

less than 1000 faecal coliforms per 100 ml or have at least been partially treated to the extent that the reused wastewater is free from helminth eggs (see also Chpt. 1.3). In practice, however, the workers' risk of becoming infected can often not be avoided since the wastewater is not treated at all or the stipulated wastewater quality is either not attainable or not enforced.

Figures Ac.1a + 1b illustrate the health protection scenarios in the various countries. Fig. Ac.1a is based on **current regulations** whereas Fig. Ac.1b is based on the **actual practice.** The following can be observed and concluded:

(a) Most countries regulate wastewater reuse by restricting the crops which may be irrigated[1] (Fig. Ac.1a). This is understandable and sensible since most of them are economically unable to treat large wastewater flows to the bacteriological wastewater quality standard stipulated in their reuse regulations.

(b) In a number of countries or areas, the stipulated crop restrictions are either not enforced or not followed, or they are not enforceable due to specific local circumstances. Therefore, wastewater reuse in Chile[2] (Santiago), India and in some localities of Peru (e.g. in North Lima) is practised essentially without any health protection measures (Fig. Ac.1b).

(c) **Mexico** (crop restriction) has adopted a strategy which protects the consumer but may not be sufficiently protective for the agricultural worker because the wastewater is used untreated.

(d) **Mendoza, Argentina,** (partial treatment) has chosen a practice which provides limited protection to the farmworker but none to the consumers. **Tunisia** (partial treatment + crop restriction) is following a concept which is close to the optimum, i.e. providing both farmers' and consumers' protection. However, farmers' protection might be limited since the secondary wastewater treatment is not geared to achieve high removal of pathogenic bacteria.

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[1] The crop restrictions for wastewater reuse in the outskirts of the City of Santiago, Chile, are not national regulations but have been set by the Santiago Metropolitan Health Service.

[2] In Santiago, a project is being planned whereby a fraction of the city's sewage shall be collected by a large interceptor sewer and be subjected to tertiary treatment.1

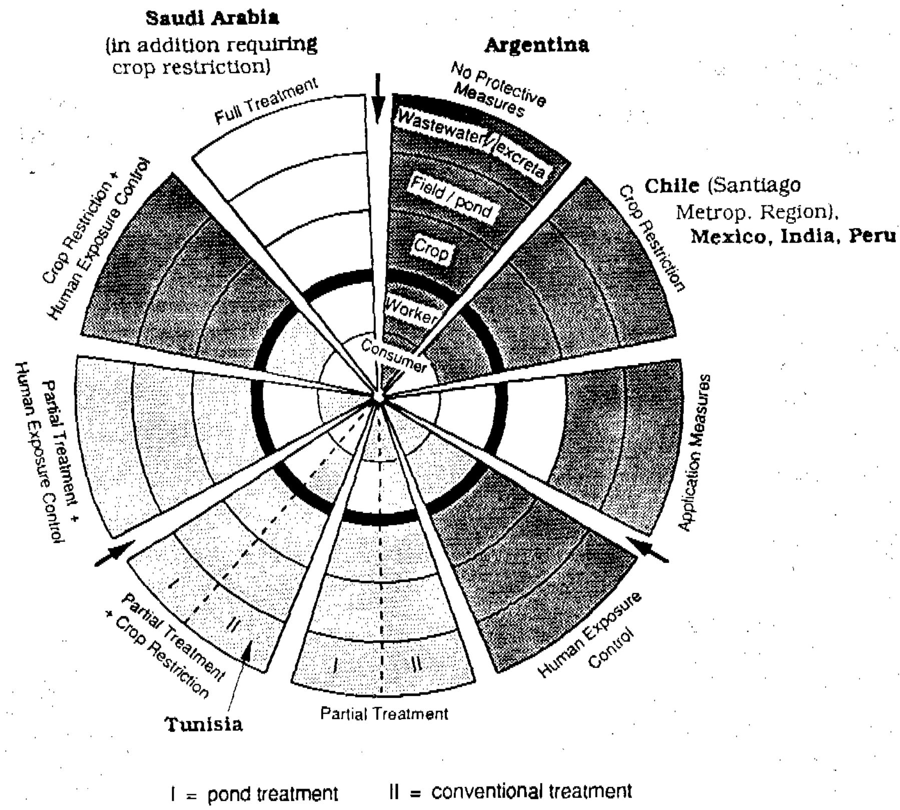

Fig. Ac.1a Health Protection Strategies in Selected Countries as per **Current Regulations**

(see Fig. 1.3 for complete legend)

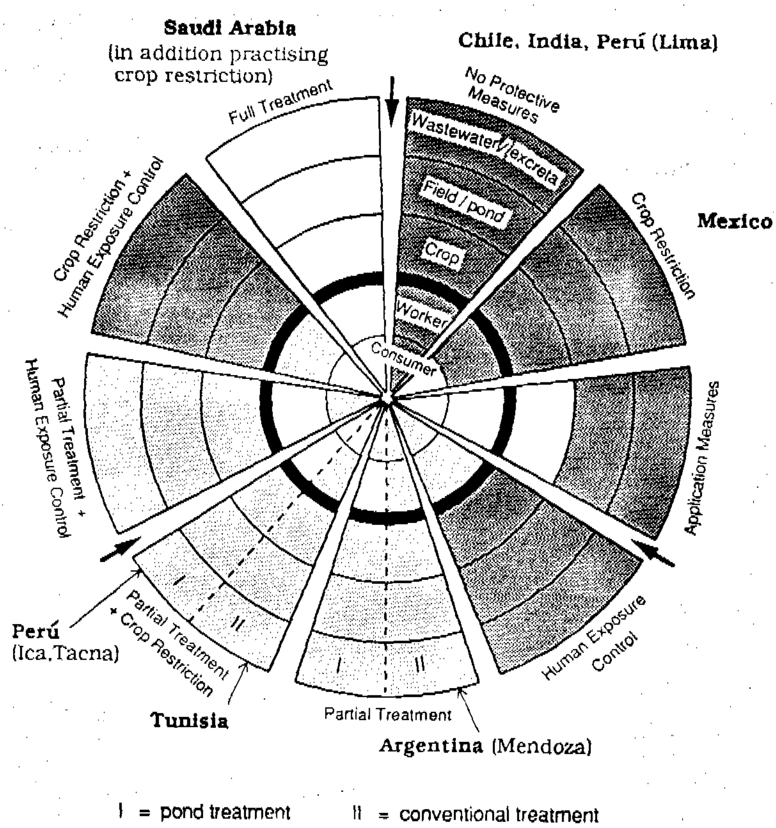

Fig. Ac. 1b Health Protection Strategies in Selected Countries as per **Actual Practice** of Enforcement and Observance

(see Fig. 1.3 for complete legend)

(e) **Saudi Arabia** (full treatment + crop restriction) has chosen an approach of double safety. It is based mainly on a judgement of the potential transmission risks through pilgrims and foreign workers. While the desire to essentially achieve a zero-risk reuse practice is understandable, this same zero-risk strategy impedes the further implementation of wastewater reuse schemes, although the national water resources policy demands that all wastewater be reused. The health protection strategy adopted by Saudi Arabia cannot serve as a model for other countries.

Enforcement is variably strict. Even within one country it might vary from one area or province to another. The team are under the impression that enforceability of and/or adherence to the regulations depended on the following **factors:**

a - Availability/unavailability of freshwater sources in the particular area to enable the cultivation of raw-eaten vegetables (if demand for these exists).

b - The legal and organisational form of wastewater distribution and the manner in which the rights of wastewater use are allocated to the farmers.

c - The market demand for a particular crop, which the farmers then go on cultivating, and the political and economic role played by the farmers and/or their organisations.

d - The capacity and willingness of the responsible authorities to monitor the actual practice and to enforce the regulations.

(a) **Availability of freshwater sources:** Where raw-eaten vegetables are in high demand and yield market prices which are substantially higher than those of other crops, the farmers are very interested in cultivating vegetables. Where wastewater of adequate quality is not available, farmers will probably adhere to the regulations which will be rather easily enforced by the authorities only if freshwater (groundwater or river run-off) is available at a reasonable price to irrigate the vegetables. If freshwater is not available or too expensive in comparison with wastewater, farmers might use inadequately treated wastewater for the cultivation of vegetables, and enforcement by the authorities might be difficult or even impossible. An example of this state of affairs was observed in Ica, Peru. There, groundwater is available to cultivate vegetables, and crop restrictions for wastewater irrigation are thereby effectively controlled. In Lima (San Martin de Porras, e.g.), however, vegetable irrigation with untreated wastewater is tolerated. There, no groundwater is available to irrigate crops.

(b) **Legal and organisational form of wastewater allocation:** A main distinction is whether wastewater is discharged into river courses from where it is extracted by the farmers further down stream, or whether (treated) wastewater is directly distributed to the farmers. The first case leads to **"indirect" reuse** and is difficult to control by the authorities as the water rights relate to the use of river water which, depending on river runoff, leads to a variable dilution of the wastewater discharged into it. Water rights for river water extraction tend to be issued on a permanent or semi-permanent basis and might be issued for a particular plot of land. In case of **direct distribution** of wastewater, authorities have the possibility of denying the renewal of reuse permits or of denying the allocation of the treated wastewater. Examples of water riths issued for indirect reuse are found in Peru and Chile. Direct distribution of wastewater with allocation closely dependent on observance of crop restrictions by the farmers exist e.g. in Mexico and Tunisia.

(c) **Market demands and farmers' role:** Where there is great demand for crops which yield high income, farmers tend to and in fact use also wastewater of inadequate quality if adequately treated wastewater or freshwater is not available. Even where there exist strict enforcement of crop restrictions, farmers might use the wastewater clandestinely. Farmers or farm owners, particularly if they own large properties, often have considerable economic and political power and/or might form influential associations (e.g. the "Juntas de Vigilancia" and "Asociaciones de Canalistas" in Chile). Under such circumstances, and where irrigation water rights for the extraction of wastewater-laden river water are issued on a permanent or semi-permanent basis, enforcement of crop restrictions by the authorities appears to be difficult. Therefore, the treatment of wastewater to an adequate quality might be the only practicable measure to reach increased health protection.

(d) **Authorities:** In order to achieve effective enforcement, the authorities require adequate manpower, both in terms of quantity and quality. The necessary legislative backup and a suitable socio-political framework are other important prerequisites for the government authorities to exert control over an appropriate wastewater use and adherence to the regulations. This will, in most cases, lead to a curtailment of the farmer's or land owner's freedom of enterprise. According to the team, the lack of effective enforcement is due to one or a combination of the above factors.

Institutions and Farmers

In every country, responsibilities in the wastewater reuse sector are spread among **several authorities.** These reponsibilities are subdividied into the following main tasks or activities in this field:

- the planning and implementation of the irrigation infrastructure;
- wastewater collection and treatment;
- operation, maintenance and administration of wastewater distribution;
- the setting, control and enforcement of regulations.

In most countries visited, notably in Mexico, Peru, Tunisia, and Saudi Arabia, **central government** authorities play an important role in the overall management of the wastewater reuse practice. At the same time, **local**, i.e. provincial or district authorities or authorities subsidiary to the central government branches, play the executing role on behalf of the competent authority, as e.g. in Mexico and Tunisia.

Table Ac.2 below lists for each country the main authorities dealing with wastewater reuse, along with their major tasks in this field. The table reveals that the planning, implementation and operation of wastewater or water distribution works for irrigation usually fall under the authority of either the **Ministry of Agriculture** or **Public Works**,or equivalents thereof. In several countries, subsidiaries of these authorities on provincial, district or area level, are resposible for these tasks (e.g. the Irrigation Districts in Mexico or the Valley Development Authorities, "Offices pour la Mise en Valeur", in Tunisia). Usually the administering of the irrigation water (including wastewater) allocation, the monitoring and the enforcement of crop restrictions also form part of these agencies' responsibilities. Vested with a number of important tasks and rights, these technical ministries play the leading role in determining and developing wastewater reuse strategies. Sometimes, they set up the regulations regarding the hygienic aspects of wastewater reuse, although this would certainly fall under the jurisdiction of the health authorities, i.e. the Ministry of (Public) Health. While the stand of the Ministries of Health regarding control and enforcement of health protection measures is relatively strong and effectual in certain countries, it appears to be weak in others.

We found that in a number of countries, the farmers who irrigate with wastewater, or both with freshwater and wastewater, have organized themselves "around the irrigation canal". While **farmers' associations** or **cooperatives** in Peru mainly administer the wastewater distribution among the farmers, **canal associations** among farm owners, as exist e.g. in Chile and Argentina, appear to be vested with considerable power. Farmers' associations in the Province of Mendoza, Argentina, are responsible by law for the distribution of the irrigation water to their members. The right to use the water is issued by the "Departamento General de Irrigación". Usually, farmers' and canal associations also cater for the maintenance and repair of the secondary and tertiary irrigation canals. Farmers in e.g.

Table Ac.2 **Authorities and Their Main Tasks in Wastewater Reuse**

Country	Authority	Main tasks; observations
MEXICO	• Min.of Agriculture & Water Resources (SARH) and its subsidiary "Irrigation Districts"	- Implementation and operation of irrigation works; administering wastewater allocations to farmers; - control and enforcement of crop restrictions; - R + D in wastewater management for reuse
	• Min. of Urban Development. & Ecology (SEDUE)	- Strategies and planning of urban water supply and wastewater collection and treatment works
	• Federal District Authority (DDF)	- Wastewater collection and treatment within the Federal District; management of wastewater reuse for greenbelt irrigation
	• Ministry of Health	- Basic rules for crop restrictions
CHILE	• Min. of Public Works	- Planning and implementation of irrigation works - allocation of irrigation water rights
	• Min. of Health	- Approval, monitoring and control of reuse from a hygiene point of view
INDIA	• State Water Corporation ("Jal Nigam")	- Planning and construction of sewage irrigation works
	• Municipal governments	- Operation and maintenance; administering wastewater allocations
	• State Pollution Control Boards	- Setting of wastewater quality standards
PERU	• National Water Supply & Sewage Authority (SENAPA) and its subsidiary administrations for Lima and 9 provinces	- Wastewater collection, treatment and allocation for reuse
	• Min. of Agriculture or its subsidiary offices*	- Monitoring and control of natural water resources and their allocation for irrigation; e.g. large proportions of the flow in rivers, might consist of wastewater
	• Ministry of Health or its subsidiary branches*	- Monitoring, control and enforcement of reuse regulations (crop restrictions)
	* issue wastewater use permits to farmers	
ARGENTINA (Prov. of Mendoza)	• Department of Irrigation	- Planning and implementation of irrigation infrastructure works; issuing water rights to farmer (canal) associations
	• Department of Public Works	- Wastewater collection and treatment
	• Department of Environmental Sanitation	- Monitoring and control of public health aspects
	• Farmer associations	- Distribution of allocated water to members
TUNISIA	• Min. of Agriculture and its subsidiary agricultural development authorities (e.g. "Office pour la Mise en Valeur de la Vallée Medjerda")	- Planning, implementation and operation of irrigation works - Administering wastewater allocation - Monitoring and enforcing of crop restrictions
	• National Sanitation Authority ("ONAS")	- Sewage collection and treatment
	• Min. of Public Health	- Monitoring and control of the hygienic aspects of wastewater reuse; - Formulation of reuse regulations
SAUDI ARABIA	• Min. of Agriculture and Water	- Planning, implementation and operation of irrigation works - Formulation of wastewater quality standards and rules for crop restrictions - Monitoring and enforcement of crop restrictions
	• Min. of Health	- Monitoring of the hygienic quality of the wastewaters used and of the crops

Mexico, India and Tunisia, are apparently not grouped as associations to deal with the irrigation authorities. They regulate individually the users' permission and irrigation water quotas with the corresponding agency.

Health Impact and Health Protection Measures

Table Ac.3 summarizes the observed and reported health situation in the various countries as it relates to the current reuse practice.

It can be inferred that theoretical or **potential health risks** do exist in a number of reuse areas where **raw or insufficiently treated wastewater** is being used. In many of these areas, however, either low levels of

Table Ac.3 **Health Impact from the Current Reuse Practice and Proposed Health Protection Measures**

Country	Health Impact: No risks	Health Impact: Risks	Current (c) or recommended new (n) health protection measures	
MEXICO	• to consumers where crop restrictions are enforced	• parasite (worm + protozoa) infection through the use of raw wastewater • residual risk of protozoal infections with reservoir-settled wastewater	• partial low-cost waste water treatment • crop restriction	n c
CHILE (Santiago)	• of worm infections since helminths are not endemic in Chile (although raw wastewater irrigation is still being practised)	• increased consumer risks to contract typhoid fever from use of raw wastewater • increased risk of amoebiasis and other gastro-intestinal infections to workers and consumers	• Tertiary wastewater treatment (incl. chlorination or polishing ponds)	n
INDIA		• intestinal nematode infections and other parasites (+ bacteria ?) to farm workers and consumers through the use of raw or insufficiently treated wastewater	• partial, low-cost treatment • crop restriction	n c/n
PERU	• to farmers and consumers using partially treated wastewater on restricted crops	• from use of raw wastewater (Lima): parasitic and bacterial infections to workers and consumers	• protective wear • partial low-cost treatment • crop restriction	n c c/n
ARGENTINA (Mendoza)	• to farmers and families using partially treated wastewater when compared to non-wastewater users	• to consumers and farmers as no crop restrictions exist	• partial low-cost treatment of primary effluent • crop restriction	n n
TUNISIA	• to farmers and consumers since secondary effluent is used for non-vegetable crops only	• slight risks to farmers contracting protozoal or bacterial infections if they irrigate without proper protection	• expanding pond treatment, incl. polishing ponds for secondary effluents • crop restriction	n c
SAUDI ARABIA	• of endemic or epidemic diseases due to the combination of tertiary treatment (incl. chlorination)		• partial relaxation of quality standards in order to facilitate wider implementation of reuse	n

[1] c/n: measure already introduced by regulation but needs to be enforced (everywhere in the country)

hygiene prevail and/or the general socioeconomic level of the farmers or farm workers is low and/or the domestic water supply might be insufficient. On account of these factors, various **concurrent routes of transmission for excreta-related infections** probably exist. Under these circumstances, it is therefore unlikely that wastewater reuse leads to excess risks, i.e. risks which would make the health status of the exposed workers and consumers any worse than without the use of wastewater. Nevertheless, a **minimum set of health protection measures** should be introduced to reduce possible transmission risks associated with reuse.

In Table Ac.3 suggestions are made how, in the individual countries, health protection measures could be amended or what type of new measures could be introduced. Thereby, consideration is given to the particular circumstances of each country, including the type of reuse regulations already in existence or experience gained in the current practice. Thus, the suggested protection scenarios are in most cases a continuation or an expansion of what is already being practised, and they should be understood as intrinsically linked to the local situation.

For a number of countries, the introduction of **partial treatment** is proposed. This implies the removal of parasites, i.e. of helminth eggs and protozoal cysts with some concurrent bacteria removal. Thereby, the **protection of the agricultural workers** will be improved, an objective which, so far, has not received much attention. In many situations, WSP might be the treatment technology of choice as it is low-cost both with respect to construction and operation. It might, however, be impossible to implement for large cities because of the huge land requirement of ponds. There already exist WSP schemes in most countries but it appears that their function with respect to pathogen removal is often not recognized. In Mexico, India, and Peru, the installation of more pond systems is proposed. Polishing ponds are a suitable treatment to improve the microbiological quality of primary (mechanical) and secondary treatment plants. The method might prove useful for treating the primary effluent in Mendoza, Argentina, or effluents from secondary plants in Tunisia, e.g.. In the case of Santiago, Chile, full treatment would be required if the cultivation of raw-eaten vegetables, which yield high market values, should continue to be practised. Pond treatment would be unfeasible because of excessive land requirement. Thus, tertiary treatment including filtration and chlorination, or secondary treatment complemented by polishing ponds, would have to be installed.

It is clear that **crop restrictions** should be continued where they are already being practised and enforced (Mexico, Peru, Tunisia, Saudi Arabia), as long as the wastewater quality does not reach a standard good enough for unrestricted irrigation. In India, crop restriction should become enforced, and in Argentina it should be introduced in order to help protecting the consumers' health.

B - EXCRETA USE IN AGRICULTURE

9 GUATEMALA

Acronyms

CCM	Comité Central Menonita (Guatemala)
CEMAT	Centro Mesoamericano de Estudios sobre Tecnología Apropiada
COPECAS	Comité Permanente de Coordinación de Agua y Saneamiento
OMS	Organización Mundial de la Salud (WHO)
OPS	Organización Panamericana de la Salud (PAHO)

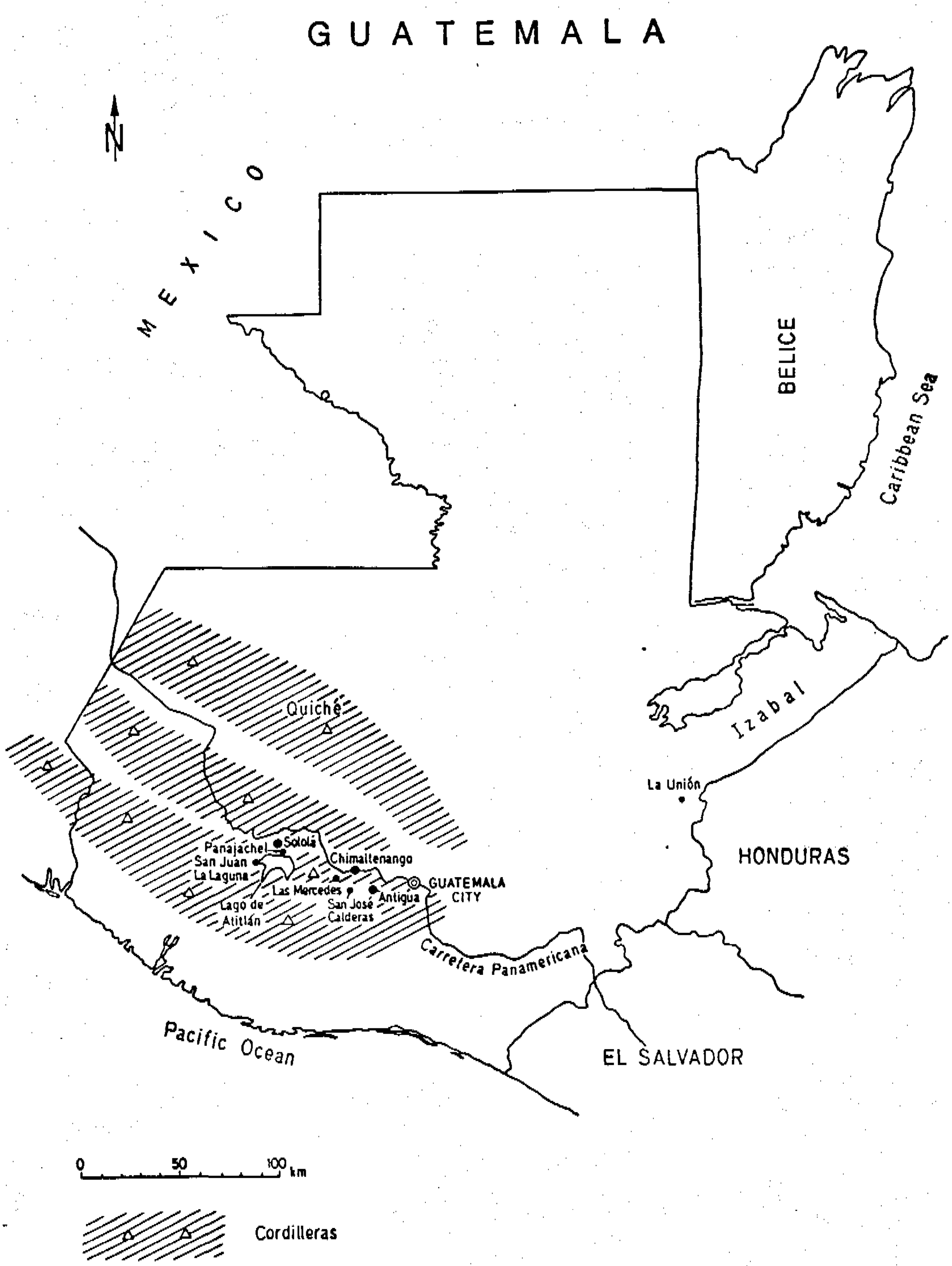
GUATEMALA
N
MEXICO
BELICE
Caribbean Sea
Izabal
Quiché
La Unión
HONDURAS
Panajachel
Sololá
San Juan
La Laguna
Chimaltenango
Las Mercedes
GUATEMALA CITY
Antigua
Lago de Atitlán
San José Calderas
Carretera Panamericana
Pacific Ocean
EL SALVADOR
0 50 100 km
Cordilleras

Photo 9.1

View of a DAFF latrine
(Photo: Vicente Gallardo)

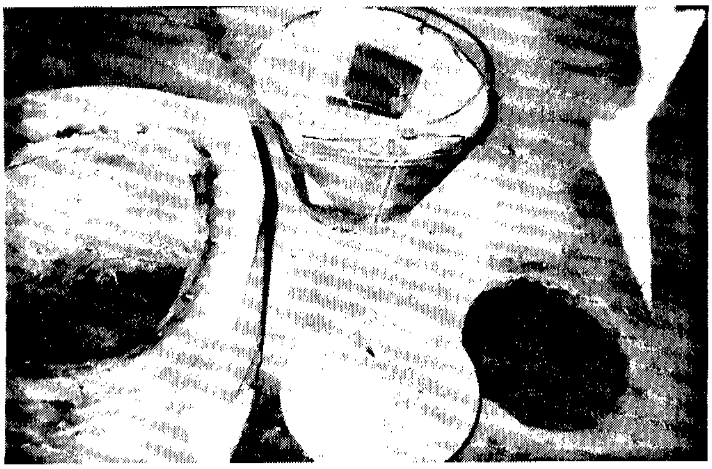

Photo 9.2

Interior of a DAFF latrine showing the toilet seat with urine separator, a bucket for ash storage and the opening of a vault at rest

Photo 9.3

Improved "comfort" toilet seat with urine separator developed by CCM-Guatemala

Photo 9.4

Access door for the removal of "abono" (decomposed nightsoil fertilizer) from the DAFF latrine vault

Photo 9.5

DAFF fertilizer harvest: 400-450 kg (280-320 l) annually are produced by a family of 5 adult equivalents (e.g. 3 adults + 4 children)

Photo 9.6

The CEMAT researcher-in-charge on a field of "güicoy" (zucchini), where agronomic investigations of the effects of DAFF "abono" are carried out

9.1 Geography and Population

Guatemala, which stretches over an area of 109,000 km^2, is bordered by the Pacific Ocean in the south, by El Salvador, Honduras, Belize, and the Atlantic Ocean in the east and by Mexico in the north and west. The Cordilleras divide the country into two major drainage areas, one sloping towards the Pacific and the other towards the Atlantic Ocean. The Pacific slope rises rather steeply from the lowlands to volcanic peaks of 2,500-4,000 meters and to high-lying intermont basins. The slope and the southern intermont areas are the most densely inhabited parts of the country. Agricultural production there is intensive as the soils are fertile and rainfalls plentiful. Maize and beans as well as wheat are the main subsistence crops cultivated in the highlands. In the southern highlands, cultivation of vegetables for export has become increasingly common in recent years. In the lower highlands of the north, coffee and cardamom are the main crops and also Guatemala's main export product. on the southern lowlands along the Pacific, mainly the cash crops cotton, sugar and bananas, as well as maize are cultivated.

Deforestation and erosion are serious problems throughout the highlands. This may have to do with the high population density in these zones, with unequitable land distribution and with the use of the more gently sloping and flat lands for the cultivation of cash crops, thereby forcing the subsistence crops to be cultivated on the steep slopes. To counteract this situation of increased soil loss, the use of human faecal matter as soil conditioner by subsistence farmers, i.e. builder of the organic soil fraction, is of particular value. This may not solve the area-wide problems of deforestation and soil erosion but can be an appropriate low-cost method for improving the fertility and productivity of the soil of the individual farming family and for the country as a whole. The use of chemical fertilizer without replenishing the organic fraction leads to an impoverishment of that soil.

The climate in Guatemala is predominantly tropical with a distinct wet season from May to October. The average annual rainfall is 1,300 mm with little temperature variation.

In 1988, Guatemala's population was approximately 8.5 million. Thereof, about 1.5 million live in Guatemala City. There are a number of major towns, the largest of being Quetzaltenango with about 70,000 inhabitants. The majority of the population, i.e. around 75%, lives in rural areas. Guatemala is the most densely populated country in Central America with a large Indian population (approx. 45%). The other main ethnic group comprises the "ladinos", most of whom are of mixed Indian and Spanish origin.

9.2 Fertilizer from Dry Double-Vault Latrines

• The development of the latrines

In the late seventies and particularly after the earthquake in 1976, several government[1] and non-government organizations embarked on latrinization and health improvement campaigns for rural areas. Initially, latrinization concentrated on introducing the simple pit latrine, but success was limited, even though the latrine slabs were donated to the users. The latrine is difficult to build in rocky underground, and in locations with high groundwater table, it usually has a rather wet content and is odorous. For these two reasons it attracts flies. Pits can become flooded by heavy rains and may cave in if they are not lined. Digging of new pits is difficult in densely populated areas and where people have only small plots to live on. In spite of these latrinization efforts, the majority of people in rural areas still practices open defecation.

CEMAT, the Centro de Estudios Mesoamericano sobre Tecnología Apropiada, evaluated several types of improved latrines, as part of its work with rural micro-enterprises and its bioenergy programme which includes such components as improved wood stoves, biogas production, cultivation of medicinal plants. In close collaboration with potential users, a **double-vault latrine with urine separation** designated as **"DAFF"** latrine (Engl.) or **LASF** (Span.)[2] was chosen as the most suitable technology for the people in this area.

• Latrine operation and fertilizer production

Approximately 4,000 DAFF latrines have so far been constructed throughout Guatemala by various government and non-government organisations. Several surveys and evaluations were conducted by CEMAT to assess user acceptance and technical, sanitary and agronomic aspects of the implemented latrines. Apparently, while the techniques to construct the latrines could be well transferred to other institutions and users, follow-up and support for the operation and maintenance of the latrines and for fertilizer application is often lacking. Where this is the case, user acceptance is low and operation inadequate.

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[1] Among them CEMAT, Agua del Pueblo, MCC

[2] DAFF = Dry alkaline fertilizer family; LASF = "Letrina abonera seca familiar" or "Lenta (slow) alcalina seca familiar"

The DAFF latrine **is built above ground** from regular masonry. Materials used for vault construction are cement blocks, stones, sun-dried bricks and pozzolan blocks. The vaults are fitted each with a simple access "door" for the removal of the decomposed material. The vaults are used alternately. **Average filling times of about 10 months** have been observed[2]. The seat is fitted with a urine separation device, and the urine is collected in a separate receptacle. Fig. 9.1 shows structural details of the DAFF latrine. Average construction costs amount to 100-300 Quetzales[1] (including 15-20% for labor, depending on the kind of superstructure).

Ash, or a mixture of ash and soil or of lime and soil, if sufficient ash is not available, is added after each defecation. This, together with the separation of urine, renders the **vault contents** relatively **dry** and helps to prevent odours. Through the addition of ash, the faecal material becomes rather alkaline, with a **pH** of around **9.** The high pH enhances the die-off of bacterial pathogens. About half of the farmers who regularly use their DAFF latrine, make use of the "abono" (organic fertilizer). The mixture of decomposed, humus-like material of faecal origin and ash is dried in the sun and then stored in bags upon removal from the vault until the farmer uses it on his field at the time of tilling. The diluted urine is used to water plants which have a high nitrogen preference. (Photos 9.1-9.4 show the latrine and its structural details.)

Those who regularly use the DAFF latrine, indicate that the order of **priority** of benefits derived from the latrine is: production of organic fertilizer, improved comfort because of nearness of the latrine to the home, improved hygiene and enhanced prevention of diseases, social status. The main problem some users are faced with is the scarcity of ash which in turn may lead to a relatively high humidity of the vault content, to unpleasant odours and fly proliferation.

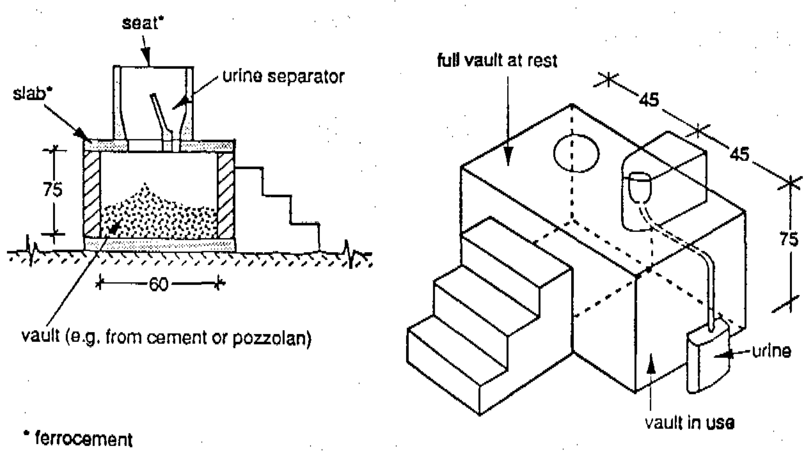

Fig. 9.1 Double-Vault Fertilizer Latrine With Urine Separation (dimensions in cm)

[1] 1989: Q. 2.8 = 1 US $.
[2] Whether vaults are emptied also at shorter intervals due to seasonal demands for "abono" is not known.

Operational and structural data for DAFF latrines are shown in Table 9.1 (Cáceres et al. 1988a, Cáceres et al. 1988b).

Table 9.1 Average Operational Data of DAFF Latrines Used in the Guatemala Highlands (after Cáceres et al. 1988b and Xet et al. 1989)

	Contents of vaults in use or at rest	"Abono"[1]
• Water content[2]	45.....35 %	30 %
• Organic matter[2]	22.....17 %	17 %
• pH	92.....9.4	9.8
• P_2O_5 (in dry matter)		3.5 %
• K_2O (" " ")		13.8 %
• N (" " ")		0.6 %

• Effective storage volume of one vault (depends on the construction material used and on individual preference):

270....350 l (0.27-0.35 m^3)

• Vault filling time in regularly used latrines (57 observations):

- average:	301 days	5 adult equivalents[3] per latrine
- median	243 days	
- range (2/3 of observations)	160...440 days[4]	

• Accumulation ("abono" production) rate (calculated from above figures and as indicated by users):

~ 60 l (0.06 m^3)/adult/year
(≅ 35 kg/adult/year)

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[1] = fertilizer/soil conditioner, upon removal from the vault
[2] Average values; range also indicates the decrease during storage
[3] 2 children = 1 adult equivalent
[4] variability depends on number of regular users, migration of a family as a whole, use/non-use of ash, use of other installations, open field defecation

Photo 9.5 shows a family's fertilizer production which has been stored over a period of about half a year.

- Hygienic quality

The proper use of a latrine which is safe against fly proliferation, possibly leads in itself to a marked improvement of the hygiene situation compared to open-air defecation. However, the factors controlling fly proliferation are reportedly not well established yet. Care must be taken that the latrine contents are hygienically safe (stored long enough) at the time of removal from the vault, as the majority of the owners of a DAFF latrine, who regularly use their latrine, apply the stored material to their fields. CEMAT has therefore established a routine monitoring programme as part of its latrine implementation activities.

Ascaris lumbricoides eggs and faecal coliforms (MPN) were chosen as hygienic quality parameters[1]. *Ascaris* infestation is endemic in many parts of Guatemala. *Ascaris* eggs, which are the hardiest of all pathogenic organisms are therefore regularly found in the latrine contents. Absence of viable eggs in the stored faecal product of users who are *Ascaris*-infested, therefore indicates that all other pathogens have been inactivated, too. Faecal coliforms (FC), which are widely used to observe the presence or absence of faecal pollution in potable water sources, serve here as indicators to examine the fate of bacterial pathogens such as - *Salmonellae*. FC usually have longer survival periods than the pathogenic bacteria. Low concentrations, but more so a marked reduction of FC during the storage process, coupled with a storage period of several months, allow the assumption that the bacterial pathogens have all become inactivated.

Average vault temperatures are 17-20°C, but minima of 8°C and maxima of 30°C have been recorded for the latrines, most of which are located at an altitude of 1500-2200 m above sea level.

Data collected so far during the monitoring programme tend to indicate the following (Cãceres et al. 1988 a + b and Xet et al. 1989):

- The die-off of bacterial pathogens is enhanced at pH > 9. However, this effect diminishes if the humidity of the material is higher than 60%.

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[1] The following analytical methods are used:
(a) Egg count: suspending faecal sample in a 10% saline (NaCl) solution; shaking and quiescent settling; observing (under the microscope) 0.04 ml to which a drop of methilene blue is added; counting.
(b) Egg viability: follow procedure for egg count; differentiate viable from non-viable eggs on the basis of morphological alterations caused by the coloring agent on the non-viable eggs.
(c) Faecal coliforms: multiple tube technique after suspending faecal sample in 10% saline.

- Within the pH range observed (pH 6-12.5), pH does not affect the die-off of *Ascaris* eggs.

- Viable *Ascaris* egg concentrations amount to several thousand per gram in fresh feces, and to an average of 300 eggs/g in feces stored for about one year.

- Within the range of humidities occurring in the DAFF latrine vaults (averages of 34-44% water content for the lower and upper strata in the well-operated latrines), there is no correlation between the humidity and the egg viability.

- During storage of the faecal material in the latrine vaults, average egg viability values do not drop below 30%, even if the storage period is one year. However, from the few observations made so far for the "abono", i.e. the faecal material which has been removed from the vaults, it appears that the viability drops rather rapidly upon removal of the faecal material from the vault. This might be due to the reported practice of many of the users to sun-dry the material before filling it into bags for the transport to the fields.

  A speculative inference from these observations is that a one-year storage period is not sufficient to achieve very low or zero egg viability at the average temperatures of 17-20°C. Neither does the humidity prevailing in the vaults, which is low relative to other types of latrines, affect the egg viability. However, the sun-drying of the "abono" may possibly lead to a further reduction of the humidity such that the dryness of the material may enhance egg die-off. This would be in agreement with information found in the literature on *Ascaris* egg die-off, which reveals that the water content of the faecal material must drop to approx. 5% or below for the dryness of the material to become a relevant factor for egg die-off (Feachem et al. 1983).

- Concluding from the above, the following **tentative storage "schedule"** might be required to achieve a hygienically safe product, depending on whether or not the "abono" is allowed to sun-dry upon removal from the vault and depending on the ambient temperature:

	Vault storage required (tentative)	
	without subsequent sun-drying	with subsequent sun-drying
• at 17-20°C (highlands)	18 months	12 months
• at 25-30°C (lowland, tropical zone)	10-12 months	8-10 months

9.3 Agronomic Observations

The **agronomic value** of the "abono", i.e. the mixture of decomposed faecal material and ash (occasionally, soil is added, too), is derived mainly from two characteristics:

- the content of the major plant nutrients phosphorus (usually expressed as P_2O_5), potassium (K_2) and nitrogen (N).
- the content of organic matter, and

It has been found that, in practice, the nutrient contents of DAFF latrines vary considerably from one latrine to another (Schiere 1989).

In Section 1.1, an-order-of-magnitude estimate of the **fertilizing potential** of a family's excreta is presented. The calculations are based on the average nutrient content (P_2O_5 = 3.5%, K_2O = 2.5%, and N = 8% on a dry weight basis) of excreta, i.e. of faeces and urine, stored without separation in a pit latrine under anaerobic conditions. How does the average "abono" from DAFF latrines compare with that estimate? It can be expected that the phosphorus level of DAFF latrine contents is the same as in fresh excreta (3.5% as P_2O_5) and would probably be so in any other type of latrine. Levels of nitrogen and potassium, however, are distinctly different: the nitrogen level is much lower than in fresh excreta and probably also than in pit latrine contents. This is due to the separation of urine which is very rich in N and to the addition of ash which raises the pH and causes much N to be lost as gaseous ammonia (NH_3). Theoretically, the **N deficiency** of the "abono" could be compensated by applying the diluted urine to the same crops as the "abono". The potassium levels of DAFF-contents are much higher than in the excreta. This is due to the addition of ash which is very rich in K.

Those who make use of their DAFF "abono" apply it to crops such as maize, coffee, beans, fruit trees and vegetables. The practice of its use varies according to the farmer and to the particular crop fertilized. Some farmers use the "abono" directly, others mix it with varying proportions of soil. The majority adds it before sowing as well as during the growth phase of the plant. Others apply it to growing seedlings and during the main growth phase, again others during plant growth and the flowering period. On the average, the application rate for the "abono" amounts to the equivalent of 2500-3000 kg/ha for each plant cycle. With the average "abono" production rate of 425 kg/year/family, the family's fertilizing potential for maize crops is approx. 1900 m^2 on the basis of the phosphorus content of the "abono" and 2580 m^2 on the basis of potassium, but only 123 m^2 on the basis of the nitrogen content. Fertilizer from DAFF latrines should therefore be complemented by nitrogen fertilizer. Else, nitrogen-fixing crops, particularly leguminosas such as beans and soybeans, may be planted in rotation with other crops.

The average selling price for the DAFF fertilizer amounted to Quetzales 9.55/costal[1] (US $ 3.80/50 kg) in 1986/87[2]. At a production rate of 85 kg "abono"/person/yr, this corresponds to a yearly benefit of $ 32.

Several tests were conducted in 1986/87 by 14 farmers who are regular users of DAFF latrines (Cãceres et al. 1988 a). Each farmer had one plot where he applied DAFF (organic) fertilizer, one plot where he applied chemical fertilizer and a third one as a control plot where no fertilizer was added. The results were observed by the farmers themselves. The 14 farmers had an average "abono" production of 300 kg, which was obtained after a 7-month vault storage. Average application rates amounted to an equivalent of between 2,500 and 3,000 kg/ha per plant cycle.

Parameters observed were:
germination, plant size, vegetation period, production (kg/ha), apparent quality, susceptibility to plant diseases.

The outcome of the tests varied according to locality and type of crop used. The results must be valued with caution on account of the limited extent and control of the experimental conditions and since the effect of an organic fertilizer and soil conditioner such as the DAFF latrine product, is mainly a **long-term** improvement of the soil's humic fraction. Table 9.2 shows the relative amounts of specific crops harvested by a total of 14 farmers in the three communities. Although only crop yield data are given in the Table, it is certainly not the only important criteria with which to assess the impact of DAFF fertilizer.

The data indicate that the effect of the latrine fertilizer on crop yield during the one year observation period was positive for the crops cultivated in the villages of San José Calderas and La Unión, but negative for two out of three crops in Las Mercedes, where yields of chemically fertilized crops tended to be higher.

At present, carefully controlled agronomic experiments cultivating spinach, beet root, carrot, peas, and coliflower are carried out in five different villages. DAFF fertilizer, chemical fertilizer, chicken manure and combinations thereof are being applied. The experiments will last three years. Photo 9.6 shows one of the experimental field plots planted with zucchini. Preliminary results obtained during the first year of observations indicate that with most plants, the best yields (measured by weight, size of plant and root diameter) were achieved when DAFF "abono" was combined with chemi-

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[1] 1 costal = 100 pounds
[2] 1985: Q. 2.5 = 1 US $

Table 9.2 **The Relative Yield of Crops Fertilized with DAFF Latrine Fertilizer**
(Cáceres et al. 1988a)

	San José Calderas (Dpto. Chimaltenango)			Las Mercedes (Dpto. Chimaltenango)			La Unión (Dpto. Zacapa)		
· Geographical data									
- Elevation a.s.l.	2,300 m			2,200 m			1,000 m		
- Average temperature	16°C			18°C			26°C		
- Annual precipitation	2,700 mm			2,400 mm			714 mm		
- Inclination	60 %			10 %			5 %		
	% Yield (crop harvested in kg/ha)								
	Control[1]	DAFF fert.	Chem. fert.	Control	DAFF fert.	Chem. fert.	Control	DAFF fert.	Chem. fert.
· Green peas ("aveja criolla")	100	232	145	100	60	94	-	-	-
· Kidney beans ("frijol de suelo")	100	1,199	899	100	67	61	-	-	-
· Potatoes ("papas")	-	-	-	100	111	214	-	-	-
· Radish ("rabano")	-	-	-	-	-	-	100	133	108
· Onion ("cebolla")	-	-	-	-	-	-	100	116	119

[1] = without fertilizer application

cal fertilizer. The "abono"-treated plots always yielded better harvests than the control plots which did not receive any fertilizer (Xet et al. 1989).

9.4 Health and Epidemiological Aspects

In this section, discussion will not be limited to water and excreta-related infections but these will be discussed in the wider context of the most important causes of morbidity and mortality in the country. This will allow the reader to assess the importance of the water and excreta-related infections that might be associated with the waste reuse practice in comparison with the predominant diseases in the area. The reader is also referred to section 1.2, where the health risks associated with wastewater use have been summarised, and to section 1.4, where the difficulties involved in evaluating the health effects of a specific reuse practice have been outlined. The data available do not allow an accurate assessment of the health risks to be made, so the following sections contain epidemiological judgements which should be considered as "informed speculation" rather than strict scientific analysis.

Components of the Health Situation

As in many developing countries, the most important causes of death in Guatemala, particularly in the under five population, are diarrhoeal diseases and acute respiratory infections (Table 9.3). Homicide is a major cause of adult death, reflecting the armed struggles continuing in Guatemala - these cause many people to become refugees or to become displaced within their own country, and have to live in makeshift communities. Furthermore, the insecurity impedes development activities such as health improvement and latrine promotion programmes. 10% of children are born underweight and infant mortality is quite high (see Country Background). Malnutrition affects three quarters of the under five population. Income is very unevenly distributed; in 1980, the 20% poorest have only 5.3% of the income (average income $ 111) and the richest 20% have 54.1% of the income (average income $ 1133.6). The health indicators for the country can not indicate the different rates applying to urban and rural sectors, or to different income groups, but differentials between sectors must be large.

Health services are not adequate to serve the majority of the population. The annual rate of medical attention was 0.4 visits per person in 1982 and the number of physicians only about 5 per 10,000 persons. The rate of immunisation of children under the age of 1 against the major childhood diseases was less than 50% in 1983, and only 12% for measles. The health expenditure per capita, however, is higher than in many developing countries ($ 22). It seems that a different distribution of those resources may be needed to tackle the health problems of the most needy population groups.

Table 9.3 10 Major Causes of Death in Guatemala 1982 - by Age Group (after OPS/OMS 1983)

Cause	0-28 days	28 days - 1 year	1-4 years	5-14 years	over 15 years	age not stated	TOTAL (%)
1. Infections and enteric infections	-	4602	4812	1046	3928	27	14,415 (18.7%)
2. Poorly defined signs, symptoms and illness conditions	-	2665	1955	640	5086	91	10,437 (13.6%)
3. Pneumonia	-	2485	1706	411	2445	12	7059 (9.2%)
4. Infections originating in perinatal period	6300	49	1				6350 (8.2%)
5. Homicide	-	33	70	226	5480	370	6170 (8.0%)
6. Protein-calorie deficiency	-	792	791	236	1545	27	3386 (4.4%)
7. Measles	-	786	1783	548	125	5	3247 (4.2%)
8. Diseases of circulatory system	-	5	5	15	2290	2	2217 (2.9%)
9. Parasitic circulatory system	-	588	723	175	171	2	1659 (2.2%)
10. Rest of causes	432	3346	2528	1173	14,423	130	18,492 (24.0%)
TOTAL	6732	15,351	14,374	4470	35,393	661	76,981

Some data are available on the prevalence of intestinal protozoa from comprehensive nutrition surveys which included surveys of intestinal parasites (reported in Mata 1986). The prevalence of *Entamoeba histolytica* (amoebic infection) and *Giardia lamblia* in different age groups in a representative sample from the country is shown in Fig. 9.2. Amoebic infection is greatest in those aged 10-24 years (about 30%) whereas *Giardia* is more prevalent in those aged 1-9 years (about 20%). Data from the same source on the prevalence of intestinal helminths could not be retrieved, but it appears to be substantial. This can also be inferred from the egg counts made in fresh feces and within the DAFF latrines.

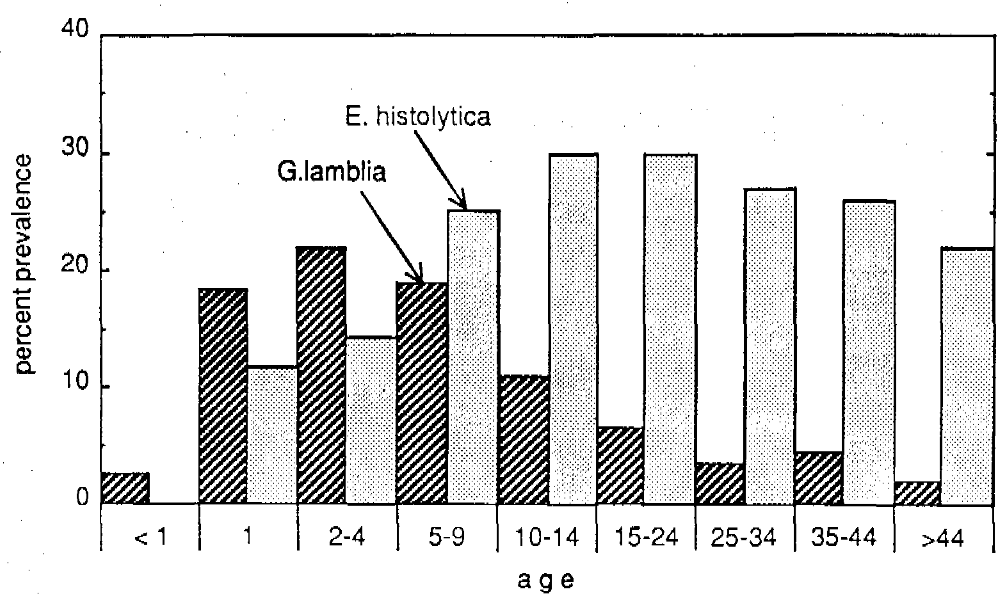

Fig. 9.2 Prevalence by Age of *E. histolytica* and *G. lamblia* in the General Population of Guatemala

Water Supplies and Sanitation

The proportion of the total population that is supplied with potable water (by house connections or with easy access), 51% in 1983, compares favourably with many other developing countries. This overall figure is misleading, however, since the distribution is not even over the country; 90% of the urban population have potable water whereas only 26% of the rural population are served. Sanitation was provided for only 36% of the population in 1983. In the urban areas, coverage was 53% whereas in the rural areas coverage reached 28% of the population. In the Central American health initiative (1985-1990), supported by the Contadora[1] group, the priority health needs in Central America were defined. These included increasing the coverage for drinking water to 83% and the coverage for sanitation to 84%, and giving priority to the marginal urban and rural populations. This constituted a paerticularly large task in Guatemala, which started off with the lowest coverage rates in the Region for both drinking water and sanitation.

- Potential Impact of the Existing Reuse Practice

The risk associated with use of the DAFF latrine and of the fertiliser ("abono") from it will depend on several factors: the microbiological quality of the product, the type of exposure of persons to it and the existence of any health protection measures, balanced by the absence of any risk associated with indiscriminate defecation.

The microbiological quality of the DAFF fertiliser will vary mainly according to the length of storage after the vault is closed, the ambient temperature and the operation (the adding of ash, primarily) of the latrine. Since the water content and the pH affect the survival of the faecal coliform and of the pathogenic **bacteria** (section 9.2), the concentration of these bacteria in the full vault/fertiliser will be affected by the amount of ash that is added to the latrine. The initial content of pathogenic bacteria is likely to vary widely between latrines, depending on the illnesses suffered by users of the latrines. Most probably, all pathogenic bacteria die-off within the storage periods occurring in DAFF latrines.

The concentration of viable *Ascaris* eggs declines with storage within the vaults and drops to low levels and even zero after drying and storing outside the vaults. However, it is not clear whether all latrines would allow long enough storage to attain such low levels of viable eggs which are epidemiologically insignificant and which would exclude significant (re-)infestation of those handling the stored faecal material or of the consumers eating vegetables which have been fertilised with latrine "abono". The current investigations will generate more data using a selected number of closely monitored latrines in different climatic zones and with varying storage periods.

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[1] The Group comprises the five Centralamerican states Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua. It was set up mainly to enhance the peacemaking efforts in the region.

It is possible that the product from latrines with short retention times (< 1 year) carries some potential risk. The risk in epidemiological terms would depend on the extent of exposure and susceptibility to the infection. If peasants handle the fertiliser with bare hands then, depending on hygiene practices, there is potential for transmission of infection via the oral route. This could occur in the case of helminth infections, such as *Ascaris*. Where the fertiliser is used before or at the beginning of the growing cycle of an edible crop, and dug into the soil, then there would be no risk to consumers of the crop. However, in cases where the fertiliser is used in a way that may bring it into contact with the edible portion of the crop, then a risk of transmission of helminth infections could occur.

The understanding of any health risks associated with use of fertiliser from DAFF latrines would be enhanced by extending the microbiological studies being carried out by CEMAT to include DAFF latrines built by other organisations as well as ones built under the auspices of CEMAT. It is important to evaluate the performance of the latrines in pathogen reduction in large scale programmes where the education component was not so well developed as in the original small scale programmes. The information so gained would help to establish with more confidence the hygienic safety of the double-vault latrine technology, which is an important link in the concept of using the human excreta as a fertilizer and soil conditioner.

- Implications for the Control of Health Risks

"Abono" which has come from vaults which have been at rest for a sufficient length of time (see p. 214), and which has been sun-dried to attain zero or only very low levels of egg viability, can be considered as "fully treated", and can be used to fertilize vegetable crops without risk to either the handler or the consumer of the crop. Additional precautions, however, would need to be taken with "abono" taken from a vault which had been at rest for less than safe storage period, i.e. only "partially treated". A choice of two strategies could be used: (i) the fertilizer could be dug into the ground prior to planting the vegetables and not added during the growing season, or (ii) the fertilizer could be used on a restricted range of crops, excluding vegetables eaten raw. In both cases, persons using the fertilizer would need to avoid touching the product, to prevent exposure to any nematode eggs which may be present and viable.

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10 SOUTH KOREA

Acronyms

EA	-	Environment Administration (previously designated Office of Environment)
KAPE	-	Korean Association for Parasite Eradication
MoC	-	Ministry of Construction
MoHA	-	Ministry of Home Affairs
MoHSA	-	Ministry of Health & Social Affairs
NIER	-	National Institute of Environmental Research (previously designated NEPI, National Ennvironmental Protection Institute)
NTP	-	Nightsoil Treatment Plant
SU	-	Saemaul Undong (= New Community Movement)

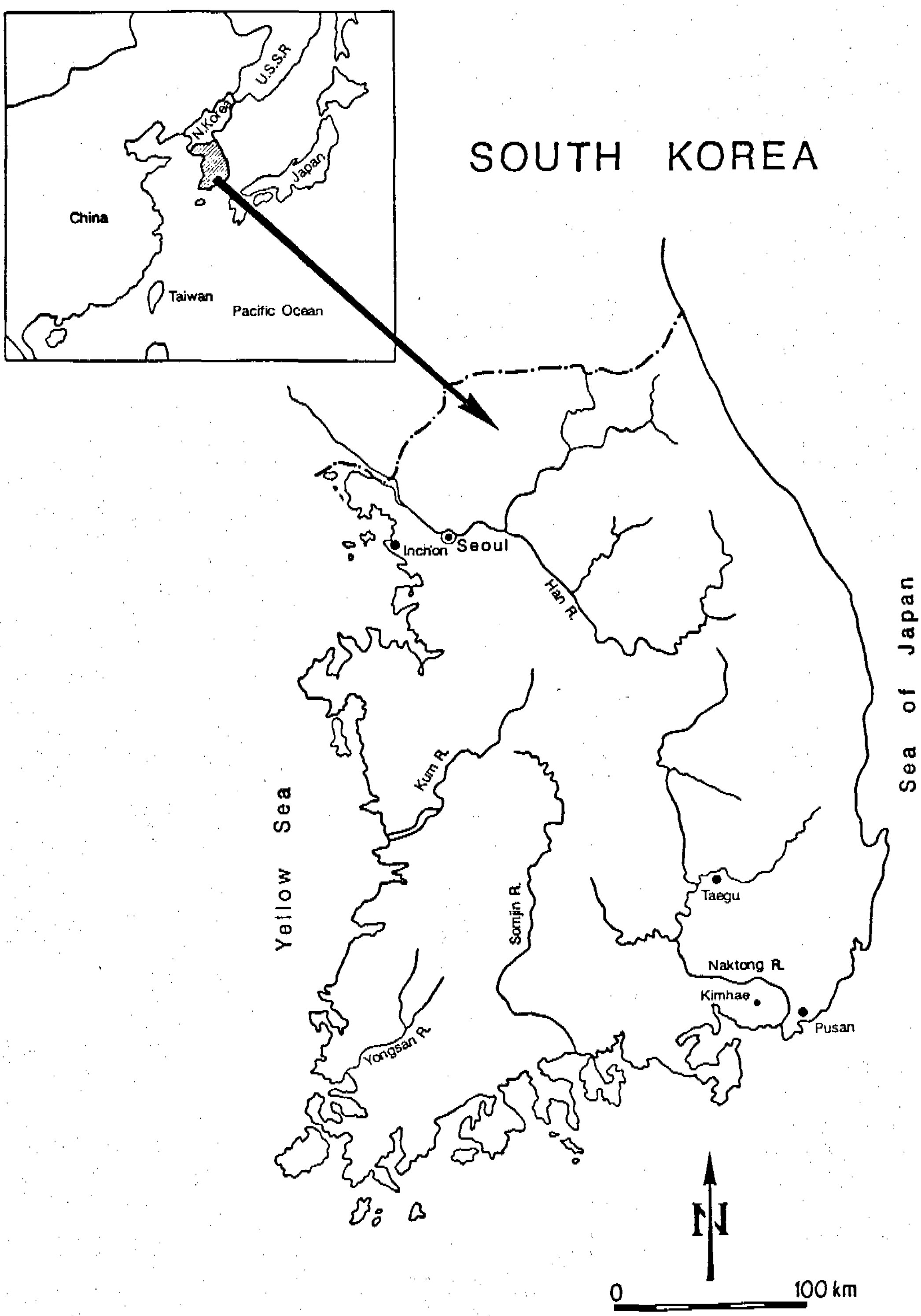
SOUTH KOREA
China
U.S.S.R
N.Korea
Japan
Taiwan
Pacific Ocean
Seoul
Inchon
Han R.
Kum R.
Yellow Sea
Sea of Japan
Somjin R.
Yongsan R.
Taegu
Naktong R.
Kimhae
Pusan
N
0
100 km

Photo 10.1

Greenhouses near Pusan

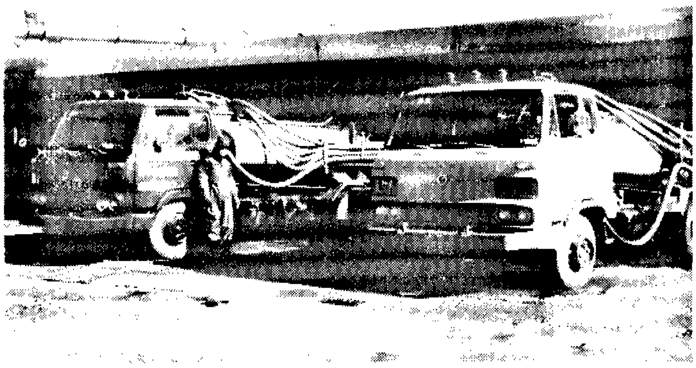

Photo 10.2

Vacuum tanker

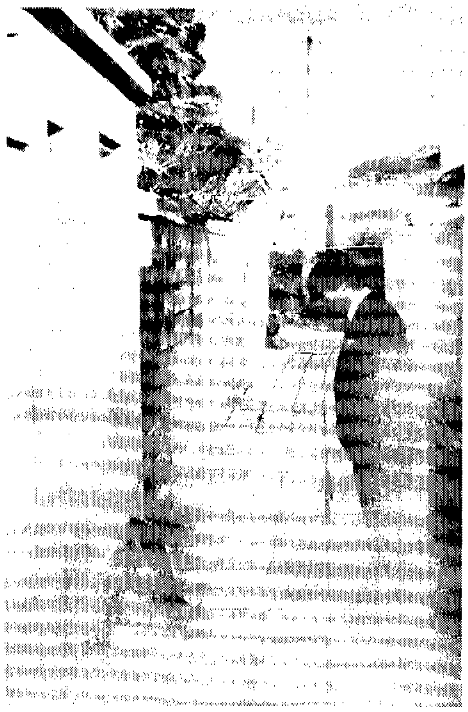

Photo 10.3

Toilet access hole for vacuum emptying (Pusan)

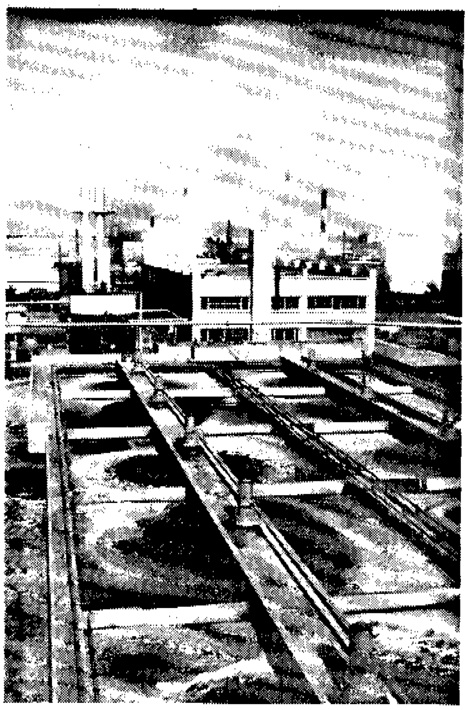

Photo 10.4

Umgung NTP, Pusan

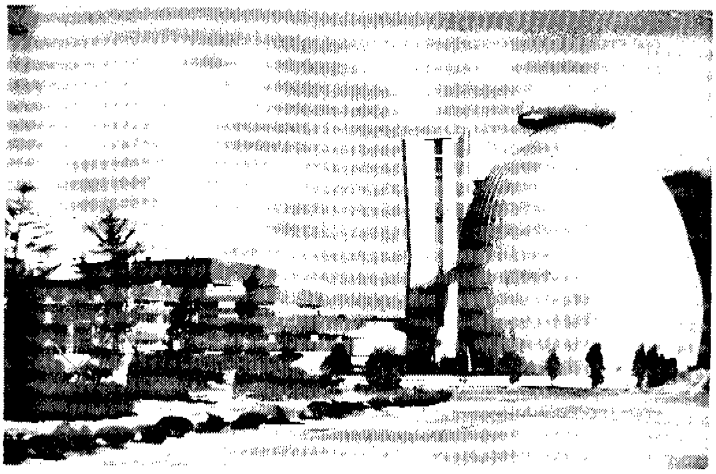

Photo 10.5

Yongho NTP, Pusan

Photo 10.6

Dewatered nightsoil sludge
(Umgung NTP)

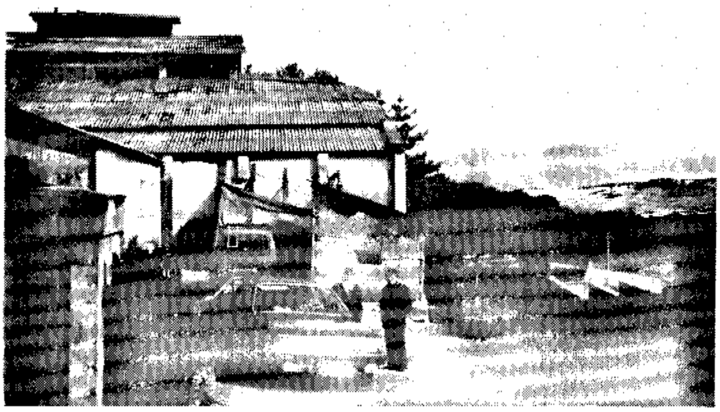

Photo 10.7

Fertilizer factory
(Chinyong, Kimhae District)

Photo 10.8

Equipment to bag the finished, mixed compost at the Chinyong fertilizer factory

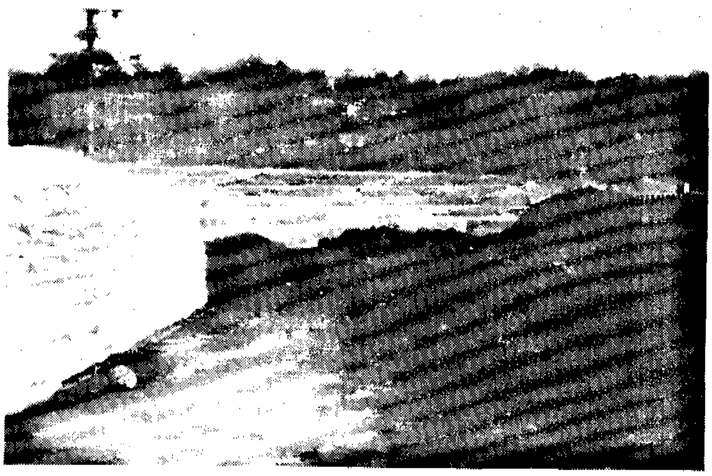

Photo 10.9

Storage of bagged compost at the Chinyong fertilizer factory

10.1 Geography, Population and Economy

The Republic of Korea (South Korea), together with the People's Democratic Republic of Korea (North Korea), forms the Korean Peninsula. It is bounded north by China, east by the Sea of Japan, west by the Yellow Sea and south by the Korea Strait situated between the Peninsula and Japan. The Peninsula is rather mountainous with only about 20% of flat area and numerous islands scattered along the south coast. Geologically, much of the area consists of granite and limestone formations. On the east coast, mountains fall steeply into the sea, whereas on the west and south coast, mountains slope gently into coastal plains. The main rivers drain into the Western[1] and Southern[2] Sea (see map on p. ii).

The climate is temperate to subtropical with dry and cold winters and warm summers with about 60% of the rains falling in the monsoon period between July and September. Mean annual rainfall amounts to 1260 mm in Seoul and 1380 mm in Pusan.

South Korea covers a land area of 99,000 km^2. Its population totalled 40 million in 1985, with a 1,6 % average growth rate during the ten-year period 1973-82. Urbanization has increased rapidly over the past two decades with 60-70% of the population now living in urban areas. Administratively, the country is divided into 9 provinces ("Do"), 183 counties ("Gun") and 1340 townships ("Myeon"). Seoul (approx. 10 million inhabitants), Pusan (4 million), Taegu (1.8 million), Inchon (1.3 million), and Kwangju (1 million) are special administrative entities with provincial status.

Since industrial development has received high priority over the past decades, South Korea has changed from a predominantly agricultural and economically rather poor country to an industrialized society of considerable wealth within a time span of merely 25 years (per capita G.N.P.: Some US $ 800 in 1960 vs approx. US $ 2000 in 1985). While, formerly, production was concentrated mainly on light consumer goods, emphasis has now been shifted towards heavy and petrochemical industry. Income and land distribution is reportedly among the best in the world (World Bank, cited in Asian Development Bank, 1984). In providing an infrastructure, the government is trying to even out disparities between urban and rural areas, resulting in, for example a relatively high service level for improved water supplies in rural areas.

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[1] Han R., Kum R., Yongsan R.
[2] Somjin, R., Naktong R.

About 20% (22,000 km^2) of the land area is cultivated. The chief crops are rice, various other grain crops and beans. Rice, fish and "Kimchi", fermented cabbage, are the main staple foods. In the Pusan hinderland, large parts of the land used for rice cultivation in summer are covered with green houses during the winter months (see Photo 10.1). Vegetables are being produced as cash crops for the urban markets. This shift towards intensive, high-input agriculture appears to have taken place only rather recently, along with an increase in people's income and standard of living. Over many centuries, agriculture was based on the recycling of animal, plant and human organic "wastes". The use of these products is now gradually decreasing as the purchasing power of the farmers has increased. This enables them to buy mineral fertilizer, but may, lead to a gradual decrease in soil organic substance which in turn, may lead to a long-term decrease in soil fertility. Mineral fertilizers do not help to maintain the humus fraction of soil.

10.2 Excreta and Wastewater Disposal and Use - an Overview

- Urban Areas

Vault latrines are the traditional excreta disposal facilities for urban dwellings. The latrines or privies are composed of a vault and a latrine cubicle which is built on top of it. The vault is located directly underneath the squatting plate and is large enough to provide storage for two to four weeks. Sullage (greywater) is collected through centralized sewerage or open-drain systems. These individual "dry" toilets serve only a few families and are usually located near the access road or path servicing the neighbourhood, i.e. some steps away from the house[1]. Fig. 10.1 shows a traditional urban toilet equipped with a urinal. Alternatively, the urinal may exist as a separate installation, in which case urine is discharged directly into the sewerage system where sullage is also discharged. Nowadays, the latrine vaults are regularly emptied by vacuum tankers (see Photo 10.2) and a long vacuum hose line if tankers do not have direct access to the vault. Photo 10.3 shows the rear side of a traditional toilet as seen from the road with a coverable access hole allowing vacuum emptying. Most houses with the described type of latrine, traditionally received their supply of water through a single in-house tap. Only the newer houses have full in-house plumbing.

[1] According to a Korean saying, the house of the mother-in-law and the latrine should always be far away from one's home!

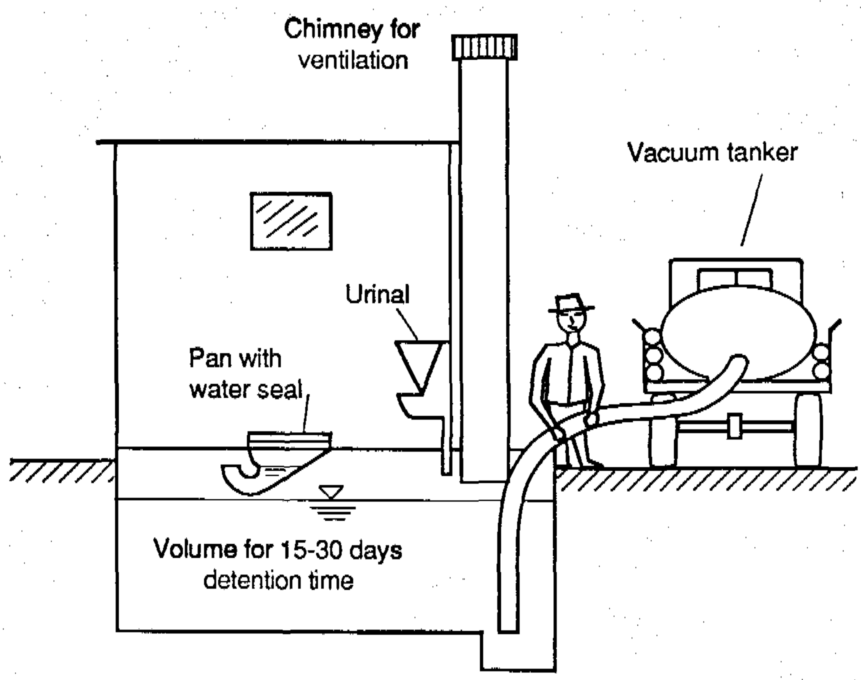

Fig. 10.1 Traditional Urban Toilet with Collection Tank and Emptying by Vacuum Truck (after Samhwa Eng. Co., unpublished document)

In recent years, the installation of flush toilets has become popular. Therefore, households now produce excreta-containing sewage (blackwater) in large quantities which will have to be discharged into sewerage systems. By law, blackwater must first pass through a septic tank before it can be discharged into the public sewer. However, sullage may be discharged into sewers directly if the building area is less than 1600 m^2. On-site sewage treatment plants must be installed if buildings cover over 1600 m^2. Most of the sullage and septic tank effluent which is collected in the combined drainage systems is dicharged into natural ditches or streams, or into the sea. In 1984, four wastewater treatment plants (STP) were in operation in the country, two in Seoul, one in Pusan and one in Kyoengju. By 1986, 16 STP should have been implemented.

Formerly, much of the nightsoil and septage collected in urban areas was used untreated in agriculture, and some of it was discharged directly into surface waters. In 1973, the Waste Disposal Law was promulgated (see also Sect. 10.3). It was combined with the Environment Preservation Law in 1986 to form the Waste Management Law (Lee 1988). It stipulates that nightsoil must be treated and may not be applied to the land raw. Prior to the enacting of this law, most of the nightsoil collected in urban areas was used in agriculture as a soil conditioner and fertilizer. Together with animal manure and plant residues, urban nightsoil certainly constituted an important farm input. Table 10.1 shows official figures on the use of nightsoil in the country between 1963-77.

Table 10.1 Use of Nightsoil in Agriculture

	Collected [m³]	Used [m³]	%
1963	1,436,000	1,399,000	97
1965	2,153,000	1,961,000	91
1967	1,244,000	611,000	49
1969	2,036,000	353,000	17
1977	2,761,000	580,000	21

As can be deduced from these figures, the agricultural **use of nightsoil has been drastically reduced after 1965.** This development probably resulted from the use of chemical fertilizer which gradually became more affordable to farmers, and from the "1973 Law" which prohibited the use of raw nightsoil. On account of this Law, an intensive programme of **nightsoil treatment plant** (NTP) construction was started, and about 60 NTPs were in operation by 1983, serving approximately 7-9 million inhabitants and treating 51% of the collected nightsoil in cities with an overall population of 12 million. There are basically three systems for nightsoil treatment in urban areas in South Korea. The difference consists in the primary treatment processes applied: Zimpro wet oxidation[1], anaerobic digestion and pre-aeration. In some plants, the liquid fraction is further treated by activated sludge, while in others it is discharged into surface waters upon dilution with freshwater.

Dewatered sludge from NTP's is used or disposed of in one of three ways:

- Direct use by farmers on agricultural land
- Agricultural use upon composting with animal manure in "fertilizer" factories (see also Photos 10.7 and 10.8 and 10.9).
- Landfilling.

[1] consists of air injection at high temperature (240°C) and pressure (74 bar.)

Dewatered sludge with a water content of 75-80% is produced at a rate of about 2.4 m^3 (3 tons) per 100 m^3 of nightsoil treated. Assuming that approx. 7000 m^3 of nightsoil are treated daily in the country's NTPs, a total of about 170 m^3 of sludge cake is produced daily. Based on nitrogen (N) and phosphorus (P) equivalents, this represents approx. 1% and 0.5%, respectively, of the annual chemical fertilizer consumption. Based on fertilizer equivalents, nightsoil is thus of little economic importance. However, through its organic content it can play an important role as a humus builder and soil conditioner. Given the relatively high intensity of agricultural cultivation now practised in the country (see Photo 10.2), the continuous decrease in the use of NTP sludge (see Table 10.1) may gradually lead to a loss of soil productivity unless other organic fertilizers are used to replace the sludge.

The Umgung and Yongho plants in Pusan are two examples of urban NTPs. The 1800 m^3 of nightsoil which were collected daily in the city of Pusan 1985 are treated as follows:

NTP	Amount treated [m^3/d]	Process
• Umgung	400	Zimpro (Photo 10.4)
	400	Aerobic stabilization (18 days) (Photo 10.4)
	600	Preaeration (3 days) + lagooning
• Yongho	400	Anaerobic digestion (Photo 10.5)

At Umgung, the sludge is dewatered by centrifugation (Photo 10.6), and at Yongho by filter pressing. In 1985, all the sludge cake produced in the two plants (approx. 43 m^3/d) was reportedly sold and transferred to the Chinyong fertilizer factory located 40 km NW of Pusan in Kimhae District. The "factory", shown in Photo 10.7 and schematized in Fig. 10.2., is located on a hill slope. It consists of a shedded storage area with two vertical batch-operated composting "wells" and with simple but robust equipment to bag the finished product (Photos 10.8 and 10.9).

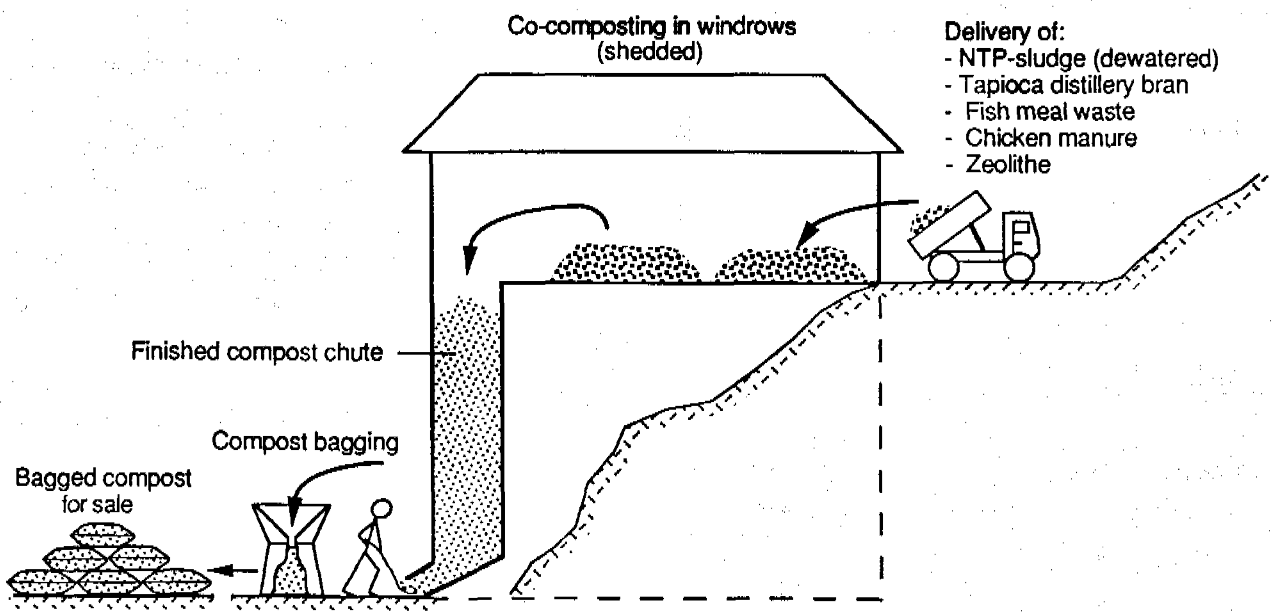

Fig. 10.2 The Chinyong, Kimhae District, Composting Plant where Dewatered NTP Sludge is Processed (schematic)

In 1985, the factory purchased approx. 6400 m^3 of dewatered sludge from the Pusan NTPs. In 1987, the purchased quantity amounted to 4500 m^3. Reportedly, on its transfer from the NTPs to the fertilizer factory, all the sludge is kept in intermediate storage for operational purposes. The water content then drops from 75-80% to about 50-60%. Two different composting regimes are applied to the sludge cake originating from the Zimpro wet oxidation process (Umgung NTP) and from the anaerobic digestion process respectively, at the Yongho NTP: the Zimpro sludge is left to ferment without the addition of other organic material. The fermenting period lasts 30 days during which the temperature rises to 50°C, and the water content of the sludge drops from about 70% to 30%. This compost is mainly used in fruit cultivation (e.g. kaki) which is intensively practised on Cheju Island off the southwestern coast. The other sludge is co-composted with one or more of the following materials: bran from tapioca[1] distillation, fish meal waste, chicken manure. Zeolite is reportedly added to secure a well-structured material with sufficient pore space and to regulate alkalinity[2]. This compost is sold to farmers in the Kimhae District who use it mainly for

[1] granular preparation of cassava starch

[2] Reportedly, farmers use zeolite also directly on their fields to secure a good soil structure

cultivation of cash crops such as vegetables, salads, grapes, strawberries and flowers. These crops fetch good market prices in the nearby city of Pusan. Some vegetables are also sold to markets in Seoul. A number of farmers grow these crops both in summer and in winter, when they cultivate them in greenhouses. The compost is not used for lowcash crops such as rice and barley. Average nutrient contents of the sold compost amount to N ≅ 2.5%[1], P ≅ 1% and K ≅ 1%. The organic carbon content totals approx. 40%. Some farmers who use nightsoil compost also use chemical fertilizer at a rate of 3 kg per 20 kg of compost. Compost produced from Zimpro sludge is sold at W 1200/25 kg, while the compost derived from other NTP sludge is sold at W 1500/20 kg (1985 prices)[2]. In 1985, NPK chemical fertilizer cost W 6300/25 kg.

- Rural Areas

Traditionally, all nightsoil produced by the rural population living in farm villages has been applied to the land, often in a practically raw stage, partly after storage over a limited period of time in the latrine or in field storage pits, and partly upon composting with farm manure or plant residues. The traditional rural latrine is a family pit latrine arranged as shown in Fig. 10.3. In many farmhouse latrines, faeces and urine are collected separately. Until about World War II, vegetable cultivation which mainly received nightsoil, was practised in spring and autumn. This allowed during the interim season for considerable storage periods of the nightsoil. Thereby, plant damages (caused by nitrogenous compounds?) could be avoided. The population increase after World War II lead to an increase in nightsoil generation and the general economic growth in the country called for an intensification of agricultural production. This, in turn, lead to an increased demand and use of nightsoil and, consequently, shorter storage periods. Due to the risk of parasitic disease transmission through this kind of practice, the Ministry of Home Affairs (MOHA), which is the authority responsible for rural sanitation, initiated a programme for the introduction of a 3-vault latrine. Such latrines allow for extended storage of nightsoil prior to use. It appears, however, that the respective programme has as yet only reached limited coverage.

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[1] % of dry matter

[2] W (Won) 880 = 1 US $ in 1985
(W 1000 = 1.14 US $)

Nightsoil and septage from small towns is nowadays collected and treated in small NTP's, where such plants already exist. This applies to a number of towns in the Kimhae District W of Pusan. The waste is collected by contracting firms and treated in an NTP in Chinyong. Kimhae, the district capital, has its own NTP. Nightsoil collection and treatment are under the control of the District Administration (Dept. of Social Affairs). At the Chinyong NTP, nightsoil is treated by anaerobic digestion. The resulting sludge is dried in drying beds and sold or given away to farmers free of charge. They then mainly use it for fruit tree cultivation.

The population of Kimhae District amounted to 98,000 inhabitants in 1985 (excluding Kimhae town) living in one town ("Eup") and 9 villages ("Myeon"). 80% of the families use traditional latrines, the contents of which are composted with farm wastes. 20% have flush toilets and septic tanks. In a village 8 km W of Kimhae which was visited to observe traditional toilets installations, 25 (70%) out of a total of 35 families have traditional toilet whereas the others use flush toilet/septic tank systems. All families make use of the nightsoil or septage, i.e. it is not hauled away from the village. Rice is the main crop grown in the area. Like in other areas around Pusan, greenhouse cultivation of vegetables is practised in the winter months. One family interviewed owns 1 ha of farmland were it cultivates rice and kaki trees. The nightsoil-containing compost is mainly used on the rice fields.

On passing through a greenhouse area, the team talks to a young farmer and his wife who are about to plough their greenhouse field. The farmer is a high school graduate who worked as a surveyor in the Pusan city administration prior to becoming a greenhouse farmer six years ago. The cultivation of vegetables pays off better than rice, and as a vegetable farmer he can earn more than in his previous employment. Apart from the greenhouse field which he rents from the government, he owns about 2 ha of agricultural land at a different location. There are two growing cycles during the winter cultivation period: cabbage, a staple vegetable, is grown from December to March, and tomatoes are grown from March till May. The farmer applies compost to the greenhouse land once at the beginning of the winter cultivation season in December and ploughs it into the earth with a small tractor mixer. He has to purchase the compost which is made up of cattle and chicken manure as he does not have cattle himself. Asked about the use of nightsoil as a component of compost, the farmer responds that he does not like to use composted nightsoil. He mentions that, while farmers of his parents' generation still were useing nightsoil, this practice is not common among younger farmers anymore. The nightsoil from his house located in the village is collected by vacuum tankers and treated in the Umgung NTP in Pusan. Some of his neighbour farmers in the village do use composted nightsoil purchased from the fertilizer factory.

10.3 Institutional and Regulatory Framework

- Regulations

The Waste Cleaning Law and the complementary enforcement ordinances and regulations, promulgated in 1961-62, which were later repeatedly amended (WHO/WPRO 1985) form the legal basis for collection, treatment and disposal of all non-hazardous wastes including nightsoil and domestic sewage. The law specifies that its provisions are to apply to the "Special Cleaning Areas" which are defined as those urban areas having a population density of > 1000 inhabitants per km^2. In these areas, all nightsoil must be collected and treated. Most areas in the larger cities fall under the Special Cleaning Area Clause. City authorities may exclude areas from these regulations if they total < 1000 inhabitants/km^2, or if they are surrounded by mountains, hills or forests. On the other hand, provincial authorities may designate specific areas to fall under the Special Cleaning Area Clause. A further law, the Waste Disposal Law, was promulgated in 1973. **It prohibits the agricultural use of untreated nightsoil** and sets forth the requirements for nightsoil treatment (Yao 1978). This law was merged with the Environment Preservation Law in 1986 to form the **Waste Management Law** (Lee 1988).

The law stipulates standards for the liquid effluent of NTPs: maximum levels of total coliform, BOD and suspended solids are established at 3000 MPN/100 ml, 40 mg/l and 70 mg/l, respectively. Standards for the hygienic quality of composted NTP sludge did not exist in 1985.

City and district authorities are responsible for the proper collection, treatment and disposal or use of nightsoil in their respective areas of jurisdiction. This includes responsibility for the operation and maintenance of NTPs. The Law explicitly allows for the operation and maintenance of NTPs to be also contracted out to private companies.

- Institutions

A number of institutions are involved in the management of nightsoil, wastewater and refuse. The important institutions along with their major responsibilities are listed below (Asian Development Bank 1984).

Authority	Major tasks
• Ministry of Health & Social Affairs (MoHSA)	• Planning and implementation of piped rural water supplies

Authority	Major tasks
within MoHSA: Environment Administration (EA) (previously Office of Environment)	• Environmental protection; planning and implementation of NTPs
within EA: NIER, National Institute of Environmental Research, previously designated National Environmental Protection Institute (NEPI)	• Research and development[1] on treated nightsoil use, nightsoil storage and treatment, NTP performance evaluation
• Ministry of Home Affairs (MoHA) within MoHA: Saemaul Undong (SU), the New Community Movement	• Planning and control of rural sanitation improvement programmes
• Ministry of Construction (MoC)	• Policy setting, planning and financing (incl. subsidies) for urban water supply and sewerage (excluding NTPs).
• City and district authorities	• Operation and maintenance of NTPs, securing of proper collection, treatment and diposal of nightsoil

[1] some nightsoil-related activities as per Dec. 1985

10.4 Health and Epidemiological Aspects

- Components of the Health Situation

In this section, discussion will not be limited to water and excreta-related infections but these will be discussed in the wider context of the most important causes of morbidity and mortality in the country. This will allow the reader to assess the importance of the water and excreta-related infections that might be associated with the waste reuse practice in comparison with the predominant diseases in the area. The reader is also referred to section 1.2, where the health risks associated with wastewater use have been summarised, and to section 1.4, where the difficulties involved in evaluating the health effects of a specific reuse practice have been outlined. The data available do not allow an accurate assessment of the health risks to be made, so the following sections contain epidemiological judgements which should be considered as "informed speculation" rather than strict scientific analysis.

The changes in the rates of infectious diseases since the 1960s have to be set in the context of the rapid development of the country and the improvement in social services. Selected trends in socio-economic and health indicators are shown in Table 10.2. Improvement in health indicators occurs alongside improved economic conditions. Trends in the major causes of death are indicated in Table 10.3. It can be seen that chronic diseases have generally replaced infectious diseases as the major causes of death; the top three causes of death in 1958-59 were pneumonia and bronchitis, tuberculosis and enteritis whereas in 1980 they were malignant neoplasm, cerebrovascular disease, and accidents.

There has been a dramatic reduction in the incidence of water and excreta related diseases since the mid-60's. This is illustrated by the case of typhoid fever (Fig. 10.3) where the reduction was greatest in the early 1970s. Enteritis was still a major cause of death in the 1960s but by 1974 was no longer in the top ten causes of death (Table 10.3). Parasite infections were highly prevalent but have now decreased to very low levels. During the period 1969 to 1985 the helminths egg positive rate in schoolchildren decreased from 73.1% to 4.3% and the prevalence of *Ascaris* decreased from 56.0% to 2.3% (KAPE 1985). This was partially due to a major control programme run by the Korea Association for Parasite Eradication (KAPE). Schoolchildren in primary, middle and high schools all over the country received anthelminthis chemotherapy every spring and autumn. The results of examinations from 1976 to 1985 are shown in Table 10.4. KAPE's specific objective is to achieve 0% *Ascaris* prevalence. Recently, additional drugs have been given to assist in the control of cysticercosis and clonorchiasis.

Table 10.2 Trends in Socio-Economic and Health Indicators in South Korea from 1975 to 1983

		1975	1980	1983
Per capita GNP ($)		591	1605	1880
Health expenditure (%) as proportion of total consumption expenditure	Urban	4.0	5.2	6.8
	Rural	3.7	4.5	5.1
Population per physician		2100	1690	1509
Proportion of population with piped water		43.1	54.6	59.4
Infant mortality rate (1000 births)		41.4	36.8	34.2
Maternal mortality rate (1000 births)		56	42	38
Morbidity rate (%)	Male	6.5	8.3	7.1
	Female	7.4	10.0	8.1
Rate of parasite positive (%)		66.0	21.8	9.2

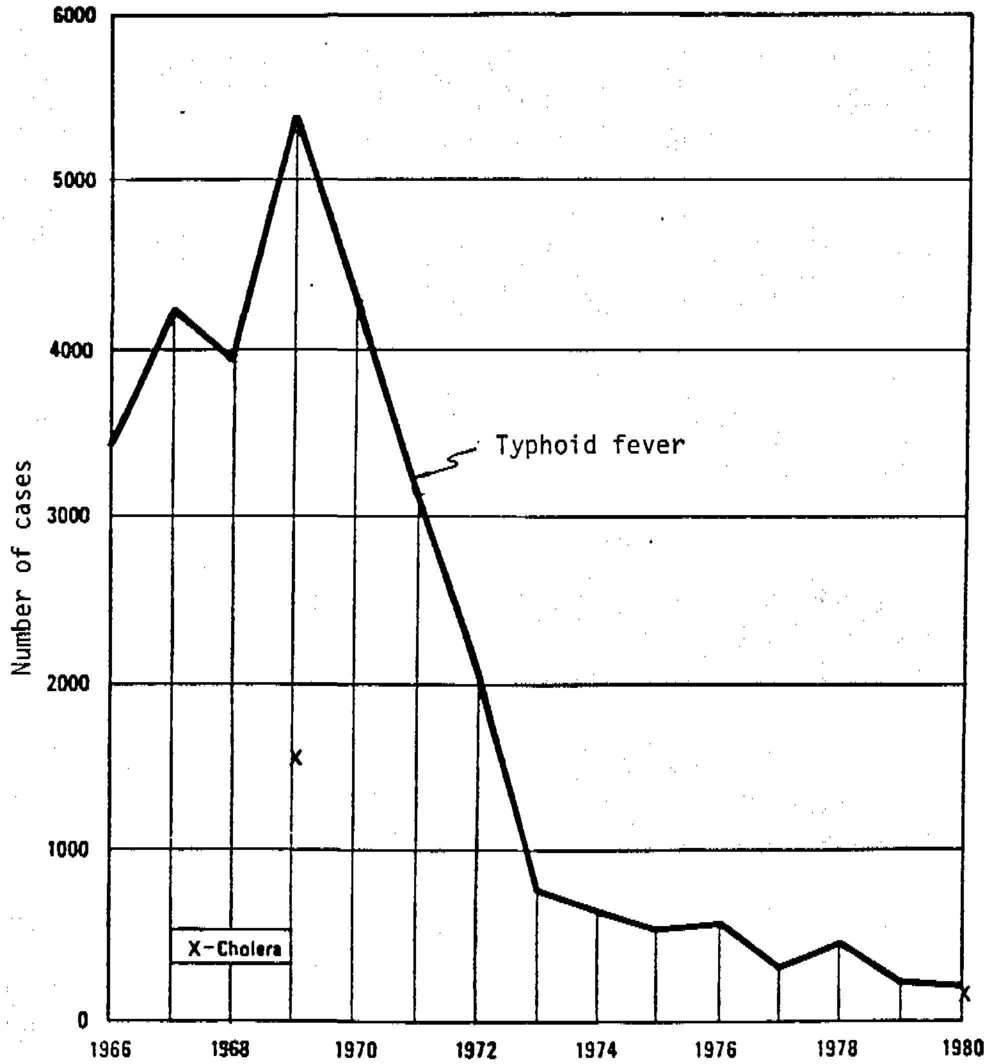
Source: Korea Institute for Population and Health, 1984.

Interest in research into intestinal infections has decreased, as the prevalence of these infections in the community has decreased. With respect to intestinal parasites, there appears to be a feeling among parasitologists that the problem has been solved: research has now moved into different areas. There is still interest among some public health engineers, however, to put into effect further measures to reduce the potential for transmission of infection, and not rely on chemotherapeutic measures.

Table 10.3 Trends of Major Causes of Death and Death Rate by Cause in South Korea: Ranking of Death Causes and Incidence Rates in No./100,000

Order	1958-59	1966-67	1974	1979	1983
1.	Pneumonia, Bronchitis (73.8)	Pneumonia, Bronchitis (43.8)	Malignant neoplasm (43.5)	Cerebrovascular disease (93.7)	Malignant neoplasm (92.4)
2.	Tuberculosis (39.5)	Tuberculosis (35.8)	Cerebrosvascular disease (40.3)	Malignant neoplasm (74.0)	Cerebrovascular disease (76.2)
3.	Enteritis (31.0)	Cerebrovascular disease (26.1)	Hypertensive disease (38.6)	Other forms of respiratory disease (73.1)	Accidents and adverse effects (76.2)
4.	Malignant neoplasm (25.8)	Malignant neoplasm (25.8)	Accidents (32.1)	Hypertension (54.5)	Hypertensive disease (66.7)
5.	Cerebrovascular disease (196.)	Enteritis (14.2)	Tuberculosis or respiratory disease (21.9)	Accidents (44.4)	Poisoning and toxic effects (39.0)
6.	Heart disease (8.5)	Accidents (12.8)	Bronchitis, Emphysema (20.0)	Tuberculosis (30.7)	Heart attack (33.5)
7.	Accidents (8.2)	Heart disease (11.7)	Pneumonia (17.0)	Chronic liver disease and cirrhosis (24.1)	Chronic liver disease and cirrhosis (27.5)
8.	-	-	Other forms heart disease (16.0)	Poisoning and toxic effects (20.0)	Tuberculosis (25.8)
9.	-	-	Cirrhosis (12.4)	Pneumonia (19.8)	Suicide (20.8)
10.	-	-	Symptoms, signs and ill-defined conditions (33.6)	Bronchitis, Emphysema, (15.2)	Symptoms, signs and ill-defined conditions (71.8)

Source: Korea Institute for Population and Health, 1984



Source: Ministry of Health and Social Affairs
(Asian Development Bank 1984)

Fig. 10.3 Incidence of Typhoid Fever in South Korea

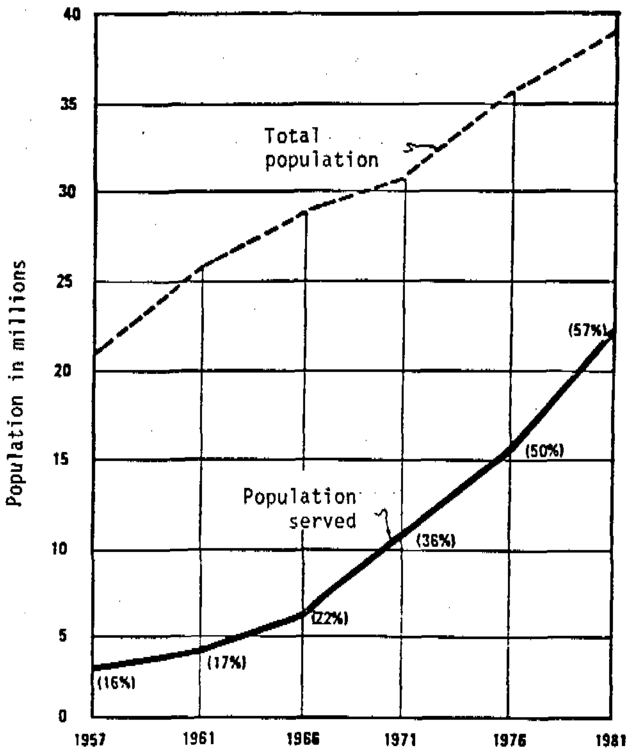
Table 10.4 Helminth Prevalence: Bi-Annual Results of Country-Wide Mass Examination of School Students (Selected Parasites)

		Proportion eggs positive %	*Ascaris lumbricoides* %	*Trichuris trichura* %	Hookworms %
1976	Spring	50.8	39.1	26.6	0.03
	Autumn	39.7	27.8	20.7	0.03
1977	S	46.0	35.8	21.0	0.02
	A	32.7	23.4	14.6	0.009
1978	S	33.4	24.5	15.4	0.01
	A	22.4	14.2	11.1	0.01
1979	S	25.9	17.8	12.4	0.01
	A	20.4	12.3	10.5	0.003
1980	S	22.8	14.6	11.2	0.003
	A	16.3	9.5	8.3	0.003
1981	S	18.1	12.3	7.8	0.006
	A	13.7	8.1	6.5	0.004
1982	S	14.0	8.4	6.8	0.002
	A	9.9	5.3	5.0	0.002
1983	S	9.3	5.2	4.5	0.001
	A	7.4	4.2	3.5	0.002
1984	S	6.2	3.6	3.0	0.001
	A	4.8	2.5	2.3	0.002
1985	S	4.3	2.3	2.1	0.002

Source: Korea Association for Parasite Eradication, 1985

• Water Supplies and Hygiene Behaviour

The proportion of the population served with a piped water supply steadily increased from 16% of the total population in 1947 to 57% in 1981 (Fig. 10.4), Asian Development Bank, 1984). This was done through water supply programmes in the urban areas and in the larger villages (over 20 houses). As a result, coverage increased to 80% of the urban population and 75% of the larger villages. The lower income populations, however, living in the fringe areas of the rapidly developing urban areas and in the smaller villages were not initially provided with improved water supplies, although plans exist to achieve higher coverage in these areas. The improvement in



Note: The figures in parentheses indicate the service ratio

Source: Ministry of Construction
(Asian Development Bank 1984)

Fig. 10.4 Increase in Percentage of Total Population Served with Piped Water Supply

piped water supplies is thought to have contributed to the decrease in the rate of diarrhoeal diseases in the country.

Patterns of hygienic behaviour have also changed over the years. For example, traditionally either water or rice straw was used for anal cleansing. In the 1950s many people switched to using newspaper. Following increased industrialisation in the 1970s, most people in urban areas were using toilet paper by the 1980s although in the rural areas, newspaper is still used. With increasing education levels and public health campaigns, there is an increased awareness of the relationship between enteric disease and hygiene practices. More people are aware of the risk of transmission of parasitic infection through exposure to nightsoil. Nightsoil treatment plant workers were observed to wear gloves to handle the sludge from the plant, and agricultural workers mostly wear boots and often gloves as a health protection measure.

There is now some reluctance to use nightsoil derived products in agriculture, particularly among younger people, who prefer to use chemical fertilizers or compost using animal manure. This may be related to a desire to preserve the increased health standards that now exist. There may now be an over-cautious attitude and an unwillingness to use products which are in fact safe.

- Potential Impact of the Existing Use Practice

The **use of nightsoil** in agriculture has **decreased** over the last two decades (see sect. 10.2, Table 10.1). Although the use of untreated nightsoil is now prohibited in the urban areas (designated as special "clean" areas), it is still allowed in the rural areas. The extent of use of nightsoil from traditional latrines in the **rural areas** is hard to estimate, but from data in Kimhae district (sect. 10.2), one may speculate that 70-80% of rural households may use **nightsoil composted with agricultural wastes** (often rice straw) and manure. The risks associated with this practice will depend on the level of microorganisms present in the nightsoil, the length of storage, the temperature reached in the compost pile and whether regular turning of the compost takes place. No data were located on the temperatures reached within traditional compost piles, or on the concentration of helminth eggs wihin them. With reference to the time-temperature graph for excreted pathogens (Strauss 1985, p.II-3; Feachem et al. 1983), it is likely that helminth eggs will survive the composting process unless high temperatures are reached in the compost piles or unless the storage period at ambient temperatures prevailing in South Korea is at least one year. It is possible, therefore, that in some cases this practice carries a risk to compost handlers, in particular for helminth infections. If the compost is used to fertilise vegetables subsequently eaten raw, it is possible that there is also a risk to crop consumers.

The **sludge from the nightsoil treatment plants** is used (after dewatering) in two ways - directly on the fields, or after having been composted. In wastewater treatment systems, helminth eggs are often found in the sludge component. In nightsoil treatment, the existence and survival of helminth eggs in the sludge phase will be affected by the process used. In the Zimpro wet oxidation process, for example, temperatures of 240°C are reached, which is lethal to helminth eggs. In the anaerobic digestion process, however, the temperature reached is only 37°C and retention times are only about 28 days; helminth eggs would remain viable through this process.

Any helminth eggs left in the sludge produced by nightsoil treatment are likely to die if the sludge is subjected to thermophilic composting process. In the compost plant visited in Jinyoung, the sludge that is mixed with tapioca waste reaches a temperature of 60°C and that mixed with chicken manure reaches a temperature of 70°C. At times, fish meal waste and zeolite are also co-composted with the sludge. The detention time in the pile is about 15 days. Using the time-temperature graph for excreted pathogens, no pathogens are likely to survive this process.

It is therefore likely that the use of compost made commercially using dewatered nightsoil sludge causes **no risk** to the people handling it or to people eating any vegetables grown with it. Any sludge used directly, i.e. without prior composting, is generally used for fruit trees and not for vegetables. Some sludge may contain viable helminth eggs which could cause a potential risk to workers handling the sludge. The **decrease in helminth infections** over the last two decades has been ascribed partially to the treatment campaign of KAPE and partly to the banning of the use of raw nightsoil in agriculture. The level of helminth infection in the community is now very low, such that the nightsoil will also contain a low concentration of helminth eggs. After treatment, and particularly after thermophilic composting, any risk will have been reduced or removed totally. Studies of pathogen die-off within the compost piles would be useful, to verify or refute these tentative conclusions. Also, the composting operation should be monitored to verify whether all parts of the composting material become subjected to the high temperature (>55°C) which leads to a rapid pathogen die-off. Such studies would help to promote the use of sludge compost, if it could be demonstrated that it did not contain living pathogenic organisms. Epidemiological studies of any risks related to the practice would only be suitable if microbiological studies showed pathogenic microorganisms to be present in the sludge in significant concentrations.

- Implications for the Control of Health Risks

Use of nightsoil composted with agricultural wastes in rural areas could cause a health risk. Decreasing the risk could be done by several methods:

i. increasing the storage time to one year or more

ii. taking increased care of the compost pile, including regular turning, to increase the temperatures reached in the pile

iii. the compost could be dug into the ground prior to planting and not added during the growing season.

Using methods (i) and (iii), or a combination of (ii) with additional precautions, would allow vegetables to be grown with the compost. In method (iii) the person handling the compost would need to take precautions to avoid direct exposure to the compost. This may involve wearing gloves, or using farm implements and increasing personal hygiene standards. Restricting the crops grown would only be necessary if compost that had not been stored for long was used during the growing season.

The use of uncomposted sludge produced by the anaerobic digestion process may carry a small health risk. This can be avoided by digging the compost into the ground prior to planting of vegetable crops (as above) or by using the sludge on a restricted range of crops. If this is used on fruit trees, there will be no consumer risk, but workers handling the sludge would need to avoid exposure, e.g. by the wearing of gloves. Studies of pathogen content, however, may reveal that there is no risk and that these precautions are unnecessary.

The composted sludge has in effect received "full treatment", and can be used on an unrestricted range of crops, with no further health protection measures being necessary. In fact, the use of such compost made from nightsoil sludge as a fertilizer or soil conditioner could probably be encouraged without increasing health risks and, in particular, without causing a rise in helminth infections (from original "potential impact of practice").

10.5 References

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11 DISCUSSION

The two examples presented under the heading "Excreta Use in Agriculture" have quite contrasting features: in **Guatemala**, the use of stored excreta is a recent development, introduced through rural sanitation programmes of both non-government and government organizations. The double-vault latrine with urine separation plays a crucial role in this: it allows the proper storage of excreta for an adequate period of time, after which the farmers use it on their fields. Small farmers, many of whom are cultivating land with poor soil, mention that the main advantage of this latrine is the fact that the stored excreta can be used as a fertilizer and soil conditioner. This is what motivates them most to use such a latrine. Excreta are indeed the most readily available fertilizer and soil conditioner and of particular value to those not being able to afford the ever increasing costs of chemical fertilizer.

In contrast to rural Guatemala, the use of nightsoil appears to be diminishing in **South Korea**. The rapid economic development led to the installation of an increasing number of sewered excreta disposal schemes and to the increased use of mineral fertilizer. The use of untreated nightsoil, which is a century-old practice, was soon prohibited. The overall economic growth, the per capita increase in income and the rigorous health campaigns are further reasons for the decline in the use also treated nightsoil. Similar to other countries with strong economic growth, the use of nightsoil or nightsoil-derived products is apparently not in line with the "modern" perception of hygiene and agricultural fertilization. "This (use of nightsoil) is something our forefathers did, we are buying cattle manure and mineral fertilizer for our greenhouse farm", a young farmer told us. Nowadays, only part of the dewatered sludge from nightsoil treatment plants is therefore used in agriculture. The non-use of large quantities of this sludge is a waste of valuable resources. In contrast to sewage treatment plant sludge which, in industrialized countries, now often contains heavy metals and refractory organics in harmful concentrations, sludge from nightsoil treatment plants is free of such contamination. What remains is the potential risk of disease transmission through pathogens. However, this is being minimized through proper treatment of the sludge (e.g. co-composting with cattle manure) and high levels of personal hygiene.

C - WASTEWATER USE IN AQUACULTURE

12 INDIA (CALCUTTA)

Acronyms

NICED	National Institute of Cholera and Enteric Diseases (Calcutta)
IWMED	Institute of Wetland Management and Ecological Design (Calcutta)

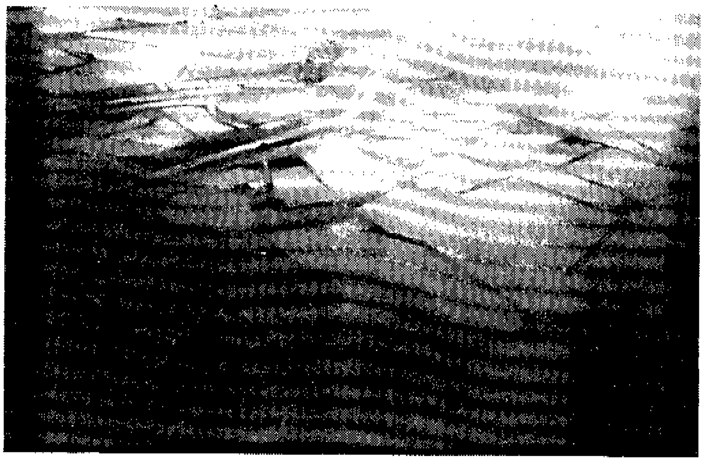

Photo 12.1

Aerial view of the Calcutta wastewater-fed fishponds

Photo 12.2

Wastewater-fed fishponds in the Calcutta Wetlands

Photo 12.3

A sewage outfall feeding into fish-ponds. The farmer in the background irrigates a vegetable field with water from a pond across the waste-water canal

Photo 12.4

Vegetable cultivated on land reclaimed from the Calcutta main garbage dump and irrigated with water from wastewater-fed fishponds

Photo 12.5

A man washing clothes in a wastewater-fed fishpond

12.1 Main Features and History of the Calcutta "Wetlands"

Fish are an important part of the diet of Bengalis. It has been estimated that there are over 100'000 ha of fish ponds in West Bengal which are under active cultivation. Fish consumed in Calcutta are brought there not only from inland fisheries in West Bengal but also from other areas in India, as well as from brackish water and sea fisheries.

The map in Fig. 12.1 shows the location, present-day extension and the major sewage conveyance system of the East Calcutta sewage fisheries which are the largest of their kind in the world. The reported figures about the present total pond area are conflicting and range from 2'500 ha (6'000 acres) to 5'000 ha (12'500 acres)[1]. Photos 12.1 and 12.2 are aerial and terrestrial views of the Wetland. Photo 12.3 shows a small sewage outfall feeding into fish ponds.

Edwards (1985) provides an account of the historical development of the sewage fisheries. Between 1875 and 1935 the sewage of Calcutta was discharged into the River Bidyadhari, but this gradually became silted up due mainly to the conversion of a vast area of waterlogged swamps, that formed the spill area of the river into salt water ponds. As the silting of the river progressed, water exchange in the fishponds became difficult, and as the volume of sewage discharged from the city increased, the level of water pollution increased. Eventually the cultivation of salt water fish (e.g. sea bass, mullet and prawns) became impossible and the land became an undrainable swamp. The discovery by a landowner that carp could be cultivated by letting in small doses of sewage to the swamps was made in 1930, according to Edwards (1985) and the whole area was soon converted to a freshwater aquaculture system. Furedy and Ghosh (1984), however, trace the use of sewage in fish culture back much further and suggest that it was widely practised by traditional fisherfolk since the beginning of the century.

The construction of two channels, the dry weather flow (DWF) channel for sewage and the storm water flow (SWF) channel for stormwater, was begun in 1935, to take the wastewater of the city to an outfall at Kulti (an estuarine tributary of the River Royamangal), so bypassing the silted-up River Bidyadhari. The DWF channel leads to two sedimentation tanks at Bantala, built in 1943 to avoid deposition of sewage solids along the 27 km long

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1 Information contained in this chapter is derived from own observations and discussions with officials and researchers in Calcutta, as well as from documents by Furedy and Ghosh (1984), Ghosh (1985a,b), Edwards (1985) and Ghosh and Sen (1988).

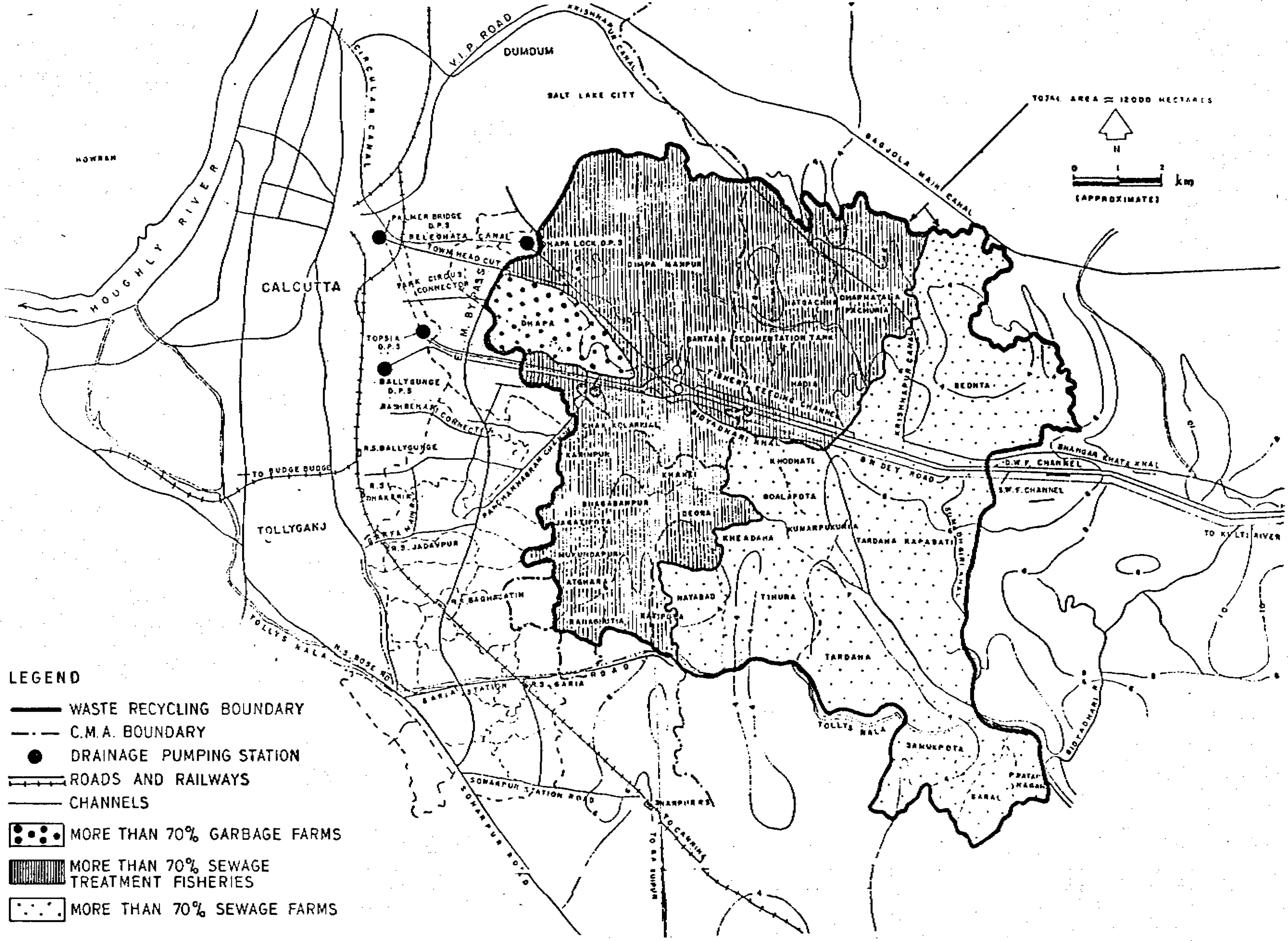

Fig.12.1 The Waste Recycling Region of East Calcutta (Ghosh 1985 b)

channel. However, both the tanks and DWF channel are inadequate to cope with the volume of Calcutta sewage today, and SWF is now another sewage channel, and much crude sewage is discharged into the river. The sedimentation tanks are not in operation anymore.

Previously, the area of Salt Lake City (see Fig. 12.1) also consisted of sewage fisheries. The "salt lakes" to the north of the present Wetlands were filled in to create the building ground for the new suburb. The pressure on the Wetlands continues to exist, both from creeping urban sprawl (residential and industrial) and, apparently on a large scale, from planned new town developments. The construction of the eastern metropolitan bypass road which runs along the western border of the Wetlands, has further enhanced pressure on land from real estate developers. There is strong opposition from fishery owners and farmers who cultivate the garbage-filled grounds at Dhapa at the western fringe of the Wetlands. Opposition also comes from those planners, administrators and researchers who see the Wetlands as a unique and vital ecological "niche" where the wastes from the city can be absorbed, converted and recycled in a productive manner. Also, the Wetlands act as a sponge-like system to absorb the drainage water of the city. Reportedly, Calcutta metropolitan authorities issued a decree in 1985 which, as some people hope, will prevent further loss of wetland area, at least for the near future.

Effluent from the pond system is used downstream to irrigate an area of approximately 6'500 ha on which 3'000 families have full or partial income (Ghosh 1985b). In this area mainly paddy is grown.

The Dhapa grounds which serve as landfill for Calcutta's garbage are another important component of the East Calcutta waste recycling area. 2,000-2,500 tons of garbage are dumped at Dhapa daily. An estimated 20,000 garbage ("rag") pickers separate out reusable material which is then streamed back into the city (Furedy and Ghosh 1984). What remains is decomposable organic material and is continuously reclaimed and put under cultivation. In this way, more than 800 ha of "garbage farms" have come into being in the past decades, which provide income to about 2'000 families. Ghosh (1985a) estimates that 140 tons of vegetables are brought daily from Dhapa garbage farms to Calcutta markets. Many different vegetables are grown throughout the year, among them cauliflower, raddish, spinach, yam and potatoes. Wastewater is at times used to irrigate the vegetable fields. Photo 12.4 shows the garbage farming and irrigation.

12.2 Owners and Fishermen

There are, reportedly, 160 owners of fish ponds in the Wetlands area. The majority of the ponds are owned by city dwellers who each employ between 50 and 200 fishermen, most of them on a seasonal basis. Based on information collected by Ghosh (1985b), 3'980 families with 24'000 people live in the pond area which is given as 4'800 ha. The size of individual pond holdings varies considerably, with maximum holdings amounting to 400 ha. The fishermen families live in small villages which are clustered in between the ponds. The social links among the fishing population are, reportedly, rather strong. This provides the fishermen a political status which can not easily be neglected.

There are several fishermen's cooperatives, one of which, the "Captain Bhery Fishermen's Cooperative Society", was visited by the team. The Society was founded in 1927 and has 16 ha of net pond area bordering the eastern metropolitan bypass. It comprises 34 families who are divided into two groups which take turns for fishing and night-watching. There are, on the average, five members per family. The majority of today's members are offspring of the founder members and belong to the cast called "Macchua" ("fish sellers") or "Jayli" ("Jal"- water). Most families live in clustered groups of houses in the vicinity of their ponds. Drinking water supply is through shallow tube wells which provide water also for washing. Some ponds are used for washing and bathing though it is not clear how widespread this practice is (Photo 12.5). There exist overhung latrines. Records of production, assets, wages paid and social benefits granted to the members of the Society are rather impressive. Productivities of 4-5'000 kg fish/ha·yr are attained. In 1987-88, fish were sold to fish traders for Rs. 12/kg. The average per-family-income amounted to about two and a half times the official minimum wage (Bartone 1989). The Society is leasing the ponds from the Calcutta Additional District Magistrate for Land and Revenue. The fee for this was 15'000 Rupees/yr in 1985.

12.3 Fish Production and Pond Operation

Fish are mostly grown in polyculture[1]. Stocking densities of 30-50,000/ha are reported (Ghosh 1985a). Traditionally, only the indigenous Indian major carps ("Rohu", "Cetla" and "Mrigal") were grown. Later, Chinese (Silver, Grass and Cyprinus) carps and tilapia (American rui) were introduced. The average, long-term yield amounts to approx. 1,200 kg/ha·yr (Ghosh and Sen 1988). Yields as high as 3-4,000 kg/ha·yr have been reported (West Bengal Fisheries Department, personal communication). Fish production is seasonal, with the main harvesting done between October and February (Edwards 1985).

It is estimated that about 20 tons of fish are brought daily to markets in the Calcutta metropolitan area from the sewage fisheries. This is thought to constitute 10-20 % of the fish consumed in Calcutta. Reportedly, relatively small fish ($\geq$300 g) are produced in the Wetlands while the larger fish are from other sources.

Fishing is done during darkness in the early morning hours. The fishermen wade through the ponds and catch the fish with nets. The fish are then tranported to auction markets alongside the ponds from where they are taken to markets within the city. Most of the catch is purchased by consumers before 7 or 8 a.m.

Sewage which feeds the extensive pond system is pumped and then conveyed by gravity from the city through two main canals, one of which was originally built as dry weather flow (DWF) and the other as storm weather flow (SWF) channel (see also Fig. 12.1). They feed into the complex system of secondary and tertiary channels, from which sewage is then fed into the ponds. The flow into ponds is regulated by simple gates.

Problems occur reportedly because the regular supply of sewage is not always maintained. A committee comprising representatives of pond owners, land owners (who use sewage downstream of the ponds) and Calcutta city authorities exists to deal with problems of common concern.

Over years and through the generations the fishermen have developed "empirical" skills in handling the wastewater and optimizing fish production. This includes e.g. the judging of pond water quality by taste, smell and eye-sight, on the basis of which the inflow of sewage is regulated. Many ponds are regularly emptied to remove accumulated sediments and sludge. Thereby, excessive oxygen demand caused by decomposition processes in the sediments is avoided and the effective pond volume is regularly renewed. Minimum oxygen concentrations in ponds, as measured in 1983, occurred at 4-6 a.m. and ranged from 2.5-4.5 mg/l (Ghosh 1985a). Reportedly, some ponds are not routinely maintained, a problem which has been emerging in recent years.

It can be concluded from this that, through the batch loading of sewage the fishermen can exert a close control over the organic loading of the ponds (in terms of kg BOD/ha/day). This, in turn, determines the oxygen levels in the ponds which are decisive for the fish to be able to live in this environment. It also affects the hygienic quality of the pond water.

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[1] "Polyculture" means the simultaneous culturing of more than one kind (species, genus or family) of fish in the same pond. The different kinds occupy different layers of a pond depending on the kind of food they live on and environmental conditions in the pond, thereby contributing to a balanced pond ecology. Different types of fish inhabit different layers of a pond, e.g., depending on the oxygen concentration which varies with depth. Bottom feeders, e.g., stir up the sediments, and through their movements release nutrients from the sediments into the water column and contribute to the oxygen exchange within the water column.

The fact that fish thrive in these wastewater-fed ponds lets one assume that the BOD loading of the ponds with untreated sewage must be rather low. The reported low coliform levels in the pond water (see below) indicate that sewage retention times must apparently be rather long (1 month or more?). Data presented at the International Seminar on Wastewater Reclamation and Reuse for Aquaculture, held in Calcutta in 1988, allowed indirect order-of-magnitude estimates of pond loading rates to be made (Bartone 1989). They do, in fact, reveal that organic loading rates in the Calcutta Wetlands are between 6-22 kg BOD/ha/day, i.e. in the order of 10-40 times lower than loading rates for facultative ponds, in which fish would not be able to survive.

12.4 Pond Water Quality Related to Health

The quality of sewage entering the Wetlands, and of the water in the ponds, influences the successful management of fish production and acceptability of the fish with respect to public health safety. Pathogenic organisms and heavy metals are the two most important parameters.

Excreted pathogenic organisms which are present in sewage might be taken up by the fish and retained primarily in the intestines. Counts of indicator bacteria of around 10^5-10^6 TC/100 ml in inflowing sewage and 10^2-10^3 TC/100 ml in the pond water are reported (Ghosh 1985b). *Vibrio parahaemolyticus* has been found in the intestines of fish grown in sewage fishponds in the course of an investigation by NICED (see Chpt. 12.5) although, normally, the natural habitat of the vibrios is the **marine coastal environment** and transmission is via inadequately cooked or cross-contaminated cooked seafood. *V. parahaemolyticus* is second in importance after *V. cholerae* as diarrhoea-causing agent in the Calcutta area (Sakazaki et al. 1971).

Heavy metals, if contained in sewage in high enough concentrations will constitute a serious health risk. They may accumulate in the fish, and be taken up by the consumers. To date, heavy metal concentrations in sewage fed to the Wetlands have reportedly been below levels which would pose a risk to the Wetland ecosystem or to the fishermen and fish consumers. Industrial wastewater discharges appear to either be small and therefore sufficiently diluted by the municipal wastewaters or well controlled, being discharged separately from the main municipal sewage channel feeding the Wetlands. Close monitoring of industrial discharges, however, and measures by which heavy metal pollution can be avoided are of importance for the conservation of the Wetlands, since pollution from industrial discharges could be of greater longer-term danger than the current risk of communicable disease transmission.

12.5 Health and Epidemiological Aspects[1]

There have been no epidemiological studies carried out on the populations in Calcutta to assess the risk attributable to the use of sewage in the aquaculture ponds. There have also been no systematic microbiological studies in representative aquaculture ponds reported which assess the level of pathogenic organisms present in the inflowing sewage or in the pondwater itself. The only health-related data available are those suggesting that the concentration of indicator bacteria in the pondwater is around 10^2-10^3 total coliforms/100 ml. There is, at present, **insufficient data** on which to base an authoritative assessment of the health risks of the current practice. The possible risks will, therefore, be described and a judgement made on their implications.

The population groups that could be at risk from the current practice are the **fish consumers**, the **fishermen** who have occupational contact with the water when they harvest the fish, and persons who have **domestic contact** with the contaminated water. The diseases of most interest would include diarhoeal diseases, typhoid fever and hepatitis A. Intestinal nematode infections are likely to be less important than where irrigation with wastewater is practised since they are generally soil-transmitted, and the eggs would probably settle to the bottom of the fish ponds during the retention of the water. Trematode infections, including schistosomiasis and chlonorchiasis, are not important since Calcutta is outside the endemic area for both infections. Protozoan cysts (e.g. *Giardia* and *Cryptosporidium*) are likely to be present in the upper layers of the water, and could possibly constitute a risk, although the transmission route is unclear. Viral infections are likely to be less of a problem than bacterial infections, since immunity is likely to be developed at an early age, if the infection is circulating in the community. The infections of most interest that could be spread through sewage use in aquaculture in India are therefore the diarrhoeal diseases and typhoid fever.

The health risk to consumers will depend on the microbiological quality of the fish, the extent of cooking the fish before eating, and hygiene practices in the home (as in Chpt. 13.3.). No data are currently available on the microbiological quality of the fish; studies are being started by researchers at IWMED. Data from Peru suggest that coliform counts in the digestive tract contents of fish are higher than in water samples (Noé M. et al. 1984). The critical level is the threshold concentration of the fish, that is, the concentration beyond which microorganisms (including pathogenic microorganisms) can penetrate freely into the blood, organs and muscles of the fish. The threshold concentration in the Calcutta ponds is

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1 The reader is also referred to section 1.2, where the health risks related to wastewater use in aquaculture are outlined and guidelines discussed.

not known; judging from data from Peru (Chpt. 13.2), however, it is possible that pathogenic microorganisms, if present, may enter the digestive tract of fish in the Calcutta ponds, but not the fish muscle. There is an urgent need to collect good quality data on the presence and concentration of bacteria, indicator bacteria and pathogenic bacteria in the pondwater in order to resolve this issue. The habit in West Bengal of cooking fish well before consumption, often by deep frying (Ghosh 1985), is likely to reduce any possible health hazards. The high level of endemic diarrhoeal disease (see Chpt. 5) may mean that there exists in some of the population a degree of immunity to some organisms. It is therefore important not to assume that the finding of pathogenic organisms in the fish would necessarily constitute a disease risk; if found, then epidemiological studies would be needed to measure disease risks (if any) attributable to consumption of the fish. At present, it seems likely that, if the concentration of microorganisms is less than 1000 faecal coliforms per 100 ml in all parts of the pond over all the growing season, then the fish are likely to be of good enough quality for human consumption providing fish are well cooked and high standards of hygiene are recommended during fish handling, especially gutting (see Discussion, Chpt. 14). However, if the level exceeds 100 faecal coliforms/100 ml, bacteria could enter the fish muscle. The necessity of good cooking of the fish would then be even more important.

Fishermen have close contact with the pond water during harvesting since dragging the net through the water involves wading, with the water often up to shoulder height. Collecting the fish from the net before transport to market involves handling the fish, and cleaning the nets would involve contact with freshwater plants; both may have pathogenic organisms associated with them. In addition, contact with pond sediments may cause contact with parasite eggs.

Some insights into the possible role of the sewage-fed fisheries in enteric disease transmission can be gained from studies on the ecology of enteric microorganisms in several freshwater habitats in the Calcutta area, carried out by the National Institute of Cholera and Enteric Diseases (NICED). Their long-term objective is to generate a data bank on enteric microorganisms in the environment. Studies of the seasonal distribution of *Vibrio parahaemolyticus* in fresh water and in association with freshwater fish have been completed (Sarker et al. 1985). Sampling was carried out at 3 stations; station 1 was an artificial lake, station 2 was a "tank"[1] receiving treated sewage water and used for aquaculture, and station 3 was on the River Hooghly. The occurrence of *V. parahaemolyticus* in the water and sediments was infrequent and restricted to the summer months; the occurrence and counts of the organisms associated with plankton were consistently higher than in the water and sediment samples. The organism was recovered throughout the period of investigation from freshly caught fish at station 2 and from market samples of fresh water fish (probably due to cross-contamination). More organisms were recovered from faecal samples from the fish than from the external surface or the gills. It was concluded that survival of *V. parahaemolyticus* in freshwater ecosystems was transient and dependent on a biological host. The studies were not done in the main wetland area of East Calcutta, but in a nearby isolated fishpond. The results, however, would probably also apply in the main fishpond area. It is interesting that most of the strains of *V. parahaemolyticus* found were untypable, and those which could be typed were serotypes associated with the environment and not those normally associated with human disease. The spacial distribution pattern of the serotypes of *V. parahaermolyticus* from several hydrobiologically dissimilar aquatic environments has also shown that there is an obvious distinction between serotypes of environmental and clinical origin (Nair et al. 1985). If types associated with human disease were present, however, it would suggest that transmission of *V. parahaemolyticus* to fish consumers during the summer months (via contamination during preparation) or to fish farmers would occur.

Studies of *Vibrio cholerae* in the freshwater environment in Calcutta (Nair et al. 1988a) have been done in a freshwater lake, a rainwater pond and open sewage canals (but not in specific aquaculture ponds). *V. cholerae* non-01 (which has caused limited outbreaks of diarrhoeal disease but not large epidemics) was found to be abundant in all sites, on a seasonal basis, but *V. cholerae*-01 (the main cholera causing organism) was not recovered. Only a small percentage of this environmental *V. cholerae* non-01 has been shown to be toxigenic, with the potential for causing cholera (Nair et al. 1988b). The role of environmental reservoirs in the transmission of cholera in general is contentious (Miller et al. 1985), as is their role in Calcutta. It cannot be ruled out, therefore, that transmission of a cholera-like diarrhoea could be facilitated through the use of sewage in aquaculture ponds in Calcutta.

It is clear that the freshwater aquaculture ponds in Calcutta represent a complex ecosystem. The public health effects of sewage fertilisation of the ponds remain unclear. There is a need for an increased intensity of research activity in the area to answer the many unresolved and complex questions. The first step would involve detailed monitoring programmes of indicator bacteria and pathogenic organisms in the water and in the fish. The second step should involve epidemiological studies both of occupational risk and of consumer risk. This could be started using cross-sectional surveys to compare enteric disease rates in the fish farmers and their families with enteric disease rates in a similar population in a control area, where aquaculture occurs without the use of sewage.

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1 designates a shallow earth pond

The risk to consumers of fish grown in the ponds is critically dependent on (i) the quality of the pond water which determines the quality of the fish, (ii) standards of hygiene during fish preparation and gutting, (iii) working practices. If further studies suggest that the pond water quality is lower than expected, then modifications should be made to the pond system to improve the quality of the water this fish grow in to reach WHO guideline level (see section 1.2). For example, large ponds could be partitioned to create a series of smaller ponds, with the fish being grown in "tertiary" and "quaternary" pond. It is difficult to improve the standards of hygiene of fish consumers, since they are likely to be scattered throughout Calcutta, and difficult to target with health education programmes. This further stresses the need to ensure that the pondwater quality is of a good enough standard.

The risk to fishermen could be reduced by encouraging them to adopt specific hygiene measures, since a defined group such as this could be gathered together for meetings, and targeted with appropriate literature. The possibility of wearing protective clothing during harvesting and net cleaning could be investigated. Where this is not possible, the need to wash thoroughly immediately after such activities should be stressed. An investigation into the exact practices that are adopted could help to define specific "risky" behaviours which could be targeted in health education programmes.

12.6 Research into Wastewater Utilization in Aquaculture at the National Environmental Engineering Research Institute, Nagpur (NEERI)

A demonstration plant containing a single stabilisation pond of 30.5 m x 24 m x 1.5 m dimension along with six fish ponds of size 16.5 m x 5.5 m x 1 m was operated at NEERI Campus from 1980-1984 Krishnamoorthi 1988). There was provision for the effluents from the stabilisation pond to flow through in parallel and in series. The first phase of the experiment was designed for direct flow of the effluents from the stabilisation pond to fish ponds with serial subdilutions of 25%, 33% and 50% and without any dilution. In the second phase the fish ponds were connected in series and the experiments were done without dilution (Krishnamoorthi, personal communication). The fish used for culture were *Cyprinus carpio* (common carp) and several air breathers such as *Heteropneustes fossilis, Channa marulius- and Clarias batrachus*. *Cyprimus carpio* was chosen because it is omnivorous and air breathers were chosen in order to overcome the difficulty encountered by nocturnal depeletion of dissolved oxygen and septic decay and other advers environmental conditions encountered in the pond. The primary stabilization pond was loaded at an average loading rate of 150 kg/ha/day and a detention time of 7 days. The fish ponds each had a detention time of 1 day. In both the experiments physico-chemical and biological parameters were monitored at different points in the stabilisation pond, and these were related to fish growth. Biological productivity, fish food availability and bottom fauna were also measured (Krishnamoorthi and Abdulappa, 1979). The research was integrated into research on the use of stabilisation ponds for sewage treatment, and the reuse of such effluent in agriculture (see Chpt. 4). Since discharge of algal laden effluents from the stabilisation pond into streams can cause eutrophication, it was thought that utilization of such effluents for aquaculture could reduce this nuisance by employing fish as an intermediate agent for grazing of algal matter.

The studies indicated that the effluents of the stabilisation pond could be utilized in continuous as well as stagnant pond systems for fish culture. The continuous system was better since heavy algal growth occurred in the stagnant system which caused oxygen depletion and adversely affected the fish. Addition of effluent to the fish pond was regulated carefully and only added during daylight hours. Shallow ponds (not more than 1 m deep) were preferred to allow aeration and to avoid anaerobic decay. Deeper ponds did not improve productivity of fish. The growth of carp was faster than that of the air breathers but it was found that the air breathers were more able to withstand adverse conditions such as nocturnal depletion of DO. The growth of carp was 2 gram/day whereas that of the air breathers was 0.6, 0.5 and 0.4 grams per day. *Cyprinus carpio* could grow up to 600-700 g (average weight) in a year in the pond. Air breathers could grow as follows: *Channa* sp. - 350 grams in one year; *Clarias* sp. - 300 grams in one year; *Heteropneustes* sp. - 160 grams in one year. The harvest figures computed were 7 tons/ha/year for *Cyprinus carpio* and 3.5 tons/ha/year for air breathers. The harvest of fish in normal waters to stabilisation pond effluents was in the ratio of 1:3.

The staff at NEERI felt that a compact treatment facility consisting of a stabilisation pond followed by fish ponds, with effluents being utilized for agriculture would be a worthwhile ecological option for the treatment of domestic waste and the generation of revenue from fish production and agriculture products. The information presented here was collated by Dr. K.P. Krishnamoorthi. The ability of the system described to reduce the concentration of pathogenic microorganisms to a level that would not have adverse health effects on the consumers of the fish or aquaculture workers, however, is not clear. Limited data suggest that the reduction of *E. coli* and of faecal streptococci achieved by the oxidation pond is 99.99% (Shende et al. 1983). Studies on an oxidation pond treating Nagpur sewage (operated with 3 cells in series) suggested that *Salmonella* could be eliminated when present at a concentration of 540/100 ml in raw sewage (NEERI 1984). No data were located that showed the ability of the experimental pond system at NEERI in removal of *Salmonella*. Studies on both aquaculture and agriculture systems of reuse of effluent at NEERI have concentrated mostly on agricultural productivity. Further studies on the removal of indicator bacteria and of pathogenic microorganisms would assist the assessment of the public health implications of adopting the proposed systems.

12.7 References

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13 P E R U (LIMA)[1]

page

[1] See Chpt. 5 for a map of Lima and a description of the climate and water resources in the coastal area of Perú.

Acronyms

CEPIS	Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente (Lima)

13.1 The San Juan de Miraflores Experimental Aquaculture System

The San Juan de Miraflores WSP scheme in South Lima comprises a total of 21 ponds covering 20 ha. The ponds treat approximately 360 lps of wastewater from 108,000 inhabitants. More detailed descriptions of the scheme are contained in Chpt. 5.2, in Bartone et al. (1985) and in Cointreau (1987).

Starting in the mid seventies, CEPIS and the government health authorities have been conducting extensive field investigations to assess and optimize pond behaviour with respect to the removal of both organic matter and pathogenic organisms under the given climatic conditions and under variable pond loading rates. Since 1983, a comprehensive study is under way to investigate the **use of WSP for fish and prawn production.** For this purpose, 11 out of the 21 ponds were arranged to form two series of ponds with tertiary, quaternary and quintenary treatment stages as shown in Fig. 13.1.

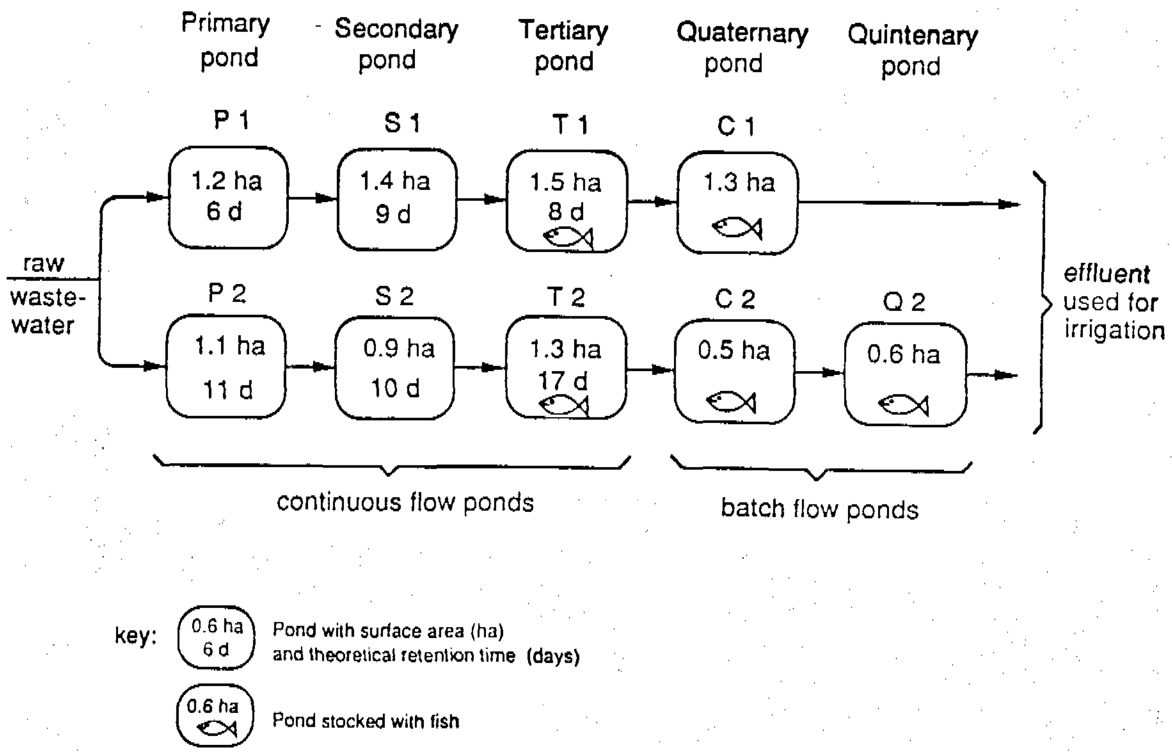

Fig. 13.1 San Juan de Miraflores WSP Scheme: Pond Arrangement for Aquaculture Study (functional sketch; after Bartone et al. 1985)

The tertiary, quaternary and quintenary ponds were stocked with Tilapia (*Tilapia nilotica*), Big Belly Carp (*Cyprinus carpio* var. *escamosa*), Mirror Carp (*Cyprinus carpio* var. *specularis*) and freshwater prawns (*Macrobrachium rosembergii*). Investigations in 1983-84 (phases I and II) served to evaluate the feasibility of the chosen arrangement of treatment and fish production ponds to produce and maintain such water quality as to allow favourable conditions for good fish growth. Also assessed were pathogen indicators and specific pathogens in the pond water and in fish organs in order to evaluate any potential public health risks. Chpt. 13.2 below contains the results of the respective microbiological observations.

In the current (1988-90) phase of investigation, the objective is to determine the optimum combination of stocking density and fish pond BOD loading for the production of marketable fish (Tilapia) during the cool and warm seasons as prevailing in Lima.

Pond characteristics and wastewater loading rates used during the 1983-84 investigation were as indicated in Table 13.1 below and Fig. 13.1 (Bartone et al. 1985). The primary ponds (P1 and P2) operated in the facultative mode, i.e. with a mixed aerobic-anaerobic environment, while all other ponds were fully aerobic.

Table 13.1 Pond Loadings in the 1983-84 Aquaculture Study

Pond	Inflow (lps)	Hydraulic Retention (days)	BOD-loading (kg/ha/day)
P1	29.7	6.1	333
S1	28.8	9.3	22
T1	28.1	8.0	18
C1	2.0	-	2.5
P2	15.3	10.8	201
S2	12.8	10.3	15
T2	11.4	17.2	6.7
C2	1.2	-	3.9
Q2	0.6	-	0.9

A number of physico-chemical treatment parameters were monitored, among them DO and un-ionized **ammonia** (NH_3-gas), two critical parameters affecting the living conditions of the fish. Average DO concentrations in the tertiary ponds were at least 1.6 mg/l at mid depth. DO levels of around 1 mg/l occurred in the early morning hours, possibly causing oxygen stress for the fish. Un-ionized ammonia, if occurring in excessive concentrations, is toxic to fish. The factors influencing this toxicity are pH, temperature, alkalinity, total ammonia (NH_3-gas + NH_4^+) concentrations, the sensitivity of the individual fish species and the duration of the exposure period. Tilapia, the main fish grown in the San Juan experiments, is more tolerant than most other fish to NH_3-gas toxicity. The researchers at San Juan observed that fish growth in the tertiary ponds was marginal, while it was very satisfactory in the quaternary and quintenary ponds. This coincided with high NH_3-gas levels in the tertiary ponds, which, in combination with the early morning low levels of oxygen apparently causes stress to the fish. At similar low DO concentrations in the quaternary and quintenary ponds, the oxygen stress appeared to be less serious, a phenomenon which the researcher attributed to the lower levels of un-ionized ammonia. The researchers concluded from these observations that the **threshold value of total ammonia (NH_3 g + NH_4^+)** for satisfactory Tilapia growth is 2 mg N/l, with average un-ionized ammonia (NH_3 g) levels not exceeding 0.5 mg N/l and short-duration NH_3 g levels not exceeding 2 mg N/l (Bartone et al. 1985). For other types of wastewater-grown fish, these tolerance limits must probably be lowered.

Table 13.2 Critical Fish Densities Observed in the San Juan Pond System (Moscoso and Nawaar 1984, cited in Cointreau 1987)

	Critical standing crop[1] (kg of fish/ha)	Carrying capacity[2] (kg of fish/ha)
• Quaternary ponds C_1 and C_2 under low temperature (20-21°C) conditions	250	550
• Quintenary pond (Q_2) under high temperature (25-27°C) conditions	600	1,350

[1]Weight of the fish population in the pond at which the daily growth rate does not increase any further
[2]Maximum weight of the fish population which the pond can support

Although fish grew in all three stages of the experimental WSP scheme, i.e. in the tertiary, quaternary and quintenary ponds, the growth rate was particularly favourable only in the quaternary and quintenary ponds. The amount of fish which could grow and live in the ponds under low and high temperature conditions was as indicated in Table 13.2.

The fact that the maximum growth rate and the carrying capacity was higher at warm than at cold temperatures was attributed mainly to the increased food (plankton) production at the higher temperatures.

.2 The Microbiological Quality of the Ponds and Fish as Related to Public Health

During the 15 months of pond operation for aquacultural observation, emphasis was given to the assessment of the pond water quality and of specific fish organs with respect to indicators of excreted pathogens and pathogens themselves. The **specific objectives** were:

- to assess the removal of indicators and pathogens through the pond sequence (see also Chpt. 5.2)
- to assess the occurrence and concentrations of indicators and pathogens in the **fish organs**, i.e. in the digestive tract content (DTC), in the peritoneal fluid (PF) and in the **muscle tissue**, which is the edible part, and
- to correlate, if possible, the levels of the indicator organisms in the ponds with those in the fish organs, the muscle tissue in particular.

Fish quality was observed during 6 of the 15 months of aquaculture investigations.

The following pathogen indicators and pathogens were **observed:**

- Total coliforms (TC), faecal coliforms (FC) and standard plate count (SPC; = total viable bacteria)
- Enterobacteria, among them *Salmonella* species
- Protozoal cysts (*Entamoeba, Giardia, Endolimax*)
- Helminth eggs (*Ascaris, Trichuris, Toxocara, Taenia*)

The results for the concentrations of indicator organisms in the fish organs as presented in the document by Noé M. et al. (1984) do not show any trend for an increase of concentrations with time of exposure in the ponds. The data were therefore aggregated to produce the information for Fig. 13.2.

The Fig. 13.2 shows the aggregated observations on indicator bacteria in pond water and in organs of Tilapia. The results must be interpreted with caution because they are based on but a few observations.

- FC, as the indicators of true faecal origin, were not recovered from fish muscle tissue in either of the fish ponds, not even in tertiary ponds where FC-levels (MPN) in the water were between 10^4 and 10^5/100 ml and where DTC of the fish had between 10^6 and 10^7 FC/100 ml.

- For TC, only low levels, i.e. between 2 and 5 MPN/100 ml, were observed in muscle tissues, although the DTC contained approx. 10^7 TC/100 ml.

- For the non-specific SPC[1], concentrations in the muscle tissues were between 10^2 and 10^3/ml while pond concentrations ranged from 10^3 to approx. 10^4/ml.

- The reported results indicate that the depuration of the fish in clean water had to some extent beneficial effects. 10 - 350 fold (1 - 2.5 orders of magnitude) reductions were observed in 9 out of 12 observations. There was, however, no difference between the 80 hours and the 1- week depuration period. The reductions occurred mostly in the digestive tract content (DTC) and in the peritoneal fluid (PF), and only in one case in the muscle tissue. In three situations, the TC and SPC concentrations increased 1.2 - 12 fold in the muscle tissue.

Summarizing the results, one can conclude that the muscle tissue as the edible part of the fish appears to be relatively safe against uptake or invasion of indicator bacteria.

Table 13.3 lists the quantitative and qualitative results of the observations for *Salmonella* species. It also shows the comparative pond removal efficiencies for faecal coliforms and *Salmonella*.

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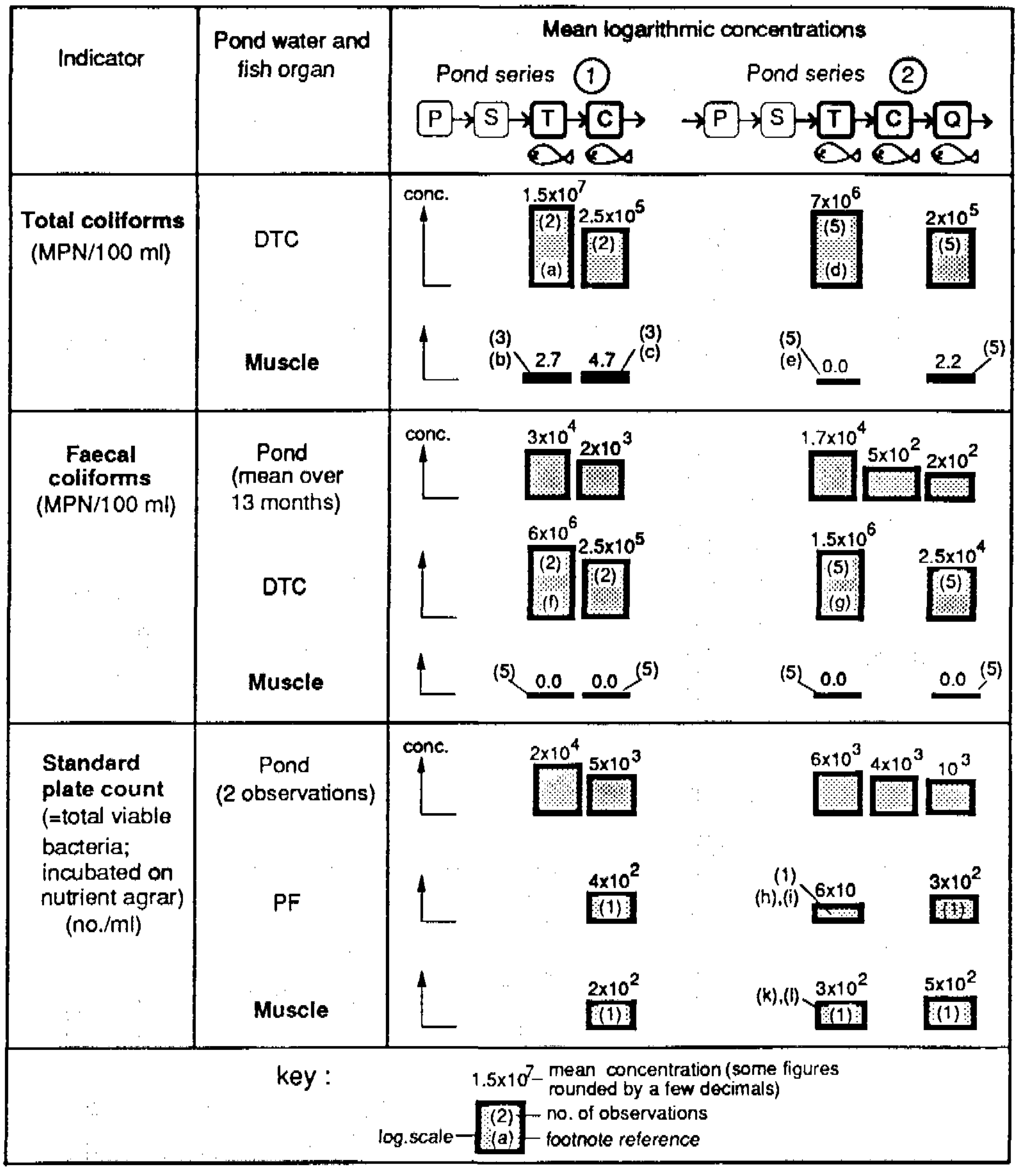
1 SPC measures the bacterial density of a solution, determined by a standarized plating and incubation technique. The method is not designed to yield particular types of bacteria.



DTC	Digestive tract content	T	Tertiary pond
PF	Peritoneal fluid	C	Quaternary pond
		Q	Quintenary pond

(a) was reduced to 2.5×10^5 after 1 week of depuration in clean water
(b) 2 out of 3 samples had zero TC concentrations
(c) 2 out of 3 samples contained TC
(d) was reduced to 2×10^4 after 80 hours and 1 week, respectively, of depuration in clean water
(e) was increased to 1.3×10^1 after 80 hours and 1 week, respectively, of depuration in clean water
(f) was reduced to 2×10^5 after 1 week of depuration in clean water
(g) was reduced to 2×10^4 after 80 hours and 1 week, respectively, of depuration in clean water
(h) was reduced to 5.0 after 80 hours of depuration in clean water
(i) was reduced to 3.5×10^1 after 1 week " " " " "
(k) was increased slightly to 4×10^2 after 80 hours of depuration in clean water
(l) was reduced to 1.3×10^1 after 1 week of depuration in clean water

Fig. 13.2 Mean Concentrations of Total Coliforms (TC), Faecal Coliforms (FC) and Standard Plate Counts (SPC) in Organs of Tilapia Raised in Tertiary (T), Quaternary (C) and Quintenary (Q) Ponds (Based on Noé Moccetti et al. 1984 and Bartone et al. 1985)

Table 13.3 Occurrence of *Salmonella* Species in Pond Water and in Digestive Tract Contents (DTC) of Tilapia and Carp (Noé M. et al. 1984 and Bartone et al. 1985)

	in water				in DTC			
Organism	T1	C1	T2	Q2	T1	C1	T2	Q2
Faecal coliforms, FC (MPN/100 ml)	$3x10^4$	$2x10^3$	10^4	10^2	(see Fig.13.2)			
Cumul. removals of FC	10^3	10^4	10^3	10^5				
Salmomella sp.:								
• MPN/100 ml	0.1	0.1	n.o.	n.o.	-	-	+	+
• Cum. removals	10^4	10^4	n.o.	n.o.				
• Frequency of positive identification								
- *S. parat. B.*	1/2	1/5	n.o.	n.o.	not reported			
- *S. typhim.*	0/2	0/5	n.o.	n.o.				
- *S. montevideo*	0/2	0/5	n.o.	n.o.				

T1, C1: Tertiary and quaternary ponds in pond series 1
T2, Q2: Tertiary and quintenary ponds in pond series 2
1/5 : 1 out of 5 samples positive
n.o. not observed
\- Organism absent
\+ Organism present

The Table illustrates that in a series of ponds, FC and Salmonella are subjected to about the same cumulative removals. This significates that for raw sewage concentrations of around 10^3 MPN *Salmonella*/100 ml as were observed in the influent to the San Juan de Miraflores WSP scheme, complete or almost complete removals of *Salmonella* (and possibly other pathogenic bacteria) can be achieved through the tertiary and quaternary ponds.

S. paratyphi B. were recovered in 1 out of 2 samples from pond T1 and in 1 out of 5 samples from pond C1.

Salmonella species were found in the digestive tract contents (DTC) of fish in the tertiary and quintenary ponds of pond series 2 while none were detected in the fish in pond series 1. Whether the occurrence of *Salmonella* was also observed in muscle tissue is not known. Respective results were not reported.

Gill, DTC and muscle of Tilapia and Carp were also analysed for **protozoal cysts** and **helminth eggs.** All results were negative. This means that the primary and secondary ponds were efficient "scavengers" for cysts and eggs.

Analyses were also made for the occurrence of **indicator bacteria** and pathogens (*Salmonella* species) in **pond sediments.** Results show that the concentration of the bacteria in the sediments (expressed as MPN/100 g) is, in general, 2-3 log units (orders of magnitude) higher than in the water above (expressed in MPN/100 ml). For example, *Salmonella* concentrations in the sediments of the ponds T1 and C1 were found to be around 40 MPN/100 g, while they were approx. 0.1 MPN/100 ml in the pond water. Faecal coliform concentrations in the sediments of the same ponds were 2×10^5 MPN/100 ml, while they amounted to 2.5×10^3 MPN/100 ml in the pond water.

In **summary,** the results of the experiments conducted in San Juan de Miraflores indicate that the wastewater aquaculture system with the tertiary and quartenary, and tertiary, quartenary and quintenary ponds, respectively, appears to be feasible to produce fish whose flesh is free of bacterial pathogens or carries only very low levels of enteric[1] bacteria and whose flesh is free of parasites. Whether the same also holds for viruses, cannot be said, as viruses were not analyzed for in this experimental phase[2].

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1 Enteric bacteria may include both non-pathogenic and pathogenic organisms.
2 Current (1988-90) investigations include the analysis of E. Coli, bacteriophage (= viruses of E. coli) in pond water and possibly also in fish organs.

13.3 Health and Epidemiological Aspects

Aquaculture with treated wastewater is not a traditional or a commercial practice in Peru. The aquaculture system in the waste stabilization ponds at San Juan de Miraflores is an experimental system. As such, the fish are not eaten, there is no 'at risk' population (apart from the laboratory staff harvesting or handling the fish) and therefore no public health impact of the practice. In this section, consideration is given to what would be the impact on health of introducing such a practice into the local population in future.

There are two main groups who could be at risk from aquaculture with wastewater; firstly, the consumers of the fish grown, and secondly, the fish farmers who harvest the fish. The **health risk to consumers** of the fish will depend on several factors.

i. the microbiological quality of the fish, influenced by the microbiological quality of the pond water
ii. the extent of cooking of the fish prior to eating
iii. hygiene practices in the kitchen, and the extent of consumption of raw food that could become contaminated.

The studies reported in section 13.2 indicate that faecal coliform bacteria cannot be detected in the fish muscle, in fish grown in the tertiary, quaternary or quintenary ponds. However, using the standard plate count (SPC) bacteria were detected in the muscle of one fish sampled from each pond (Fig. 13.2). SPC was included since studies in Israel showed that when faecal coliform concentrations in muscle are very low or non-existant, contamination by other bacteria may be found. MPN tests for coliforms were therefore thought to be inadequate as a means of identifying pathogenic contamination in aquaculture studies (Cointreau, unpublished). SPC procedures showed a population of bacteria, including enteric bacteria, in the peritoneal fluid and muscle in raw tilapia samples from both T2 and Q2. An average of 3.1×10^2 bacteria per gram of muscle were found in tilapia grown in T2, and 4.8×10^2 bacteria per gram were recovered in those grown in Q2. International standards for freshwater fish allowable for human consumption state that the standard plate count of 3 out of 5 fish sampled should not exceed 10^5/100 g and the faecal coliform count should not exceed 4/100 g (quoted in Cointreau, 1987). The **quality of fish** grown in the San Juan lagoons were therefore determined to be **acceptable for human consumption**, on the basis of bacterial counts in the **fish muscle.**

In addition to the fish muscle, the microbiological quality of the **digestive tract contents** (DTC) is important when consideration is given to the possibility of **cross-contamination** of other food occurring during cleaning and preparation of fish. The concentration of faecal coliforms in DTC is usually similar to or higher than the concentration in the water (Fig. 13.2). *Salmonella* bacteria were isolated from DTC in some of the tilapia samples taken from T2 and Q2 (Noé, M. et al. 1984). It is therefore possible that cross-contamination to vegetables that are eaten raw could occur in the kitchen. It has been suggested that cross-contamination of fish muscle could also occur, due to the practice in Peru of eating fish raw in a marinated salad known as "ceviche". Controlled fish processing and packaging has been recommended as a means of minimising public health risk. This would apply to commercial operations but not to local marketing of fresh fish and domestic processing. It would be useful to have more data on **food hygiene practices** and **fish consumption habits** among consumers to evaluate whether the risk of cross-contamination is overrated or not. There may well be a code of practice that causes fish preparation to occur separately from raw vegetables or raw fish preparation; if this does not occur, then it may be difficult to change habits in people's homes. The preferred way of eating the specific types of fish that will be grown in the wastewater ponds needs to be known. If such fish is generally eaten cooked and not raw, then the risk will be reduced. Investigation of hygiene and consumption habits could be supplemented by microbiological studies, to verify whether cross-contamination occurs or not.

Decreasing the bacterial concentration in the contents of the digestive tract has been tried, using **depuration** procedures. Results of the limited studies done in Peru suggest that depuration may reduce the bacterial content, but that this is not always the case. In studies elsewhere depuration for 8 days in clean water has been shown to remove the bacterial content of muscles (using *Streptococcus montevideo*), but in the digestive tract, although a big reduction was recorded, bacterial recovery was still at 3.0 x 10^2/ml (Buras et al. 1985). In these latter experiments, the water was changed daily, a practice that would not usually be possible in field conditions. The effectiveness and practicality of depuration as a health protection measure needs further evaluation.

A potential risk could exist to **fish farmers** who harvest the fish. This will depend on the harvesting practice and the extent of exposure of the farmer to contamination in the water or on the surface of the fish. The extent of exposure will depend on whether harvesting involves contact with the water and whether protective clothing is worn to minimise such contact. In the experimental studies, harvesting the fish involved draining the pond and catching the fish by seining. It is not clear whether seining involved any body immersion in the water before hauling the net (as occurs in Calcutta) or not. In some countries, wading in the water would carry the risk of percutaneous infections, such as schistosomiasis. There is no risk in this case, as schistosomiasis is not endemic in Peru. The risk of enteric infection due to occupational exposure is not clear until further microbiological and epidemiological studies have been done.

No epidemiological studies have been located which specifically examine the risk associated with occupational contact with excreta-fed or wastewater ponds (where farmers may accidentally ingest pathogens and be at risk of faecal-oral infections) or which examine the risk associated with consuming fish from such ponds (Blum and Feachem, 1985). The exposure of the people studied in Kibbutzim in Israel (Fattal et al. 1981; Fattal 1983) where wastewater effluent was used in fish ponds may have been partly occupational and partly through fish consumption, but some Kibbutzim also used the effluent in agricultural irrigation. It is therefore impossible to define which risks are due to which exposure. The attribution of the risks to wastewater use has also been questioned sinced some disease differences between exposed and control Kibbutzim (e.g. in throat infections) could not be related to wastewater use, suggesting that the Kibbutzim were different in more ways than just effluent use (Blum and Feachem 1985).

Further epidemiological studies are needed to characterize the risk associated with wastewater aquaculture and to define which is associated with occupational exposure and which is due to fish consumption. Analysis of the results of an epidemiological study of risks associated with the use of excreta in fishponds in Java will address some of these issues (see Chpt. 15).

Further studies are in progress at San Juan de Miraflores. The main objective is to determine the optimal stocking density for the production of marketable fish (Tilapia) in hot and cool seasons. The public health issues that will be considered (Buras 1988) during these experiments are:

a. the quality of water in the feeding lagoon;
b. the microbiological quality of water in the experimental ponds, as influenced by various fish densities;
c. the microbiological quality of the fish in the experimental ponds as influenced by stocking density,
d. the impact of stress on the fish.

The microbiological parameters to be determined in the feeding lagoon are:

weekly:	Standard Plate Count, total coliforms, faecal coliforms and bacteriophages of *E. coli B.*
monthly:	*Salmonella, Clostridia* (sulphate-reducing), *Acromonas*, protozoa and helminths
periodically:	*Giardia* (using monoclonal antibody method), rotavirus, hepatitis A and B, enteric viruses.

In the experimental ponds, water will be examined for the same organisms, but on a monthly schedule. Fish will be examined before introduction into the ponds and at the end of the 6 month experiment. These microbiological studies will help to define further the potential risk of occupational exposure and consumer exposure. Actual risks cannot be defined until fish are produced in quatity and eaten by consumers. This is discussed further in Chpt. 14.

13.4 References

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14 DISCUSSION

The Calcutta and Lima case studies constitute two contrasting examples of wastewater-based fish production: In **Calcutta**, where the overall pond area is large relative to the flow of untreated wastewater, the organic loading of the ponds is low and corresponds to the loading rate of tertiary ponds in full treatment WSP schemes. The Calcutta pond system can therefore not be looked at as a WSP scheme in the conventional sense. The Wetlands, east of the city of Calcutta, have established themselves as an ecological niche enabling both the production of large amounts of protein in the form of fish as well as the low-cost treatment of a proportion of the municipal wastewater. For many years and still today, urban sprawl and real estate pressure represent a threat to the seemingly unlimited pond area. Over many decades, fishermen and their families have acquired the art of practising wastewater-fertilized aquaculture. Much effort goes into protecting the livelihood of the fishing families and into safeguarding the overall scheme from eradication. Due to these struggles and to the nutritional and economic necessity of producing fish (an important part of Bengali diet), relatively little attention has been paid until very recently to the public health aspects of this practice. Investigations are now under way to assess the potential and actual risks of enteric disease transmission for fishermen, their families and consumers of the fish. Neither epidemics nor particularly high endemic levels of enteric diseases have been reported in the pond area where the fishermen live. Epidemiological studies are needed to assess the true health status and levels of infection in exposed population groups as compared with non-fishing inhabitants of comparable socioeconomic levels. Along with a microbiological monitoring of the pond water and the fish, such studies could help determining whether or not wastewater-based fish culture contributes significantly to the level of enteric disease in the area.

In recent years, the use of waste stabilization ponds for fish production has been repeatedly suggested. The productive use of maturation ponds could help to partly recover the pond investment cost. Although these are lower than for conventional STPs, land investment cost for large ponds might often be substantial.

Towards this end, CEPIS has been continously carrying out aquaculture research at the WSP in San Juan de Miraflores, **Lima**, Perú. The system differs in several ways from the Calcutta wetland aquaculture: (1), This research scheme with just 5 ha of fish ponds (Calcutta: approx. 6,000 ha), aims at determining the pond water quality requirements for optimum fish growth and hygienic fish quality, as well as establishing the optimum stocking densities in the fish ponds for marketable fish production. (2), The WSP scheme of San Juan de Miraflores includes full pond treatment, i.e. the wastewater passes through primary and secondary ponds prior to its use in the fish ponds. (3), As fish are not sold to consumers, the population is not at risk, and therefore it is not possible to conduct epidemiological investigations. Microbiological investigations of pond water and fish organs are carried out to find a correlation between the two parameters. The project has shown so far that **fish grow well in tertiary, quaternary and quintenary ponds** and that the water quality in these ponds **is hygienically safe for fish** to be grown and harvested there.

A lot of **microbiological data** from pond water quality observations have been gathered at the San Juan de Miraflores scheme in Lima in comparison to the very few observations and measurements made to date on the Calcutta scheme. Yet, by comparing the BOD loading rates of the Calcutta ponds with those of the Lima ponds, one may deduce, as a tentative approximation, the hygienic quality of the Calcutta pond water: in the **Lima WSP scheme,** BOD **loading rates** in the **tertiary ponds** were 6.7-18 kg/ha/day. BOD loading rates in **Calcutta** were estimated at about the same range. Assuming for both schemes similar BOD concentrations in the raw wastewater, the hydraulic loading rates and therefore also the pond retention times tend to be of a similar magnitude. As a consequence, the indicator and pathogen concentrations in the Calcutta ponds are likely to be of the same order of magnitude as in the Lima ponds. The microbiological water quality in the Calcutta ponds might even be better and result in a more rapid die-off of pathogens due to Calcutta's hot and tropical climate with hot season temperatures considerably higher than in Lima.

As mentioned above, it is important to note the basic difference between the Calcutta wastewater-fed fishponds and the Lima waste stabilization pond (WSP) scheme: In **Lima,** the total wastewater flow is treated in facultative primary and in secondary (maturation) ponds **in series** operation prior to being used as fishpond water in tertiary, quaternary and quintenary ponds. In **Calcutta,** where **all** the ponds are operated as fishponds, the system historically developed and came into use for fish production, mainly, using the wastewater as a means of fertilization. The ponds which receive raw wastewater are operated with **low BOD rates** in order to maintain minimum oxygen levels in the pond water for fish survival. The Calcutta ponds are operated **batch-wise in parallel.** They occupy a much larger land area than they would if they had been designed as a WSP scheme where the wastewater is treated for BOD removal prior to fish cultivation. Land cost versus employment opportunities for fishing families and retailers, and nutrition derived from fish production have to be balanced against each other when comparing the two basically different systems and when planning wastewater-fed aquaculture systems elsewhere. In the case of large cities and large sewage flows, the WSP-cum-aquaculture concept as applied in Lima is likely to be more feasible since land values at the outskirts of big cities tend to be rather high.

The authors should like to emphasize that although the microbiological aspects should be considered as important, it is necessary to remember the importance played by the wastewater-based fisheries in providing part of the **protein diet** for Calcutta's inhabitants. There should thus always be an equilibrium between the advantages and disadvantages of the practice, i.e. the **nutritional and economic aspects**, and the theoretical **health risks** associated with it. It would be wrong to advocate a zero risk strategy as this could seriously restrict fish production and is not feasible. However, there is a need to quantify the potential and actual health risk of the practice, since it is possible that there are risks present which could be reduced by modifying the operation of the system, by modifying the fishing technique or by improving the personal hygiene, or a combination thereof.

Where centralized municipal sewerage exists, **industrial wastewaters** are likely to be discharged into the sewerage scheme. Chemical constituents may, if occurring in harmful concentrations, seriously affect any kind of reuse system, including wastewater-based fisheries. It is well-known that in developing countries, the industries' efforts towards in-plant pollution control and the enforcement of environmental pollution control measures are often neglected on account of the usual economic constraints. Should substantial quantities of industrial effluents enter the Calcutta Wetlands, the system might be seriously harmed. According to the authors, the potential impacts of **industrial discharges** pose a more **serious threat** to wastewater-based fish production schemes than the potential or even actual risks of enteric disease transmission if minimum health protection measures are taken: i.e. pre-treatment or low batch loading of the wastewater discharged into the fish ponds, cooking of the fish, and adequate hygiene measures when handling and gutting the fish.

In **Indonesia**, a type of fish pond has been in use for many centuries which differ from the wastewater-based fish ponds in Calcutta and Lima. Indonesian ponds are subsistence ponds which allow the culturing of fish usually by one family and which are small relative to wastewater treatment ponds. Pond culture is particularly common in the highlands where use is made of the abundantly flowing water and of human excreta which is dropped into the ponds from overhung latrines for pond fertilization. The organic (BOD) loading rate is low relative to primary ponds of WSP schemes. Fish are therefore not subjected to the harmful effects of oxygen depletion. A more detailed description of the Indonesian fish ponds is provided in Chpt. 15 below.

No epidemiological studies have been located which specifically examine the risk associated with occupational contact with excreta-fed or wastewater ponds (where farmers may accidentally ingest pathogens and be at risk of faecal-oral infections) or which examine the risk associated with consuming fish from such ponds (Blum and Feachem 1985). The exposure of the people studied in Kibbutzim in Israel (Fattal et al. 1981; Fattal 1983) where wastewater effluent was used in fish ponds may have been partly occupational and partly through fish consumption, but some Kibbutzim also used the effluent in agricultural irrigation. It is therefore impossible to define which risks are due to which exposure. The attribution of the risks to wastewater use has also been questioned since some disease differences between exposed and control Kibbutzim (e.g. in throat infections) could not be related to wastewater use, suggesting that the Kibbutzim were different in more ways than just effluent use (Blum and Feachem 1985). Analysis of the results of an epidemiological study of risks associated with the use of excreta in fishponds in Java will address these issues (see Chpt. 15).

The combined information from the **Calcutta Wetland scheme** and the **Lima full-scale WSP research project** leads to the following **conclusions** and **recommendations:**

(i) Fish of good hygienic quality can be grown in wastewater which has been subjected to adequate treatment in WSP systems for the removal of organic matter and pathogenic organisms prior to its release into fish ponds.

(ii) The risk of enteric disease transmission associated with the Calcutta wastewater-based fisheries remains unclear, so investigations are needed to determine whether or not the scheme increases the risk of enteric disease among fishermen and fish consumers.

(iii) The information available suggests that disease risks are likely to be low for fish consumers in Calcutta, as the wastewater loading rates on the individual ponds are low, thereby leading to long hydraulic retention times and correspondingly low pathogen levels. Moreover, all fish are cooked prior to consumption.

(iv) In contrast to the consumers, fishermen and their families are at a potentially higher risk due to their intimate contact with the pond water and its sediments during fish harvesting. As a result of the scavenging effect of the sedimentation and entrapment processes, pond sediments are rich in pathogens.

(v) Wastewater-based fish production appears to be an economically and ecologically attractive method of combining both wastewater treatment requirements and the production of valuable protein diet. The income generated from the WSP aquaculture contributes to a partial recovery of the cost for sewage treatment and thereby improves the economic viability of WSP schemes, particularly where land cost in the urban fringe areas are high. Pond schemes must be designed and operated in such a way as to guarantee the safety to public health of fish production.

(vi) There is urgent need for full-scale demonstration WSP schemes with fish culture in order to collect more experience with "real-life" systems.

(vii) As for wastewater reuse in agriculture, aquacultural use should become an integral part of wastewater management planning. This comprises a careful evaluation of industrial wastewater discharges and their treatment and disposal in order not to pose a risk to the fisheries and the consumers through the accumulation of toxic substances in the fish.

(viii) When planning and implementing a wastewater-based fish production scheme, not only the technical aspects of wastewater treatment and fish production must be taken into consideration, but also the organizational and institutional form of pond operation and fish production. Private, commercial enterprises are usually better suited than government agencies to manage successfully production and marketing. Suitable forms of joint venturing between the public agency responsible for wastewater collection and treatment, and the enterprise responsible for fish production and sales may still have to be found.

(ix) Further epidemiological studies are needed to characterize the risk associated with wastewater aquaculture and to define which is associated with occupational exposure and which is due to fish consumption.

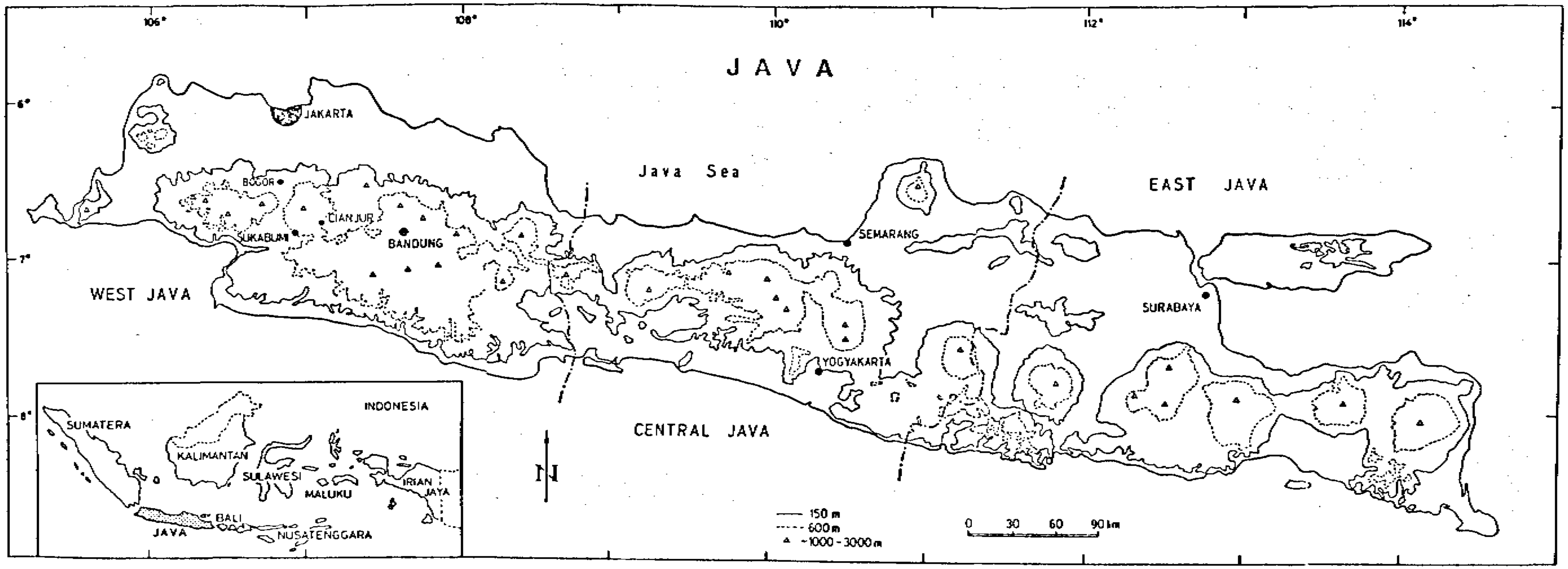
D - EXCRETA USE IN AQUACULTURE

15 INDONESIA

15 INDONESIA

Acronyms

CARE	-	Cooperative for American Relief Everywhere
MCK	-	Mandi (bathing)/ Cuci (washing) / Kakus (defecation); a type of sanitary unit for all 3 activities
MOH	-	Ministry of Health
REPELITA III	-	Third Five-Year Development Plan 1979/80-1983/84)
REPELITA IV	-	Fourth Five-Year Development Plan 1984/85-1988/89)


JAVA
106°
108°
110°
112°
114°
6°
7°
8°
Java Sea
JAKARTA
BOGOR
CIANJUR
SUKABUMI
BANDUNG
WEST JAVA
SEMARANG
EAST JAVA
SURABAYA
YOGYAKARTA
CENTRAL JAVA
N
150 m
600 m
~1000 - 3000 m
0 30 60 90 km
INDONESIA
SUMATERA
KALIMANTAN
SULAWESI
MALUKU
IRIAN JAYA
BALI
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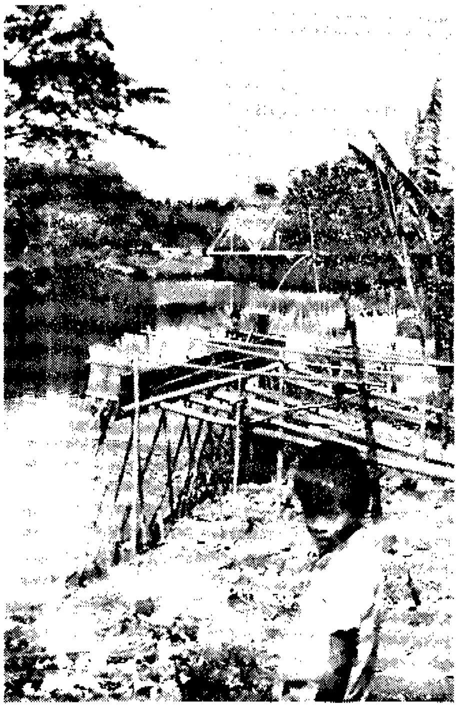

Photo 15.1

An overhung communal latrine on a river in Cirebon (Java)

Photo 15.2

Running water fish culture in a river carrying variable loads of human waste discharges (Bogor, West Java)

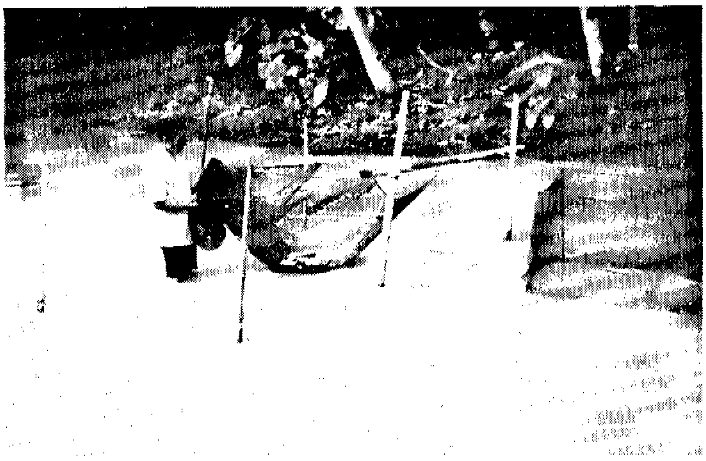

Photo 15.3

Fingerling production in a pond receiving soybean processing waste (Bogor, West Java)

Photo 15.4

Common carp (Cyprinus Carpio) feeding on algae attached to the walls of a running water tank which receives a mixture of drainage and wastewater (Bogor, West Java)

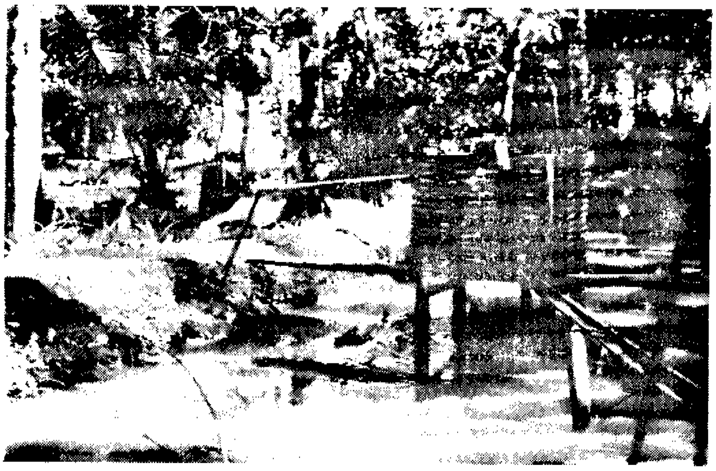

Photo 15.5

An overhung latrine on a fish pond (near Bandung, West Java)

Photo 15.6

An overhung latrine-cum-wash place on a fishpond in which also water vegetables are grown (near Bandung, West Java)

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Photo 15.7

A fishpond receiving excreta and washwater from an MCK (near Bandung, West Java)

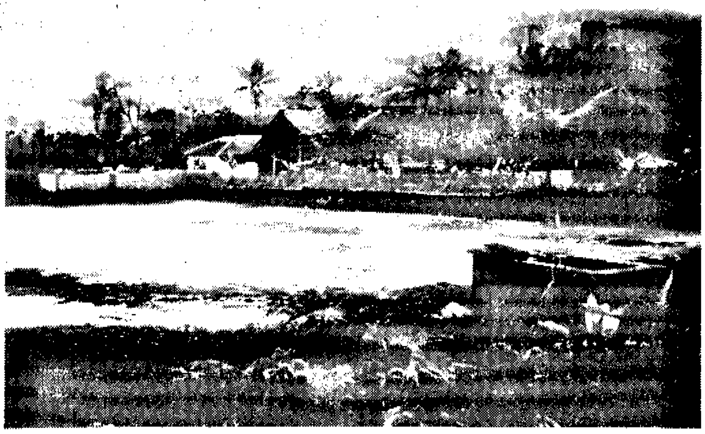


Photo 15.8

An excreta-fed fishpond which was been emptied for fish harvesting and desludging (near Bandung, West Java)

Photo 15.9

Washplace at an MCK unit in Ciaro (near Bandung, West Java)

15.1 Into the Highlands of Java - Personal Impressions

"A train ride from Jakarta to Bandung enables a person to view the geographical features of West Java, i.e. its topography, agriculture and settlement patterns. It also allows a person to escape from the hot and humid climate of Jakarta which prevails during the rainy season lasting from November to February. Jakarta, the capital of Indonesia, borders on the West Java sea. It is situated in the 60 km-wide lowland belt which extends from the volcanic highlands to the Java sea. Like in other similar metropolitan areas, tremendous economic resources have apparently been put in recent years into the construction of high-rise buildings, highways, a new airport, and department stores.

Upon leaving the downtown railway station, the train passes through miles of suburban settlements of one-storey houses built next to each other, looking as if they could hardly provide protection from the pouring rains. Finally, the train travels through wide plains covered with paddy fields. It is the rainy season and most of the plots have recently been planted with rice seedlings. Planted in a geometrical pattern, they emerge like fingers pointing upward into the sky through the field-flooded water. There is no fallow piece of land. The train passes numerous clustered villages. Houses are single-storied and covered with clay tiles or corrugated iron sheets.

The speed of the train reduces as the track starts winding through the hills towards the plateau of Bandung at 700 m a.s.l. The hills are gently rolling at first, then the terrain gets rugged. Rice fields, which are often but only a few meters wide, are terraced and look like a full-scale contour map. Some of the hillsides are deforested but not terraced. On some, banana trees and manioc are being cultivated. In many places, the soil is exposed to the rain which pours with great intensity while the train passes through bamboo forests and over narrow valleys. The high hills and volcanoes are hidden behind curtains of clouds and fog. The landscape is impressively wet, every ditch and stream is engorged with water. Bright green is the dominating colour of the landscape. While seeing the lushness of the Java highlands, it is difficult to recall the aridness of northern India, Tunisia or the Pacific coast of South America, where farmers break sewers in order to irrigate their fields!

Bandung is the provincial capital of West Java and numbers almost two million people. Its commercial and industrial activities certainly exert great influence on the smaller towns and villages on the plateau and on the hills surrounding the city. The city provides jobs for a good number of people from those villages. Much of the surplus agricultural production finds its way to the Bandung markets. It would be interesting (even important for epidemiological investigations) to know to what extent the income is dependent on and generated by urban employment or the selling of produce on the urban market. Do most or only a few families in a village profit from the proximity of a large urban centre?

There are extensive rice fields on the plateau around Bandung. Monsoon has begun and men are ploughing and hoeing the heavily soaked soil. Women working in groups, are planting the seedlings. Clustered villages are located partly hidden behind banana, palm and bamboo groves. Agricultural land in the Bandung area is decreasing as the city's residential and industrial areas are expanding, particularly along the roads leading to and from the city. Where the plain leads over onto the hillsides surrounding the plateau, fields are terraced. Numerous streams, some of them flowing through deep valleys, drain the mountains. In some places, the hills are thickly forested, elsewhere, forests have been replaced by cultivated plots. Where slopes are steep, it looks as if the fields might start sliding down at the next heavy downpour.

15.2 Geographical Features

Indonesia is an archipelago of some 13,700 islands, extending over 5,000 km from west to east and 1,900 km from north to south.

The country's population IN 1985 was 164 million, the largest in South-East Asia and the fifth largest in the world. Close to 100 million people (60%) live in Java which covers only 7% of the country's total land area of 1.9 million km^2. The population density in Java is therefore among the highest in the world. This can be readily seen when travelling upcountry: no piece of land remains uncultivated, and densely built-up villages follow each other in short distances. Besides Java, the major islands are: Sumatra (approx. 30 million), Kalimantan (7 m.), Sulawesi (11 m.) and Irian Barat (1.2 m.). Nusa Tenggara, the group of islands east of Java, counts about 6 million inhabitants, and the Maluku Islands 1.5 million. The largest cities are: Jakarta, the capital (7 million); Surabaya (2.2 m.); Bandung (1.6 m.); Medan, Sumatra (1.5 m.); Semarang (1.1 m.), and Ujung Pandang, Sulawesi (800,000).

Indonesia has more than 300 ethnic groups. The largest group is composed of Deuteromalays who are the descendants of the immigrants who reached the Archipelago during the last important migration from South China. Later, immigrants from Arabic countries, India and China contributed to the cultural and religious diversity of the country. Today, the majority of the Indonesians are Muslims. There are also large minority groups of Hindus, Buddhists and Christians.

Climatic conditions, although varying among the many parts of the Archipelago, are monsoon-influenced and characterized by uniform temperatures, high humidity and intensive rainfalls. The average temperature is 26°C, with daily maximums from 32-35°C and minimums from 9-20°C. Annual rainfall totals 1,800 mm in Jakarta, 4,400 mm in Padang (Sulawesi) and 1,300 mm in Surabaya. There are no distinct dry seasons except on Nusa Tenggara islands and in East Java. Availability of rain water does not appear to be a limiting factor for agriculture. However, fertilization of the soil may well be a limiting factor since most farmers are peasants who are heavily indebted to their landlords and unable to buy products themselves such as mineral fertilizers which are necessary for farming.

Indonesia is mainly an agricultural country, with 2/3 of the working population involved in agricultural production. The main crop cultivated for domestic consumption is rice. In colonial times, agricultural production was largely based on the cultivation of spices, coffee, tea, crops and palm oil. Nowadays, rubber, palm oil, tea, tobacco, and fish are important export products.

70% of the country's foreign exchange earnings come from oil exports. Other industrial export products are gas, tin ore and copper. Industries producing for local needs include, among others, cement, fertilizer, textiles, chemicals, as well as car and bicycle assembly factories.

15.3 Traditional Methods of Excreta Disposal in Indonesia

In Indonesia, water plays a crucial role in defecation, more so than in many other cultures and countries: people use water for anal cleansing, and defecation sites and facilities are traditionally chosen in such a way that the excreta are carried away or "swallowed" by the water. Dry excreta disposal is uncommon. The following traditional methods and installations are used:

- Overhung latrines on family and village fishponds (see also Sect. 15.5)
- Overhung public latrines on canals or rivers (see Photo 15.1)
- Latrines floating on rivers with a fish-cage underneath, used e.g. in Sumatra and Kalimantan
- Squatting along river banks.

The prevalence of these practices varies according to the geographical area, i.e. between one Indonesian island and another, local conditions and preferences.

15.4 Fish Culture in Freshwater Ponds in Indonesia[1,2]

- Overview[3]

Freshwater fish represent an important part of the diet and source of protein for the people in Indonesia. Table 15.1 shows the fish production in Indonesia including the fish grown in freshwater ponds. Although pond culture accounts for only about 3.5% of all fish consumed, it plays an important part in specific areas such as e.g. West Java. In areas where most of the population often have insufficient or only marginally sufficient protein intake, subsistence fish culture in small, family-owned ponds is of great nutritional value.

Table 15.1 Marine and Freshwater Fish Production in Indonesia during the Seventies (Djajadiredja et al. 1979)

	Tons/year	%
• Overall (freshwater + marine)	1,600,000	100
• Freshwater (Rivers, lakes, paddy fields, ponds)	400,000	25
Thereof in ponds:	56,000	3.5

Fish culture in freshwater **ponds** is a century-old tradition in the Indonesian Archipelago. The overall fish pond area in the country totalled 34,000 ha in 1976, with about 2/3 located in Java (Table 15.2). Indonesians eat on average about 13 kg of fish per year. In West Java, Kalimantan and Sumatera, consumption is well above this average[4].

1 Information received mainly from the Inland Fisheries Research Institute, Bogor

2 "Freshwater" designates the "sweet" inland water, as opposed to the salty seawater

3 Sources: Atmadja and Jangkaru (1985) and Djajadiredja (1979)

4 Figures include both freshwater and marine fish.

Table 15.2 Freshwater FishPond Culture in Indonesia (1976) (Djajadiredja et al. 1979)

Island	Pond area ha	Pond area %	Tons	kg/ha/year
Java	21,600	63	46,200	2,140
Sumatera	6,600	19	4,870	740
Nusa Tenggara	800	2.3	460	575
Kalimantan	500	1.5	13	26
Sulawesi	4,500	13	920	204
Maluku & Irian	200	0.5	150	750
	34,200	100	52,600	1,540

The fishpond culture in Java is concentrated in the western part of the island with about 17,000 ha (1976) or 80% of the overall pond area, or 50% of the country's overall pond area. The major fishpond areas of West Java are found around Bandung, Cianjur, Sukabumi, Bogor, Tasikmalaya, Ciamis, and Garut (see map on p. ii).

The production figures and total pond areas on the main islands are listed in Table 15.2. In Indonesia, approx. 53,000 tons of fish cultured in freshwater ponds were produced in 1976. Thus, an average of 1,540 tons of fish/-ha/year were harvested. Most pond cultures are small family holdings. One family may own more than one pond. A study conducted in the areas of Bandung, Cianjur and Sukabumi (West Java), where fish ponds are particularly popular, revealed an average pond holding between 500 and 1000 m^2/family (Djajadiredja et al. 1979). The average size of the individual pond is about 400 m^2. In an area near Jakarta (lowlands), holdings were found to be larger, i.e. from 1,500-6000 m^2/family, while the size of individual ponds is also approx. 400 m^2.

Ponds are found where only fish is grown and also where both water vegetables and fish are produced. Fish are raised as monoculture or as polyculture, i.e. the simultaneous raising of two or more fish types (species, genera, families or orders) in the same pond and at the same time (see also the chapter below). Important vegetables grown are "Kangkung" and "Genjer", two leafy vegetables which are cooked before consumption. Also grown are water hyacinths which are used as fish food. Beside the "normal", small-sized village-based or backyard ponds, there are also ponds located along sea shores. These are larger in size than village ponds and their water is slightly brackish. They are mainly found in East Java. Most ponds are 0.5-1 m deep. Vegetable ponds are sometimes dug deeper over part or the entire pond area so that fish can take shelter in the deep water.

Fish feeds and pond fertilizers consist of organic household wastes, night-soil (through the use of overhung latrines), rice bran, tapioca (cassava starch), soybean wastes and plant residues. In recent years, more well-off, commercial fish farmers or pond owners have introduced the use of artificial pelleted fish feed, composed of rice bran, fish meal, soybean meal, vitamins and wheat pollard. There are several pelleting factories in the country.

- Commonly Cultured Fish

Over 600 indigenous freshwater fish species are found in Indonesia (Atmadja and Jangkaru 1985). Only about a dozen are commonly cultured, some of which are exotic, i.e. not indigenous but introduced into the country.

In Java, which is the main fishpond culture area, the most commonly cultured fish species, are:

Fish Species	Family
• Common Carp	Cyprinidae
• Nilem Carp	"
• Java Carp	"
• Nile Tilapia	Ciclidae
• Java Tilapia	"
• Giant Gourami, and	Anabantidae
• Kissing Gourami	"

Also cultured in ponds:

• Snakehead	Ophiocephalide
• Milkfish, and	Chanidae
• Catfish	Clariidae

Table 15.3 illustrates and lists these cultured species with their English designations as well as their scientific names, along with some additional information.

In West Java, the production of pond-cultured fish in 1976 rated in the following order of magnitude:

	% production by weight
• Common Carp	32
• Java Carp	13
• Kissing Gourami	10
• Nilem Carp	9
• Giant Gourami	6
• Tilapia	2
• Others	28

- Old and New Forms of Fish Culture and Feed

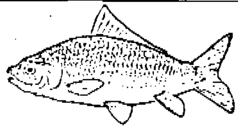
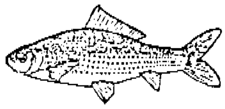
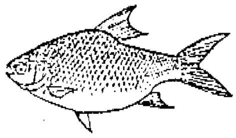
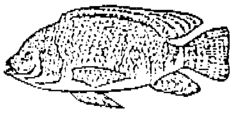
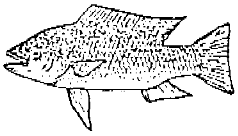
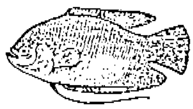
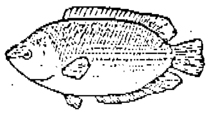
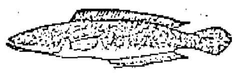
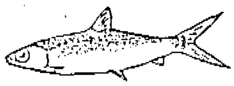
Traditional fishpond culture is practised in small holdings consisting of one or more small ponds, mostly owned by village farmers. The different fish species are raised on rice bran, tapioca, residues from soybean processing, nightsoil, organic household wastes, and plant leaves, while only a minimum of artificial feed or fertilizer is used. The organic fish feed consists of products to which smallholders usually have easy access and for which they do not require a large cash income. Traditionally and in village areas in particular, pond fish culture covers in the first place the subsistence of the owner family and is only used for commercial purposes in the second place.

Most fish do not spawn in "grow out" ponds, i.e. in ponds where they grow to consumption size. Spawning is induced in small breeding ponds, which are stocked e.g. with one female and two male fish. The spawn which floats on top is collected and introduced into hatching ponds. The fry[1] is collected from there after about three weeks for culturing in rearing ponds. There, the fish is allowed to grow to consumption size. Some farmers transfer the fry to paddy fields where it is left to grow to fingerling[2] size. From there, the fish are taken to regular ponds and left until maturity. Yields from traditional pond culture amount to a maximum of 1700-2000 kg/ha/year, with an average of 3 catches per year of fish grown to 100-200 g.

Excreta play an important role in the fertilization of fishponds. A study conducted in western Java and comprising 700 fishponds, revealed that 85% served also as excreta disposal ponds with the use of overhung latrines (Djajadiredja 1979). Reportedly, users primarily dispose of excreta in this manner for sanitation and aesthetic purposes. The importance of excreta as pond fertilizer appears to have second priority. Whether fish feed directly

[1] Fry = very young fish, from 1 to 3 cm in size
[2] Fingerling = young fish, 8-10 cm in size and weighing up to about 100 g

Table 15.3 Fish Commonly Cultured in Freshwater Ponds in Indonesia (after Directorate of Fisheries 1977; Djajadiredja et al. 1979; Atmadja and Jangkaru 1985)

Fish name English (Scientific)	Specific information	Pictures of the fish
· Common Carp (Cyprinus Carpio)	Very common in western Java; exotic; feeds on macrophytes mainly	
· Nilem[1] Carp (Osteochilus hasselti)	Mainly in mountainous areas; periphyton[2] feeders; indigenous	
· Java Carp (Puntius gonionotus)	Very common in eastern Java; indigenous	
· Nile Tilapia (Tilapia nilotica)	Introduced from Taiwan in 1969; common in eastern Java; omnivorous[3]	
· Java Tilapia (Tilapia mossambica)	Observed for the first time in central Java in 1939; common throughout Java; omnivorous	
· Giant Gourami (Osphronemus goramy)	Omnivorous	
· Kissing Gourami (Helostoma temmineki)	Plankton feeder	
· Snakehead (Ophiocephalus striatus)	Animal (incl. fish!) feeder; grown in cages in Sumatra and Kalimantan	
· Milkfish (Chanos chanos)	Common in brackish water ponds	
· Catfish (Clarias batrachus)	Animal feeder; mainly in lowland areas; can also breathe in open air and can therefore live in deoxygenated water	

[1] a designation used specifically in West Java

[2] small plant and animal organisms (algae, protozoa, e.g.) growing on stones or water plants

[3] feeding both on plant and animal microorganisms

on excreta or only on plant and animal matter growing in the excreta-fertilized pond, has not been established with certainty. The analysis of the stomach contents of common carp living in river cages showed that the fish were mainly feeding on organisms attached to the cage structure; only little excreta were found in the stomach. In an experiment conducted in running water ponds where fish were fed commercially produced and pelleted fish feed, fish did not eat excreta which were flowing through the ponds (Atmadja and Jangkaru 1985).

In some areas, the production of fish in cages floating in the river is also a traditional form of fish culture (Photo 15.2). There is no purposeful fertilization with excreta, but the river might be contaminated with excreta or wastewater.

Some 10-15 years ago, so-called **running water ponds** were introduced. These are considered to offer an intensive fish culturing alternative to fish raising in river cages. Running water ponds are small, e.g. 8 m x 3 m and a 1.5 m in depth, and generally made of concrete. They require a large and regular flow of freshwater. A pond of 50 m^3 requires a flow- through rate of 50 l/s. It might typically be stocked with about 300 kg of fingerlings (say 4000 fish) whose monthly growth rate amounts to 50-60% of their own weight (Atmadja and Jangkaru 1985). The propagation of running water ponds coincided with the introduction of industrially-produced, pelleted fish feed which is mainly used in these ponds. This type of fish culture is thus relatively cost-intensive, both in terms of pond structure and operation. Therefore, probably only quite well-off, commercial fish farmers who produce fish for urban markets are able to afford such systems.

Reportedly, urban fish consumers have started recently to favour larger fish. This may be explained by the trend towards smaller families in urban areas and an increase in income of part of the urban population. Therefore on Bogor market, consumers are offered both small (100-200 g) and large (⩽ 500 g) fish.

Furthermore, some urban consumers have reportedly become reluctant, for reasons of taste, to buy fish grown in excreta-fertilized ponds. On account of this fact, and also for reasons of public health concern raised by the health authorities, fisheries extension services are now recommending that the **alternative culture and feed sequence** as shown in Fig. 15.1 be used in areas where excreta fertilization is common.

Market prices for fish vary not only considerably according to the type of fish, but also reflect consumers' preference: in 1985, one kg of Java

Tilapia or Milkfish cost approx. R. (Rupiah) 500-600[1], Nile Tilapia R. 1200, Kissing Gourami or Common Carp R. 2500, and Catfish R. 3000[2].

- Additional Examples

Two examples of commercial fish cultures operated by pond owners in Bogor, West Java are given. Bogor is an important fish culturing area. There, fish raising in ponds or in river cages is a traditional practice.

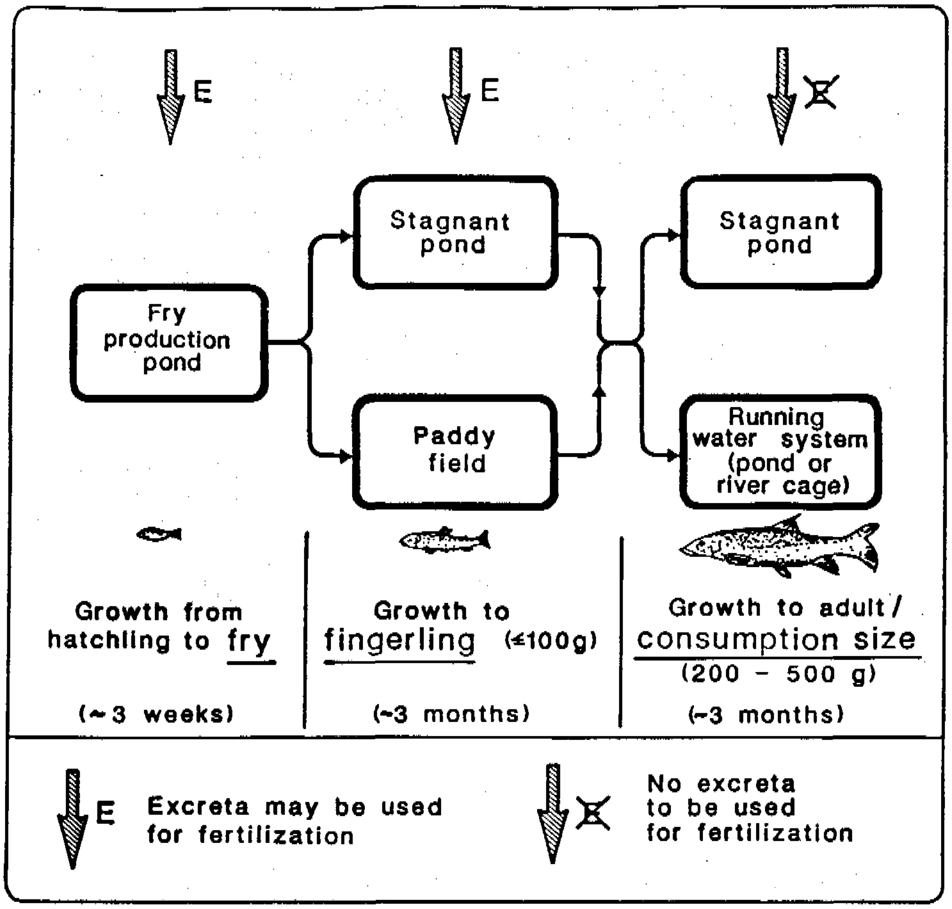


Fig.15.1 Alternative System of Fish Culturing in Ponds Which Avoids the Use of Excreta in the Final Growth Stage

1 R. 1085 = 1 US $ (1985)

2 For comparison's sake, one kg of rice cost in 1985 R. 250.

One of the interviewed pond holders owns 4 ponds of a total surface area of approx. 1500 m . The family runs a small soybean cake processing factory ("tahu") within the home. One of the four ponds totalling about 150 m in size and 70 cm in depth, serves as the family's household pond, i.e. it receives the wastes from the in-house toilet and from the kitchen. The pond also has overhung platforms for washing and bathing. It was then stocked with 10,000 Nile Tilapia ("Nila") fingerlings, 300 Kissing Gourami of approx. 100 g each and 150 Giant Gourami of 500 g each. The fish are caught about three times a year by draining the ponds completely. The "Nila" are harvested when 10-20 cm in size and sold to retailers for R. 800/kg. They are then sold to consumers for R. 1200/kg. Two of the owner's ponds in which fingerlings are being cultured (Photo 15.3), are fertilized with soybean processing waste.

Another pond owner whom we visited holds approx. 2000 m of ponds, divided into two large ponds of about 900 m each and several small, brick-lined running water pond tanks. Apart from producing fish for commercial purposes, the family runs a small shop and lets lodgings to food handlers and students. While the two large ponds are fed with river water and fertilized mainly from overhung latrines, the small ones are fed by surface runoff from the nearby "kampung"[1]. The main ponds are stocked with Nilem and Common Carp, Nile Tilapia and Kissing Gourami. The fish are harvested by draining the ponds about three times a year. At the time of our visit, the owner was holding in the small ponds Common Carp which he let grow to a weight of about 3 kg each by special order from a fish retailer. The fish could be observed feeding on algae growing attached to the tank walls near the tank inlets (Photo 15.4).

15.5 In a Village with Excreta-Fertilized Fishponds

- Entering the Village

Cikoneng is located at approximately 20 km SE of Bandung, in the Ciparay subdistrict. It lies at an altitude of 800 m and totals 3,900 inhabitants (1985). The village lies within the area which was earmarked as a sample area to investigate the impact of excreta-fertilized family and village fishponds based on the disease history of villagers who use the pond water for domestic purposes, i.e. washing and bathing[2] (see Sect. 15.8). Fig. 15.2 shows the District of Bandung ("Kabupaten") and the location of Cikoneng in the Ciparay Subdistrict ("Kecamatan").

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[1] low-income housing area

[2] The epidemiological investigation is undertaken by Dr Bakir Abisudjak of Padjadjaran University, Bandung

Small fishponds are a common sight in hill villages around Bandung. Use is made of the natural surface drainage through rivulets and streams. These either discharge into the ponds, or the water is diverted from the streams by open trenches, bamboo gutters or pipes. The ponds are interconnected and the water flows in a cascade-like manner from upper to lower ponds. Particularly during the rainy season, flow-through periods are likely to be short and renewal of the pond water relatively rapid. Presumably, the continuous replacement of the pond water with water which is aerated during its downward passage from the upper ponds, is one of the main reasons why many fishponds are seen in hilly areas but very few in the plains. Most ponds are found in sloping terrain with a natural gradient ranging from 5-15% (Abisudjak 1986). In the plains, the slow exchange rate of the water may lead to oxygen depletion at night (in darkness, the algae cannot replenish the oxygen consumed by bacterial degradation) and may cause possible fish death. Where villages are surrounded by rice fields, water from paddy fields might be diverted and channeled to nearby village fishponds[1]. Some farmers turn harvested rice fields into temporary fishponds in order to raise fingerlings[2].

The village fishponds are closely linked with the daily life of the villagers who defecate in overhung latrines. Excreta are thereby "washed" away while the ponds become fertilized. A second piled structure used for washing and bathing is usually built over the pond. This structure is placed where water from an upstream pond or ditch is discharged into the pond through a gutter or pipe. Also common are overhung structures ("pancilingan") where all these activities, i.e. defecation, washing and bathing, are done in one phase. Most of the pond latrines and wash places are made up of bamboo poles, and some of concrete. Photos 15.5, 15.6 and 15.7 show village ponds with overhung latrines and wash places.

In a study conducted in West Java, the use of fishponds for different purposes was observed in six villages (see Table 15.4; Djajadiredja et al. 1979). The ponds are widely used for defecation and washing/bathing. The use of the pond water for drinking purposes was observed only in one village where it is practised by only a small percentage of the families.

There are but only few data on the microbiological quality of ponds with overhung latrines. In a survey conducted in the Bandung District in 1986/87, the average faecal coliform concentration of 11 ponds was found to be around 10^5/100 ml (Abisudjak 1985).

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[1] In discussions with government officials, concern was expressed over potential damage to ponds and fish due to pesticides or herbicides applied to the rice plants.

[2] See Sect. 15.4 for explanation of fish sizes

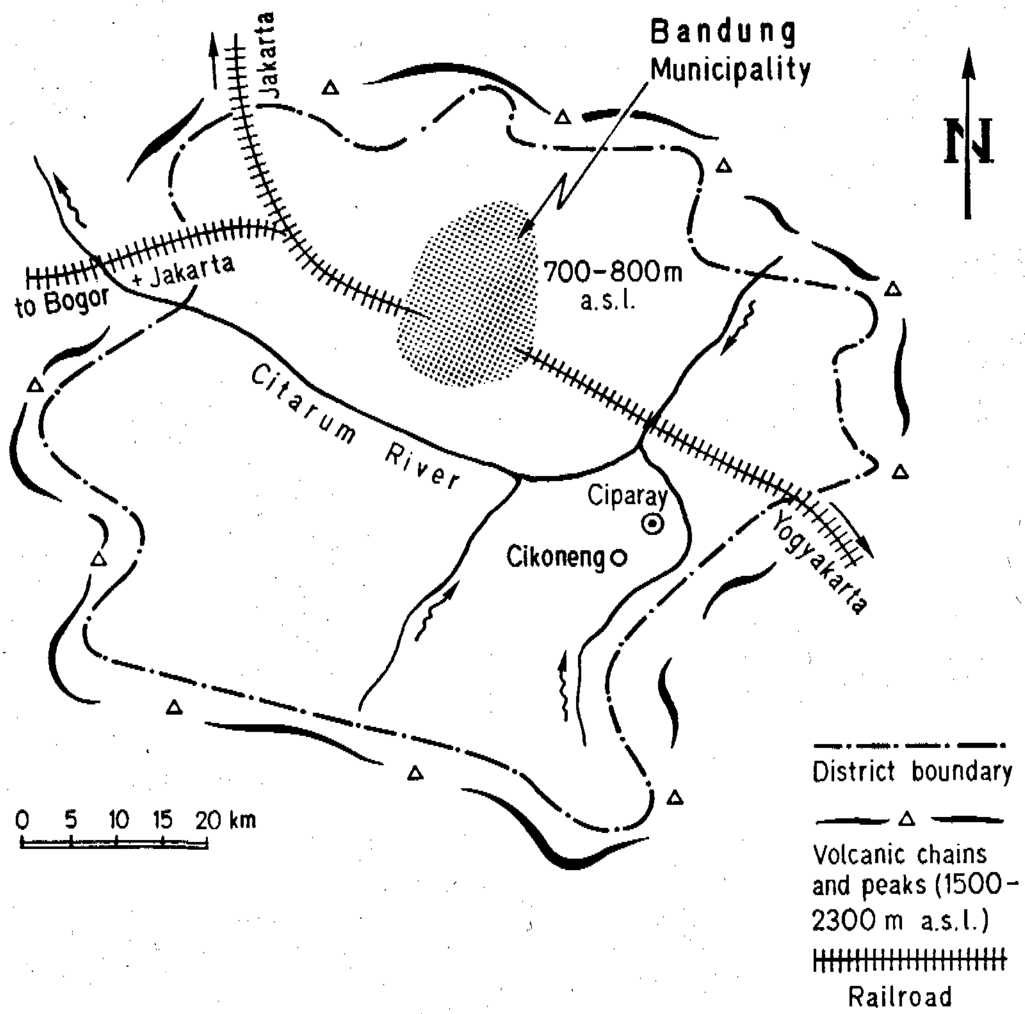

Fig. 15.2 Bandung District with the Location of Cikoneng, a "Pond Village" (schematic)

The pond's depth ranges from 0.5 to 1 m. In Cikoneng, the size of ponds ranges from 20 to < 1300 m^2, the average being 211 m^2 (Abisudjak 1986). Cikoneng may be considered a typical "pond village". According to a detailed survey by Abisudjak (1986), the majority of the ponds are found at the edge of the village. At the time of our visit (November 1985), the water in most ponds looked brownish-yellow due to soil erosion caused by heavy rains, and there was water flowing all around us in and out of ponds. In some places, bamboo or iron pipes run from ditches or ponds into nearby houses; in others, water is used for washing, bathing or to flush toilets. Such installations match the habit and need to defecate into flowing water. The flow-through water is discharged into the nearest downstream pond. In

Table 15.4: Usage Pattern of Fishponds in Six Villages in West Java (Djajadiredja et al. 1979)

	% of people using ponds for:				
Village	Drinking & cooking	Washing & bathing	Defecation	Garbage disposal	Sewage discharge
Parseh	-	14	67	7	11
Ciwidey	-	41	23	10	12
Sabandar	-	33	31	-	17
Cipanas	-	60	47	-	8
Salajambe	-	52	69	24	27
Limbangan	9	78	57	-	13

Cikoneng, - but not necessarily in other villages - most people who do not own or use an overhung latrine, have an in-home flow-through "flush"-toilet (Abisudjak 1986). Fig. 15.3 gives a bird's-eye and a sectional view of a "pond village".

Houses in Cikoneng are built very closely to each other, as if to save land for ponds and the surrounding rice fields. Narrow footpaths lead through the village and run alongside ponds and between adjacent houses. In some places, the paths are so narrow that walking becomes difficult. The importance of the ponds in the life of the village is evident: Washing and bathing places over the ponds are in heavy use. At a short distance, i.e. only a few meters from the ponds, villagers have dug shallow "wells". These are unlined and covered with a bamboo basket.The water is polluted on the surface. A few wells are lined and somewhat deeper, with walls raised above ground. They are used by up to 20 families who lift the water by pulleys and buckets.

Upon arrival in Cikoneng, we called on the "Desa" Office. The village secretary answered our first questions and provided us with some village statistics. All the families in Cikoneng are Sundanese. They form the main

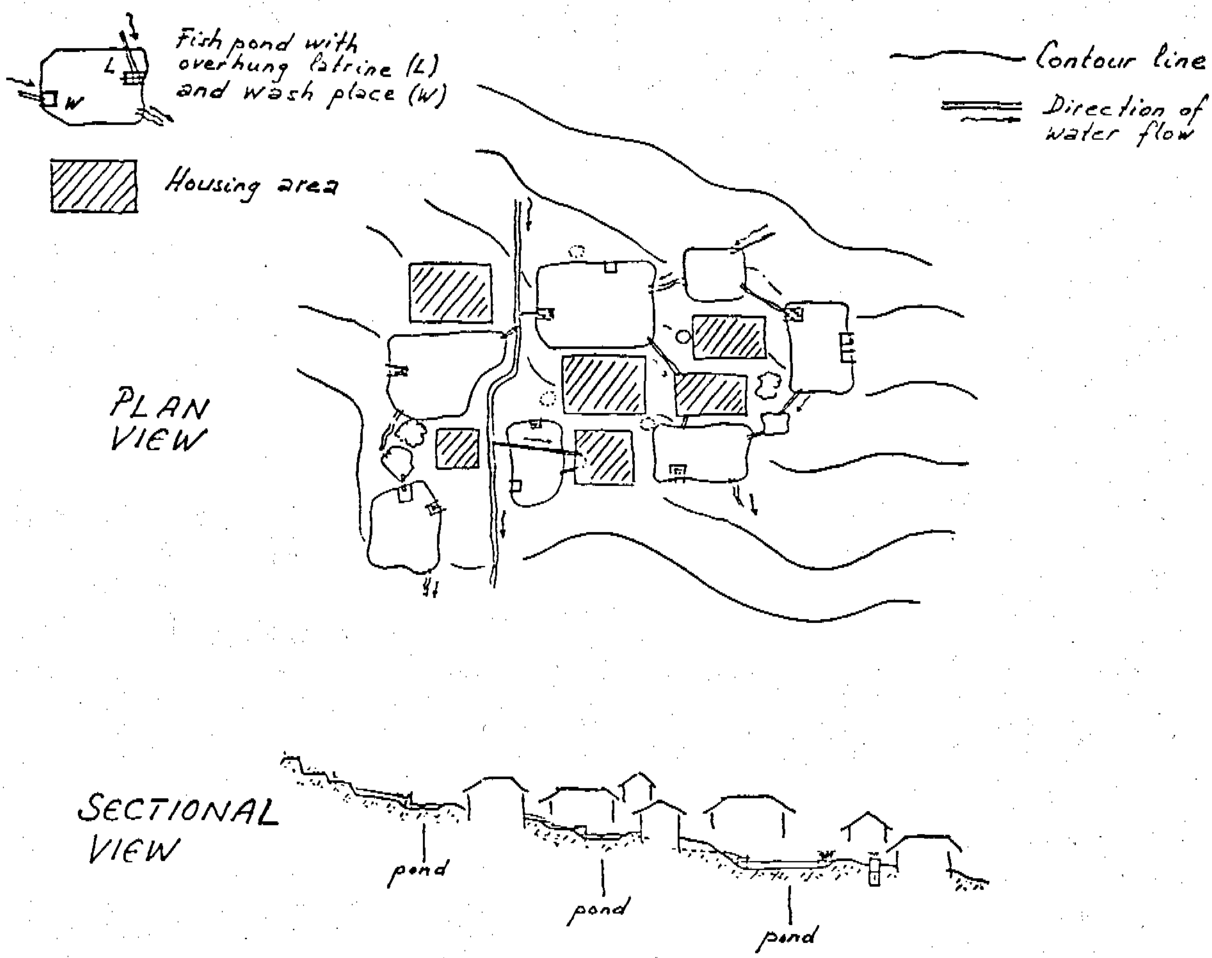

Fig. 15.3 Sectional and Plan View of a Village with Fishponds (schematic)

ethnic group in western Java. The 3900 inhabitants live in 892 households. 270 farmers own a total of 208 ha of paddy land. The smallest plot is 100 tumbak[1] (1400 m^2), the largest about 2100 tumbak (3 ha). 400 persons work as farm labourers, as they own no or too little land to make a living. Overall, more rice is produced in the village than is needed for subsistence. Fields are fertilized and conditioned with cattle manure and fish pond sludge; some farmers also use mineral fertilizers.

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[1] 700 "tumbak" = 1 ha

The village has a public primary school as well as a private secondary and high school run by a Muslim organization. There are about 5 ha of fishponds divided among 85 villagers. The average pond holding size per family thus amounts to 590 m^2. Many ponds in Cikoneng are, however, smaller since some pond owners have more than one pond, while others do not own any pond. Formerly there were more overhung latrines. Those not using overhung latrines anymore own in-house latrines and use piped pondwater for continuous flushing for privacy purposes. On overhung latrines, privacy is obviously limited. It is, however, difficult to say whether this is the main reason why overhung latrines are abandoned in this cultural setting.

Fertilization of ponds is mainly through human excreta. In addition, ground rice husks (bran) are used by some owners. Others may have a chicken house built on piles above the pond to achieve additional fertilization from chicken manure. Apparently, no artificial fish feed is used in Cikoneng.

In some areas of Bandung District, people reportedly do not commonly use fishpond water for washing and bathing. Instead, they use water from streams which do not receive any or only little effluent from excreta-fertilized fishponds. Others take water from paddy fields which is conveyed to the village by bamboo gutters. Excess incidence of waterborne excreta-related disease might be less with such water use patterns than if water of excreta-fertilized ponds is taken for washing and bathing.

- Talking to Pond Owners

Heavy monsoon clouds dropped their content over us who were sitting in the candle-lit "guest-room" of a tiny bamboo-made tea stall built between ponds and bamboo groves. There, the 16-year old son of a villager and pond owner gave us an account of how the family makes use of its fish ponds. They are eight children and the family owns a few rice fields, two ponds and a small shop. Its economic status might therefore be above village average. The ponds are used by the family itself and 10-12 other families for washing, bathing and defecation. Drinking and cooking water is drawn from a privately owned shallow well[1]. Usually clothes and dishes are washed at the pond and at times, well water is used for clothes washing. Infants are bathed in the home up to the age of about two. Similarly, the use of the overhung latrine does not begin before the age of two.

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[1] At the tea shop, rice is washed with water discharged through a bamboo gutter from a nearby pond or paddy field.

Common carp, Java Tilapia and Nile Tilapia are the fish cultured in the ponds owned by this family[1]. Once a year, the ponds are completely drained. All the fish are caught and most of them sold to fish dealers or "middlemen" who sell the fish within the village, in other villages or in Bandung. Occasionally, and at irregular intervals, fish are caught when special need arises. The bottom mud is removed after complete drainage and used on the family's rice fields as soil conditioner and fertilizer. Photo 15.8 shows a drained pond.

The family eats fish once a week. The fish is scaled, gutted and fried in coconut oil. The two or three daily meals consist of rice and vegetables such as cucumbers, soybeans, pumpkins and beans. Water spinach ("kangkung") is grown in one of the ponds. This vegetable is very common and eaten cooked.

According to the boy's account, diarrhoeal infections do not play an important role in his family, i.e. members of the family have not had more than one diarrhoeal attack per year.

The second "farmer" to whom we talked, is a rather well-off villager. He is a government official dealing with the religious education in the Bandung District administration. His wife is a primary school teacher and a "kader kesehatan desa" (village health promotor). Health promotion comprises nutrition, women skills and advice about the home environment. Sanitation, particularly as regards the use of ponds, is not dealt with. Their home serves as a gathering place for health promotion activities. The family owns five fish ponds totaling 130 tumbaks (~ 0.125 ha) which are located in the vicinity of the house, and 300 tumbak (0.4 ha) of paddy land. The family uses well water for domestic purposes. Washing and bathing is done at an in-house wash place. There is also an in-house flow-through latrine, the effluent of which is drained into the nearest pond.

The five ponds have each one to two overhung latrines. At one of the ponds there is a communal MCK[2]. Fish are grown in polyculture, i.e. several types of fish live in the same pond. This is the common pattern of fish culture in Indonesia. Fishing is done at 1-3-month intervals. Every 3 months the ponds are totally emptied to remove accumulated mud. This is necessary to

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[1] See Chpt. 15.4 for a list of fish culture patterns in Indonesia

[2] MCK ("Mandi/Cuci/Kakus") is a sanitary unit comprising a bathing ("mandi") and washing ("cuci") place as well as a latrine ("kakus")

prevent fish from suffering or dying. This occasionally happens at night if the renewal of water in the pond is reduced due to blockages of channels or gutters upstream. Fishing is carried out by family members or hired fishermen who walk through the ponds using small nets. The catch is sold partly in Cikoneng itself, partly on outside markets. Outside marketing is done by the hired fishermen who themselves might receive payment in kind, i.e. in the form of fish. The various figures for annual fish yields as reported by the owner, range from 1,600 to 2,800 kg/ha depending on the kind of fish. Fish are raised by placing 10 kg of fry bought from the Dept. of Agriculture into a 400 m^2 pond and allowing fingerlings to develop for 6 months. Starting from its fry stage, common carp grows up to six times its weight in one year. It is normally caught and marketed at a weight of 1 kg, but at times, fish of up to 4 kg may be produced.

15.6 Where People do not Use Overhung Latrines (anymore)

There are in the hills of Java also many villages which do not have fishponds. An example is a village which lies at a ten-minute drive from Cikoneng and which forms part of the same "Desa" administration. There the terrain is more rugged, slopes are steeper than in Cikoneng village. Only a few families have got own land. Stone cutting is a major source of income. Domestic water is mainly supplied by wells. Most villagers **defecate in the river** flowing through the village. Some families have in-house latrines with drain pipes to the nearby river.

In some villages, alternative methods and installations for excreta disposal have been introduced in recent years. In **Ciaro village**, e.g., which lies at about 25 km NE of Bandung, an improved water supply system and latrines were built with the support by CARE in 1985. Water is drawn from a spring and distributed through **MCKs**, i.e. public washing-bathing-defecation facilities. Each MCK serves 100-150 inhabitants, or 20-30 households. Excreta are stored in leaching pits which will eventually have to be emptied. CARE continues to provide training support to village health workers in family planning, immunization, nutrition, sanitation and oral rehydration. Photo 16.9 shows an MCK in Ciaro village.

There are more than 100 ponds in Ciaro. Prior to the construction of the new water supply and sanitation facilities, overhung latrines were in common use which were later removed to a large extent. Formerly, water piped from nearby paddy fields was used for washing and bathing. Drinking water was fetched from wells.

Fish are produced in all the ponds, while water vegetables ("kangkung", "genjer") only in some. A number of pond owners allow water hyacinths to grow in order to use them as fish food. Formerly, pond fertilization was achieved by excreta discharge from the overhung latrines, and by the addition of rice bran which farmers purchased from a nearby rice mill. When asked about the means of fertilization after abandoning the overhung latrines, owners replied that they increased the quantities of rice bran to make up for the loss of excreta. Reportedly, fish grow even better now with the added bran, which is applied more regularly than before.

Due to the limited time spent in the village, it was not possible to determine whether all pond owners are financially secure to make up for the "lost" excreta. Neither was it possible to establish whether farmers, for whom the newly built MCKs are not conveniently located, do not in fact continue to use overhung latrines.

15.7 Institutions and Policy[1]

Recently, the Government of Indonesia has adopted the strategy of decentralizing government services and responsibilities. Thus, many functions which were previously mainly, though not exclusively, carried out by the central ministries, will be gradually shifted to the local governments and administrations. Ideally, under this new strategy, the local authorities will, in future, become the bodies which will carry out infrastructural projects, while the central authorities will mainly formulate policies, exert monitoring and control functions, provide technial assistance and channel central government funds to the local government authorities. Investment capital for infrastructural projects will have to be generated to an increasing extent by the local government bodies and parastatal agencies (e.g. the municipal water works). At present, a transient stage exists during which both strategies are functioning side by side. The pace of change depends largely on the pace with which the technical and managerial expertise can be built up at the local (district and municipal) administration level.

In the light of this new strategy, responsibility for the provision of water supply and sanitation will lie with the governments at the provincial, district and municipal level. In addition, three ministries of the central government are involved in the water supply and sanitation sector. These are the Ministry of Public Works (DEPPU) which is responsible for development in urban and semiurban areas, and later also for piped rural supplies, the Ministry of Health (DEPKES) which, as part of its preven-

[1] This chapter was originally based on a sector report on water supply and sanitation prepared by the Asian Development Bank (1984). It was later amended according to recent changes in government structures and responsibilities (Tjiook, personal communication).

tive health activities, also deals with rural sanitation and hygiene promotion, and the Ministry of **Home Affairs** (DEP DALAM NEGERI) for operation of water supply schemes, drainage and sewerage systems, as well as for the promotion of community participation, by virtue of its responsibility over the Local Governments and the Local Governments' enterprises.
Cipta Karya is one of the three Directorates General of the Ministry of Public Works, the two others being the Directorate General of Water Resources Development (PENGAIRAN) and the Directorate General of Highways (BINA MARGA). Cipta Karya comprises six Directorates: (i) Planning and Programming; (ii) Urban and Regional Development; (iii) Housing; (iv) Building Development; (v) Sanitation; and (vi) Water Supply. The Directorate of Sanitation was formed in April 1984. This clearly indicates the increasing attention paid by the Government to the sanitation subsector. This department plans urban sewerage schemes, solid waste management programmes, solid waste pilot schemes, and surface drainage systems. The Directorate for Housing is partly responsible for the construction of MCK units, solid waste equipment provisions, micro-drainage as part of the Kampung (low-income neighbourhood) Improvement Programmes as well as for household latrines in new housing facilities.

In recent years, so-called **Integrated Urban Infrastructure** programmes have gained increased importance. They are implemented by the municipal administrations and include, among other things, water supply and sanitation projects. Ciptakarya provides technical guidance, although the municipal administrations will increasingly develop their own technical and managerial expertise.

An agency which carries out R & D activities in the fields of its three directorates, i.e. Cipta Karya, Water Resources and Highways also exists within the Ministry of Public Works.

The Ministry of Health (DEPKES) and its Directorate General of Communicable Diseases Control and Environmental Health (CDC & EH) are in charge of promoting sanitation schemes not covered by the urban and semiurban systems. DEPKES may to some extent still be involved in the development of point water supplies such as shallow and deep tube wells fitted with handpumps, artesian wells, rainwater collection tanks, and spring protection facilities. These activities will probably be gradually taken over by the local authorities. As regards sanitation facilities, the Ministry is involved mainly in latrine construction programmes, sullage disposal facilities, as well as with the guidance and advice on solid waste collection and disposal issues mainly in rural areas. Furthermore, DEPKES is vested with the important task of controlling and enforcing the water quality standards in rural as well as in urban and semiurban water supply schemes.

Planning and implementation of rural water supply and sanitation projects are, in most cases, covered by the INPRES (Presidential Decree) budget, which was developed specifically to promote the autonomous implementation of projects within the Districts (Kabupaten). INPRES funds are administered and disbursed to local government authorities by the Ministry of Home Affairs which is the governing authority for district and village administrations. The funds are used according to the villages' own development priorities. The INPRES programme is used within the subsector for the construction of family latrines (Jemban Keluarga), for sullage disposal and water supply projects. These projects are technically supported by the central level through the Ministry of Health, Directorates for Water and Sanitation within the Directorate General of Communicable Diseases Control and Environmental Health, and implemented at village level with the support of the health centres (PUSKESMAS).

Fisheries development is dealt with by the **Ministry of Agriculture** and its extension services. An important subsidiary of this Ministry is the Inland Fisheries Research Institute at Bogor (West Java), which devotes itself to production-related aspects of fish culture in ponds. In 1979, the Institute prepared a case-study on pond culture and the use of human excreta for pond fertilization in West Java (Djajadiredja et al. 1979).

The Ministry of Health has been carrying out latrine promotion and construction programmes over the past ten years. A presidential decree was issued to ban the use of overhung latrines. Reportedly, in some areas, the decree was enforced by police force. The government's latrine promotion programme has apparently had only limited success and has not brought about much change in people's excreta disposal habits. This is particularly evident in areas where the use of overhung latrines and excreta fertilization of ponds are practised. Reportedly, the government now wants to concentrate its latrine promotion activities in areas where there is no practice of excreta disposal in ponds. The programme uses various modifications of family twin-pit latrines and also promotes the construction of latrine blocks where each family is responsible for its own individual latrine. The government's Institute for Human Settlements (Ministry of Public Works) and WHO are planning to investigate the use of latrine pit contents on fields and in ponds.

15.8 Health and Epidemiological Aspects

In this section, discussion will not be limited to water and excreta-related infections but these will be discussed in the wider context of the most important causes of morbidity and mortality in the country. This will allow the reader to assess the importance of the water and excreta-related infections that might be associated with the waste reuse practice in comparison with the predominant diseases in the area. The reader is also referred to section 1.2, where the health risks associated with wastewater use have been summarised, and to section 1.4, where the difficulties involved in evaluating the health effects of a specific reuse practice have been outlined. The data available do not allow an accurate assessment of the health risks to be made, so the following sections contain epidemiological judgements which should be considered as "informed speculation" rather than strict scientific analysis.

- Aspects of the Endemic Disease Situation

The health situation in Indonesia is characterised by a high infant mortality and high incidence and mortality due to communicable disease. Environmental sanitation is not available for most of the population and utilisation of health services is low, especially in rural areas. Low levels of

Table 15.5 Socioeconomic Indicators in Selected Countries: 1979[1]

	Indonesia	Philippines	Malaysia	Korea	Singapore
Total Population (millions)	147	46.7	13.1	37.8	2.4
Urban Population (%) [2]	18	36	29	55	100
Crude Birth Rate (per 1000)	35	34	28	25	18
Crude Death Rate (per 1000)	12	8	6	8	5
Rate of Natural Increase (%)	2.3	2.6	2.2	1.7	1.3
Infant Mortality Rate[2] per 1000 live births)	93	65	32	37	13
Life Expectancy at Birth	53	62	68	63	71
Adult Literacy Rate (%)[3]	62	33	60	93	87
Per Capita Income (US$)	520[4]	600	1370	1480	3830
Annual Per Capita Health Budget (US$; 1978)	4	3	15	2	52
Health Budget as % of Total National Budget (1978)	2	3.6	5.2	n.a.	4.8

1. Source: IBRD, World Development Report, 1981; Data are for 1979 unless noted otherwise.

2. 1980

3. 1976

4. 1981

nutrition, in addition to infectious diseases, are a major contributing cause to infant and child mortality, while the low utilisation of health services adds to the difficulties of control of communicable diseases, especially those preventable through immunisation. Data on both morbidity and mortality rates are incomplete and are often unreliable, due to the low level of disease reporting to the low utilisation of health services.

In 1979, infant mortality rate was estimated at about 93 per 1000 live births, higher than in many other countries in the region (see Table 15.5). Comparing Indonesia with the Philippines, which are of similar income per capita, adult literacy although higher in Indonesia, reveals a lower life expectancy at birth and a higher infant mortality rate and crude death rate than in the Philippines. The situation has improved since 1969, when infant mortality rate amounted to 140/1000 live births, and life expectancy was only 47 years. Economic growth lifted Indonesia from the ranks of the low-income countries in the early 1970s to the middle-income countries in the early 1980s. So, although internal progress has been achieved, the health conditions are still poor in comparison to countries with currently similar income levels. In 1980, life expectancy was 53 years compared with an average of 57 years in low-income countries and 61 years in middle-income countries.

Children under 5 make up 40% of deaths, and maternal mortality is also high. Children are at high risk of mortality from acute respiratory infections and gastoenteritis. Preventable diseases such as tetanus, pertussis, measles and polio are also important causes of childhood deaths. The four chief causes of death for all ages are acute lower respiratory tract infections, diarrhoeal disease, cardiovascular disease and tuberculosis (Table 15.6).

The disease pattern in the country showed some differences between the 1972, 1980 and 1986 household surveys (Table 15.7). The most common diseases were infections of the respiratory system, including tuberculosis, followed by skin infections, diarrhoea and childhood diseases against which immunisation is available. The trend for the numbers of reported cases (per 1000 population) to rise and not to fall for many diseases suggests either that health conditions have not been improving or that the diseases have been reported more frequently than previously. Significant rural, urban and inter-regional differentials exists in levels of both mortality and morbidity. Variations in disease patterns (Table 15.8) may be influenced by climatic conditions, aspects of socioeconomic development, and, possibly, by cultural practices.

Table 15.6 Principle Causes of Death in Indonesia, as Shown by Household Surveys in 1972 and 1980

Causes of death	1972 Survey Number of deaths	%	1980 Survey Number of deaths	%	1986 Survey Number of deaths	%
Acute lower respiratory tract infection	70	12.0	180	19.9		6.2
Diarrhoeal diseases	99	16.9	170	18.8		12.0
Cardiovascular diseases	30	5.1	90	9.9		9.7
Tuberculosis	35	6.0	76	8.4		8.6
Tetanus	27	4.6	59	6.5		6.0
Diseases of the nervous system	30	5.1	45	5.0		3.1
Liver diseases	-	-	37	4.2		3.3
Injuries and accidents	12	2.1	32	3.5		4.7
Neoplasm	-	-	32	3.5		4.3
Typhoid fever	12	2.1	23	2.5		3.1
Other infectious diseases	-	-	27	3.0		-
Complication of pregnancy, childbirth	13	2.2	23	2.0		1.7
Neonatal condition	241[a]	42.3[a]	62	6.8		5.3
Other	-	-	43	4.8		-
TOTAL	583		905		2.055	

Source: MOH, Household Survey, 1972, 1980 and 1986

[a] includes causes of death listed above

Table 15.7 Disease Patterns in Indonesia, as Shown by Household Surveys in 1972 and 1980

Diseases	1972 Survey		1980 Survey		1986 Survey	
	Number of cases reported	Per 1000 population	Number of cases reported	per 1000 population	Number of cases reported	Per 1000 population
Upper respiratory tract infection	980	0.9	3,796	3.1	6,242	21.3
Lower respiratory tract inf.	422	0.4	1,041	0.9	1,861	6.4
Tuberculosis	577	0.5	732	0.6	1,235	4.2
Diarrhoeal diseases	297	0.3	947	0.8	1,283	4.4
Skin diseases	721	0.6	1,013	0.8	2,226	7.6
Cardiovascular diseases	120	0.1	717	0.6	1,546	5.3
Eye infections	224	0.2	451	0.4		
Diseases of musculo-skeletal and connective tissues	26	0.0	442	0.4	1,164	4.0
Malaria	279	0.2	219	0.2	1,772	6.1
Diseases of the nervous system	74	0.1	254	0.2	1,659	5.7
Anaemia	182	0.2	150	0.2		
Arthro-skeletal diseases	94	0.1	321	0.3		
Dental diseases	70	0.1	293	0.2		
Other infectious diseases	107	0.1	268	0.2	1,911	6.5
Accidents	55	0.1	248	0.2	388	1.3
Others	1,319	1.2	2,937	2.4		
TOTAL	5,547		13,929		24,789	

Source: Ministry of Health, Household Survey, 1972, 1980 and 1986

Data on specific diseases related to environmental sanitation are difficult to obtain; an indication of trends can be seen using data on all gastro-intestinal infections reported under the category of "diarrhoea" in the Ministry of Health statistics. Data from the years 1977 to 1979 show a vast difference in the number of cases per 100,000 population between different provinces (Table 15.9). For example, East Kalimantan and East Timor have a consistently high level of diarrhoeal disease, whereas the Moluccas and South Sulawesi have a consistently lower level, at less than 25% of the rates for the former provinces. This has sometimes been related to climatic conditions (such as dryness in East Timor) and to poor water supplies and

Table 15.8 Reported Cases of the Major Notifiable Diseases in Selected Provinces in Indonesia (including Java), 1979 (cases per 100,000 population)

	West Java	Central Java	East Java	Bali	East Timor	West Timor	Irian Jaya
Influenza	381.15	418.2	304.25	1241.8	730.7	430.97	587.8
Diarrhoea	157.53	146.42	95.78	231.75	331.45	219.64	n.a.
Malaria	1.55	23.72	20.7	6.28	600.49	324.54	405.9
Filariasis	0.007	0.009	0.013	0.009	1.06	0.0	0.33
Rabies	0.036	0.021	0.003	0.0	0.0	0.0	0.0
Yaws	0.009	0.002	0.0	0.02	1.25	0.007	11.99
TB	1.42	0.86	0.85	2.51	0.36	0.69	2.1
Leprosy	0.13	0.04	0.262	0.24	2.47	0.591	0.26
Gonorrhoea	5.17	11.38	1.65	2.0	33.81	1.53	3.89
Syphilis	0.028	0.11	0.05	0.25	1.87	0.1	0.06
Diphtheria	0.008	0.12	0.04	0.12	0.0	0.021	0.007
Pertussis	1.61	1.1	1.451	0.54	8.03	0.19	0.1
Tetanus	0.046	0.0514	0.175	0.63	0.019	0.016	0.0

Source: Ministry of Health, routine statistics.

sanitation facilities, and may be influenced by differences in socioeconomic levels (higher in the Moluccas and South Sulawesi). Data from point prevalence studies of diarrhoeas in 15 provinces (Winardi and Kantun 1983) also show a great variation between provinces, although the ranking is not always consistent with that shown by the routine data (Table 15.8). The high level of diarrhoeal disease in West Java in relation to its high socioeconomic status (among the highest in Indonesia), shown by both data sources, has led to speculation that the practice of defecating over fishponds is responsible for the spread of diarrhoeal disease in this area. This practice is most widespread in West Java, and occurs to a lesser extent in Central Java. A morbidity survey of diarrhoea in several districts within the West Java province (Table 15.10) indicates that the point prevalence of diarrhoea is highest in Garut, which is also the area with the highest concentration of excreta-fed fishponds. However, a closer look at the data on the number of cases in children under 5 years of age in the last two weeks, indicates that the rates in Sukabumi are equivalent, and the there are far fewer excreta-fed ponds in that area. Data such as these

Table 15.9. Cases of Diarrhoea per 100,000 Population/Province, 1977-1979

Province	1977		1978		1979	
	cases	rank	cases	rank	cases	rank
1. Bali	179.12	4	205.41	5	231.75	3
2. West Java	120.45	8	162.69	6	157.53	7
3. Yogyakarta district	52.74	20	122.21	11	91.05	17
4. Central Java	88.22	13	130.04	8	146.42	9
5. East Java	42.43	24	76.50	18	95.78	16
6. Irian Jaya	177.85	5	349.28	2	-	
7. West Kalimantan	69.85	17	89.65	17	149.88	8
8. South Kalimantan	64.78	19	72.24	21	191.22	5
9. Central Kalimantan	88.23	12	113.09	13	108.08	14
10. East Kalimantan	237.31	1	308.54	3	626.02	1
11. Moluccas	24.10	25	27.67	25	21.96	24
12. West Timor	189.94	2	208.76	4	219.64	4
13. East Timor	179.49	3	416.75	1	331.45	2
14. Central Sulawesi	50.57	23	73.59	20	104.50	15
15. South Sulawesi	65.88	18	56.74	24	50.17	23
16. South-east Sulawesi	124.41	7	122.65	9	119.96	10
17. North Sulawesi	99.37	10	122.22	10	187.90	6
18. Aceh	52.59	21	71.26	22	50.17	22
19. West Sumatra	96.96	11	93.28	16	73.50	20
20. Bengkulu	143.62	6	109.80	14	89.50	19
21. Jambi	70.30	16	76.40	19	89.58	18
22. Lampung	51.57	22	155.51	7	73.22	21
23. Riau	87.06	14	121.27	12	119.96	10
24. South Sumatra	100.01	9	100.13	15	117.95	12
25. North Sumatra	73.87	15	69.41	23	117.67	13
TOTAL	101.23		126.72		22.838	

Source: Ministry of Health, routine statistics.

cannot therefore be used to indicate the reasons for the difference in diarrhoeal disease rates in different areas. Carefully designed epidemiological studies set up to test hypotheses need to be carried out where the reasons for differences are sought.

Table 15.10 Morbidity Survey of Diarrhoea in Districts of West Java, 1985

Kabupatan	No. children in survey		No. cases in last 2 weeks (%)		Point prevalence
	<1 year	0-4 years	<1 year	0-4 years	
Bandung (rural district)	739	3791	96 (13.0)	342 (9.0)	25/1000
Bandung (urban)	868	4284	91 (10.5)	441 (10.3)	30/1000
Garut	646	3750	89 (13.8)	489 (13.0)	54/1000
Sukabumi	329	4076	90 (10.9)	490 (12.0)	14/1000
Bogor	841	3750	33 (3.9)	149 (4.0)	15/1000
Karawang	758	3837	105 (13.9)	357 (9.3)	18/1000
TOTAL	4681	24488	504	2268	22/1000

Source: Provincial Health Office, Bandung, West Java.

- Water Supply and Excreta Disposal

The situation of water supply and sanitation from the beginning of Repelita III (the third 5-year development plan) and the target of service levels for the end of Repelita IV are given in Table 15.11. It is clear that development of rural water supplies is lagging behind the development of urban supplies, and developments in sanitation are less advanced than those in water supplies. By 1985, only 34% of the rural population had access to safe excreta disposal facilities and 32% had access to improved water supplies (Pancaroglu, 1985). Data from West Java indicate that only 6.4% have improved sanitation facilities, whereas 39.9% have improved water supplies.

Table 15.11 Water Supply and Sanitation Service Levels for Repelita III and Targets for Repelita IV

	Service Levels (%)			
	1979 (March) Beginning of REPELITA III	1984 (March) End of REPELITA III	1989 (March) End of REPELITA IV	1989 (December) End of Decade
Water Supply				
Urban	35[1]	60[2]	70	75
Rural	18	32	55	60
Sanitation				
Urban	17	*[3]	*[4]	60
Rural	25	34	40	40

1. Installed production capacity
2. Installed production capacity; estimated actual utilization 40% through house connections and public taps.
3. Solid waste disposal: 15 cities; drainage: 25 cities; and sewerage: 4 cities.
4. Solid waste disposal: 200 cities; drainage: 200 cities (both through low-cost technologies) and sewerage: 10 cities.

Source: Pancaroglu (1985).

Progress in the development of the water supply and sanitation sector has been hindered due to limited resources, lack of trained technical personnel and lack of institutional capacity at local government level. Developments are planned by central government agencies (due to insufficient capacity at the local level). The Ministry of Public Works is responsible for programmes within the urban and sub-urban areas, while the Ministry of Health is responsible for rural water supply and sanitation schemes. Within the Ministry of Health, these are the responsibility of the Directorate General of Communicable Disease Control and Environmental Health (see Chpt. 15.7). Progress in the sector was further hindered in the mid-1980s by the deteriorating financial situation, particularly affected by the drop in the oil price. Progress in the rural sector became heavily curtailed in 1987, when the health budget did not contain any allowance for rural water supply and sanitation throughout the country. The only funds available were those received from foreign agencies. However, in Repelita III and in early Repelita IV, 90% of the external assistance went to finance urban water supply and sanitation while the rural subsector received less than 10%. In addition, improvement in water supplies was given a higher priority than improvement in sanitation.

- Potential Impact of the Existing Practice and Studies in Progress

Several studies have been carried out to investigate the effect of overhung latrine use on human health. Two studies were carried out by the Ministry of Health in Jakarta (Mrs Sri Soewesti Soesanto). The first study (1978/79) included microbiological analyses of water and fish from 20 fishponds. Water samples were positive for total coliforms and faecal coliforms, but samples tested for *Salmonella, Shigella, Vibrio parahaemolyticus*, Vibrio cholerae and pathogenic *E. coli* were all found to be negative. Stool samples from fishpond users (n = 233) were tested for the same pathogenic microorganisms, and all were found to be negative. In the second study (1980/81), two villages were studied, one where defecation over fishponds was practised; and the other where there were no fishponds. 300 persons in each village were studied and their stools tested for a range of bacterial and parasitic infection. Bacteria were isolated from 12% of the stools in each group, however, the majority isolated were not known pathogenic bacteria. Stools were negative for *V. cholerae, Salmonella* and *Shigella*. The rate of infection with specific parasites was different in each group, i.e. the prevalence of both *Ascaris* and hookworm infection was higher in the area without fishponds than in the fishpond area. Since it is unlikely that the transmission of these soil-transmitted helminths will occur through the fishponds, such differences are likely to be caused by other factors in the two villages.

From these studies it is difficult to draw conclusions about the absence or presence of health risks associated with the practice of defecating over fishponds. The 'exposure' of concern was not clearly defined; it is not clear whether all the persons tested had contact with the water and ate the fish in the period before samples were taken. The sample size was very small, so the magnitude of the risk associated with fishpond use would have to be very large to be detectable.

A preliminary study of health aspects of waste recycling in aquaculture in West Java was done by Dr Bakir Abisudjak at the Institute of Ecology, Padjadjaran University, Bandung. In this study, the number of diarrhoea cases in household members rather than the presence of pathogenic organisms in their stools was used as the outcome measure. Households were sampled from 5 villages in Ciparay and Pacet Subdistricts of Bandung District, West Java. The results indicated that the risk of diarrhoea was 1.7 times higher in pond users' households than in households where people did not use the pond for defecation (Table 15.12).

Table 15.12 Results of a Preliminary Study on Health Aspects of Waste Recycling in Aquaculture in West Java (Abisudjak, pers Comm.)

Diarrhoeal status	Pond users' households	Non-pond users' households	Total
With diarrhoea	27	32	59
Without diarrhoea	359	740	1099
TOTAL	386	772	1158

Odds ratio $= \frac{27/359}{32/740} =$ **1.74** ($x^2 = 4.32$ $p < 0.05$)

Relative risk $= \frac{27/386}{32/772} =$ **1.69**

Given the contradictory nature of the results of these past studies, further studies of disease rates in clearly defined 'exposed' and 'control' groups using increased sample sizes would be needed to confirm the existence of any risks and to define through which exposure route the diarrhoea was transmitted. Until this is done, a preliminary evaluation of the potential impact can be made using knowledge of the practices themselves, data on water quality and data gathered from other areas.

There are several population groups who could be at risk from the existing practices. These can be categorised as follows:

(a) Consumers of fish grown in excreta-fed fishponds
(b) Fishpond workers who manage the fishpond and harvest the fish
(c) Persons who use fishpond water for domestic purposes

Consumers of Fish

The health risk to consumers of fish grown in excreta-fed fishponds will depend on several factors, including

(i) the microbiological quality of the pond water
(ii) the microbiological quality of the fish
(iii) the extent of cooking of the fish prior to eating
(iv) hygiene practices in the kitchen, with regard to the preparation of the fish (including gutting).

It has been shown in Israel that **invasion of fish muscle** by bacteria is unlikely to occur when fish are grown in ponds which contain concentrations of faecal coliform of less than 10^4 per 100 ml (Buras et al. 1982). At higher concentrations, the potential for muscle invasion increases with the duration of exposure of the fish to the contaminated water. The data available on **pond water quality in West Java** from the Institute of Ecology in Bandung suggest that the concentration varies depending on the size of the pond and the load of the excreta input. The range is from 10^3 up to 10^6 faecal coliforms per 100 ml, the average concentration probably being between 10^4 and 10^5 per 100 ml[1]. It is therefore possible that in some fishponds, some bacteria may penetrate the muscle of fish, although this may not occur in all ponds. On the other hand, during investigations on aquaculture in waste stabilisation ponds in Peru, concentrations of faecal coliforms in the digestive tract contents of fish were as high as 10^8/100 ml, even though the concentration in the water amounted to only 10^4/100 ml on the average (Noe Moccetti et al. 1984). It is likely, therefore, that fish grown in excreta-fed fishponds in West Java may have contaminated digestive tracts.

Cooking practices have to be considered before the actual health risks from eating such fish can be judged. In West Java, fish are always cooked well before consumption. The methods used include baking, steaming, frying and boiling. It seems likely, therefore, that any bacteria which may be present in the muscle would not survive the cooking process. The habit of eating raw fish, common in other parts of the Far East including China and Korea, is not part of the culture in West Java. Clonorchiasis, caused by the liver fluke *Opisthorchis sinensis*, is contracted by eating raw or undercooked fish (particularly *Cyprinid* fish). It is common in Japan, China, Korea, Taiwan and Vietnam, but not in Indonesia.

Cross-contamination of other food in the kitchen could occur during the gutting and processing of fish raised in excreta-fed ponds. In the villages where the fish are grown, gutting usually takes place outside, reducing the chance of contamination in the kitchen. However, where this occurs inside, a risk of bacterial infection could occur. The transmission of diarrhoeal disease by this route therefore remains a possibility.

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1 More detailed studies are under way at the Institute of Ecology, Bandung, West Java (Drs Abisudjak and Siregar).

Epidemiological studies of the risks of eating fish grown in excreta-fed fishponds have not been possible, due to the difficulty in defining the origins of fish once they reach the market. There, fish grown in uncontaminated freshwater ponds are mixed with those grown in excreta-fed fishponds. However, the use of comparative microbiological studies of the fish grown in each type of pond, and studies of cooked fish, supplemented by studies of fish preparation and cooking behaviour, would increase our understanding of the potential risks from the consumption of such fish. Limited microbiological studies of fish quality are at present being conducted by the Institute of Ecology, Bandung, in collaboration with the Microbiological Laboratory of the Department of Health, Bandung. Further studies, including the fate of pathogenic bacteria in the water and the fish, as well as the survival of faecal coliforms, would be useful.

Occupational Risks of Fishpond Workers

Harvesting of the fish grown in the fishponds, which are later sold in the markets, is usually done by draining of the pond and harvesting of the whole catch at one time. However, some fish are caught for consumption by the family or friends and this may involve the owner/worker **wading into the pond** with a net to catch the fish. Persons who wade into excreta-enriched ponds are thought to be potentially at risk of contracting percutaneous infections, such as schistosomiasis. However, the known range of *Schistosoma japonicum* are encountered in China, the Philippines and Sulawesi, with limited foci in Vietnam, Thailand, Laos and Cambodia. Since there are no known foci on Java or on the islands of Indonesia other than on Sulawesi, workers wading into fishponds in West Java are not at risk of contracting schistosomiasis.

The pond owner or worker in close contact with the excreta-fed pond may accidentally ingest pathogens and be at risk of contracting faecal-oral infections. There are no known studies that quantify such risks, but they are being investigated using a sub-set of the study group in the epidemiological study described below.

Users of Fishpond Water

The most common exposure to contaminated fishpond water in West Java occurs through **domestic use of the pond water** more than through consumption of the fish grown in the ponds or through occupational contact. Domestic water is not taken directly from the fishpond, but is delivered into the overhung latrine-cum-wash-place through a network of pipes and channels which brings it from other ponds ("feeder" ponds). The presence of an overhung latrine over a "feeder" pond would signify a potential risk to the person using water from the "feeder" pond. Such water can be used for **bathing, washing clothes, washing household utensils, and washing some foodstuffs.** It is very rarely used for drinking. Direct contamination or cross-contamination of foodstuffs could occur from these practices.

The microbiological quality of the water coming into the overhung latrines is about 10^4-10^5 faecal coliforms/100 ml (Abisudjak 1985). Pathogenic organisms are likely to be present on some occasions, particularly if persons defecating into the "feeder" fishponds are ill. The health risks from use of this water are likely to depend on whether pathogenic organisms are present, for what purposes the water is used, hygienic practices in the home, to what degree the food is cooked, and the susceptibility of persons exposed to it.

At present, it is not clear whether or not the practice causes excess health risks. The most likely infections that could be transmitted by this route include diarrhoeal diseases and typhoid fever. Diarrhoeal disease is a leading cause of morbidity and mortality in West Java (see Tables 15.6-15.8). An **epidemiological study** has thus been set up by Abisudjak and others at the Institute of Ecology, Bandung, to investigate whether **excreta use in fishponds poses a risk factor for diarrhoeal disease**, and whether this role can be diminished by the provision of clean water supplies for domestic use. The study has been funded by WHO (South East Asia Regional Office) with additional support from the United Nations Environment Project.

The study uses a cross-sectional methodology and 3 study groups - two "exposed" groups and one control group (for comparative purposes). The first exposure group designated as "high risk" group, consists of families where the adults use water from excreta-fed fishponds for domestic purposes and defecate over fishponds using overhung latrines. The second exposure group consists of families where the adults defecate over fishponds using overhung latrines, but whose domestic water originates from wells or springs. This group, designated "semi-exposed", is used to represent a case where the positive benefits from the defecation practice are retained (that is, fertilisation of the fishpond), but the possible negative effect of use of the contaminated water is outweighed by the provision of clean water supplies. The control group consists of families living in villages with no or few fishponds, where the domestic water supply is taken from wells or springs and where excreta is disposed of into pit latrines, septic tanks, streams or rivers.

The study population selected from 10 or more villages, numbers about 650 households in each study group. The prevalence of diarrhoeal disease in currently exposed individuals is found in each study group both among children under 5 years of age and among persons over 5 years of age. At the same time, a survey of the contamination of the domestic water supplies is being carried out. The results will be used to assess the level of faecal contamination of the water sources used (quantitatively) and to determine whether this is associated with any excess in diarrhoeal disease among those using it.

Preliminary results indicate that the level of diarrhoeal disease among children under 5 is high even in the control group (over 10% in a 1-week period), and may be increased in the high risk group. The level of diarrhoeal disease in adults appears to be the same in all groups (Abisudjak, personal communication). Detailed analysis is needed to show whether these results change when allowance is made for the effect of other exposures and any possible confounding factors such as the socioeconomic status.

Further analysis will be made on sub-groups within the study groups, i.e. those

(i) who are in contact with fishpond water while catching fish, and those

(ii) who eat fish raised in excreta-fed ponds.

These groups will be identified through questionnaires and used to address issues of occupational and consumer risk. While field work for this study was completed by mid-1988, data analysis is now in progress.

• Implications for the Control of Health Risks

In the past, the Ministry of Health, in response to the potential health risks from the practice of defecation over fishponds, has persuaded people to discontinue this practice. Attempts have been made to ban the use of overhung latrines, but they have generally not been very successful. Usually there are few alternatives to the use of overhung latrines. Some people may be fortunate enough to have a pit latrine or communal latrine nearby, however, since coverage of the rural areas with sanitation is so low (see the section above on water supply and excreta disposal), many people have to walk even further in order to use a stream or river.

Removal of any health risks from this practice may best be done by modifying it instead of stopping it. Firstly, the risks must be identified, since they may be lower than imagined. Where risks exist, possible interventions could be developed:

(i) If risks come from **domestic contact** with the contaminated water, the **provision of clean water supplies** could reduce these risks. Where this is not possible, health education could be provided, e.g. discourage people from washing food and utensils with the pond water.

(ii) If risks come from **occupational contact** with pond water, fish catchers could be advised on safer methods to catch the fish, and could be encouraged to practise **better hygiene** after exposure to pond water.

(iii) If risks come from **consumption of contaminated fish**, the level of contamination should be reduced by some method. Investigations should be done into the feasibility and outcome of depuration of the fish in clean water prior to marketing, and into ways to improve food hygiene, especially in relation to the handling of the digestive tracts of fish. Treatment or storage of excreta prior to use in the pond is impracticable without totally changing the tradition of the practice - and removing some of its practical and cultural benefits.

The quality of the water in most fishponds probably exceeds the tentative guideline level recommended by a WHO Scientific Group (see section 1.2). The above interventions are all based on control of human exposure to the contamination. Another possibility would be to change the position of the overhung latrine(s) relative to the pond outlet to minimize short-circuiting and to thereby allow greater pathogen reduction within the individual pond.

16.9 References

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E - SYNOPSIS AND RECOMMENDATIONS

16 SYNOPSIS

Although it is not easy to bring all the reuse practices described in the preceeding chapters under one "roof", we believe that there are a number of salient features if these practices are viewed from a global standpoint.

(i) Wastewater reuse has been practised since the institutionalization of centralized sewerage, i.e. over 100 years ago. In countries with temperate climates, the rationale behind this practice was initially and primarily the disposal of the sewage on land, the then cheapest treatment method. The rationale in **arid or semi-arid climates** is dictated by a true necessity to regard the wastewater as a precious **water and nutrient source.** This need has been growing continuously in the past and is likely to increase further in the years to come. As a consequence, the planning and implementation of new wastewater reuse schemes and the expansion of existing schemes in arid climates is on the increase.

(ii) Although **wastewater reuse** is widely practised and an increasing number of new schemes are being planned, designed and implemented every year, it seems that, so far, the wastewater reuse potential and the conditions affecting its implementation form part of an overall **strategy for integrated water resources planning** in a few countries only (e.g. in Tunisia). Reuse schemes have either evolved historically driven by the need to dispose of the city's drainage water, such as in Calcutta and Mexico City, or evolved due to the absence of regulations or due to the non-enforcement of regulations, i.e. farmers diverting the wastewater from sewer lines to their fields (e.g. in Lima). Wastewater irrigation schemes were also added later on to centralized sewerage and sewage treatment schemes, a posteriori, i.e. they did not form a component part of the city's general water supply and wastewater management plan already from the outset.

(iii) In arid and semi-arid climates, where natural freshwater sources are often scarce due to overuse, farmers resort to wastewater to meet their needs, often irrespective of existing regulations. This is representative of the great value given to wastewater in unfavourable climatic and economic conditions. In the light of these circumstances, authorities may often be hesitant to enforce existing regulations. In a number of countries, however, authorities do respond both to the great need for wastewater as well as to adequate health protection measures by adopting wastewater treatment measures and/or enforcing crop restriction regulations.

(iv) In contrast to the upward trend in wastewater **reuse, the use of excreta** is gradually decreasing. Excreta use is or has been a traditional practice mainly in south-east Asia for many centuries. In countries like South Korea, Thailand, Taiwan and Malaysia, excreta use was rather widespread and customary. However, the general economic development led farmers to abandon excreta as soil conditioner and fertilizer and instead mainly use chemical fertilizers. Reportedly, in some places in China also, excreta is gradually being replaced by chemical fertilizer, although it is still of great importance in the country as a whole. This change in fertilization practice is probably a consequence of such factors as increase in income among farmers, improved public health status, and a change in aesthetical values and in the perception of hygiene and disease transmission risks.

(v) There are indications that the **actual or true (in contrast to the potential) health risks** of human waste reuse in agriculture and aquaculture are less pronounced than has customarily been assumed. Several factors may explain this:

a - The transmission path for excreted infections relevant to reuse (see also Chpt. 1.2) might become interrupted through the die-off of the pathogens to levels below the infective dose.

b - Traditional habits such as the cooking of fish or of certain vegetables help preclude the transmission of pathogens from waste-fertilized crops to the consumers.

c - In many, though not all, countries, reuse regulations do exist and waste is often treated prior to its use, or crop restrictions are being followed.

(vi) When viewing the illustrative case studies from the point of view of **health protection measures,** it becomes evident that the authorities in the various countries and those using the wastes have chosen or developed a **variety of different approaches.** Table 16.1 below provides an overview of the measures as they are practised. One may differentiate between two kinds of approaches: one which has developed out of traditional, behavioural customs, such as the cooking of fish or of particular crops, or a specific hygiene behaviour. The other kind of approach consists in the purposeful adoption of a health protection strategy through the setting up of regulations by government authorities.

Table 16.1 Health Protection Measures: Overview of the Practice

Country, location	Kind of Reuse	Health Protection Measures Practised
MEXICO Mezquital Valley	Irrigation of alfalfa, maize, cereal crops, tomatoes and beans mostly with untreated wastewater	Crop restriction, some exposure control for agricultural workers
CHILE Santiago	Irrigation of raw-eaten vegetables, cereal crops and grapes with untreated wastewater	None (treatment being planned)
INDIA Kanpur	Irrigation of rice, wheat, forage and flowers with diluted untreated wastewater	None
Calcutta	Fish growing in ponds receiving untreated wastewater at low loading rates	Cooking of the fish
PERU Lima (S. Martin de P.)	Irrigation of vegetables and non-food crops with raw wastewater	None
Ica (Cachiche)	Irrigation of maize and cotton with primary pond effluent	Partial wastewater treatment and crop restriction
Tacna	Irrigation of maize, alfalfa and fruit trees with effluent from overloaded WSP	Partial treatment and crop restriction
ARGENTINA Mendoza	Irrigation of raw-eaten vegetables with settled sewage	Partial treatment
TUNISIA Tunis	Irrigation of non-vegetable crops and fruit trees with secondary effluent	Partial treatment and crop restriction
SAUDI ARABIA Riyadh	Irrigation of wheat, forage and date palms with tertiary (filtered and chlorinated) effluent	Full treatment and crop restriction
GUATEMALA rural areas	Use of stored faecal material as a fertilizer in agriculture	Prolonged excreta storage
SOUTH KOREA Pusan	Use of sludge from nightsoil treatment plants in agriculture	Dewatering and composting of the sludge
INDONESIA Java	Use of excreta for fish pond fertilization	Cooking of the fish

The Table shows that in several countries, a **combination** of health protection measures has been chosen. The choosing of a particular strategy or "measure mix" is very much dependent on the local setting, i.e. the local economic, sociocultural, agronomic, climatic and institutional conditions. To illustrate this, one may look at the practices in **Mexico and Saudi Arabia**, two contrasting **examples:** In Mezquital Valley, most of the wastewater from **Mexico City** is being used for irrigation in RD 063. Except for occasional storage of part of the wastewater in seasonal storage reservoirs, the wastewater is used untreated. Because of this, **crop restrictions** were established and they appear to be enforced rather effectively. This is being aided by the fact that maize, which is a crop particularly suited for restricted irrigation, is a staple food in Mexico and therefore in high demand. Under the very tight economic conditions of the country, the emphasis on crop restrictions - as opposed to wastewater treatment - is a sensible strategy. The raw wastewater is used in a way which, to a large extent, precludes consumer risks. However, the occupational risk is not excluded unless the farmers and farmworkers wear protective clothing (boots) and practise good personal hygiene. Partial treatment may have to be introduced in future, particularly for the wastewater from small and medium-sized towns, in order to help protecting the health of the agricultural workers.

Saudi Arabia, in contrast, has adopted a rigid approach with some government bodies demanding both the advanced treatment of wastewater as well as crop restrictions. The rationale for this is the justified fear for epidemic disease outbreaks in the pilgrimage areas and the zero-risk or near-zero-risk concept which was developed in California and later adopted by a number of countries, among them Saudi Arabia. Also, Saudi Arabia is among the few countries which can economically afford the advanced treatment of wastewater.

An important lesson which can be drawn from comparing the diverse approaches is that there is, in fact, **no single standard or best strategy** which should be adopted. **The situation and needs** of each country or locality should rather be viewed on its own merits and the appropriate strategy of health protection measures be chosen accordingly.

(vii) In most countries, there are several **government authorities** involved in matters concerning reuse. Usually, though, one of them plays the leading role while the others appear to have "less to say". Leading agencies are the Ministries of Agriculture, Water Resources or Public Works. The role of the health authorities is often secondary. This is not abnormal, as the agriculture and public works agencies deal with larger-scale infrastructural works and are therefore empowered with larger budgets and correspondingly higher prestige than the health authorities. The task of the health authorities in formulating and enforcing health protection regulations is therefore often impeded.

(viii) In Central America, notably in Guatemala, **excreta use is being introduced** although the use of faecal material is not part of the traditional farming practice. It is linked to the development and use of double-vault latrines and is unlikely to be associated with an added attributable health risk. Successful promotion of this is based on intensive **collaboration with the latrine users.** People in rural Guatemala apparently do not have any cultural barriers against excreta use, and this facilitates the introduction of the practice considerably. These observations and those from other countries make the authors conclude that hygienically safe use of faecal matter can be successfully introduced as an innovative fertilization practice if it is accompanied by intensive agency/village collaboration. There are signs that **cultural habits** are indeed not always and **not everywhere absolutely rigid.** People may adopt new customs if they can derive a sustainable benefit from them.

17 GENERAL RECOMMENDATIONS[1]

Based on the observations and conclusions from the manifold practices of human waste use in agriculture and aquaculture, and with a global perspective in mind, the authors wish to make the recommendations listed under (A) - (E) below.

(A) - Authorities are encouraged to consider introducing new or expanding existing wastewater or excreta reuse schemes, wherever this might be dictated by situations of water scarcity and where there is high demand for crops or fish which might be produced by recycling the human wastes. Health protection measures must be an integral component of reuse.

(B) - Waste reuse, both in agriculture and aquaculture should become **fully integrated into** national, provincial and watershed **strategic water resources planning.** It should thereby be upgraded to a standard alternative option to be examined along with other basic options of wastewater management plans.

Industrial waste streams should be kept away from reused wastewater and faecal matter or be adequately treated in order to prevent any contamination of the human wastes by toxic substances which, may otherwise accumulate in crops and fish.

(C) - When considering appropriate health protection measures in connection with new reuse projects or planned reuse scheme improvements, all **four basic options**, viz wastewater or excreta treatment/storage, crop restrictions, appropriate methods of applying the wastes to the crops, and human exposure control should be examined (see also Chpt. 1.3). Authorities are encouraged to be flexible in choosing suitable measures, thereby letting themselves guide by the local economic,

[1] For country-specific recommendations, the reader is referred to the sections titled "Implications for the Control of Health Risks" contained at the end of each chapter. For comments and reflections related to the particular reuse practices, the reader may consult the Discussion chapters Ac., 11 and 14. The guideline documents recently published by WHO (1989) and WHO/UNEP (1989) provide useful information about the health implications of reuse, the suggested quality values of reused wastewater and excreta and about the types and implications of health protection measures.

agricultural, sociocultural, health-related, and institutional conditions. For instance, full treatment of large wastewater flows, i.e. treatment to the standard for unrestricted irrigation, might often be uneconomical and therefore other measures, possibly in combination with partial treatment, might be envisaged. All four options require continuous administrative and institutional efforts and capacities as well as the political will and necessary legal back-up from the various government institutions involved.

(D) - Efforts should be made to **promote the use of faecal material**, particularly in association with rural or semi-urban sanitation programmes in which the use of **double-pit or vault latrines**[1] proves to be feasible, and where the handling of stored excreta is not an absolute taboo. Such efforts must be paired with intensive and prolonged **communications** between the users and the implementing agency, a task which non-government organizations are often better suited for than government agencies.

(E) - Further field-level investigations with an epidemiological perspective are needed. They should focus on two kinds of situations: (1), on reuse practices where no adequate health protection measures are taken in order to assess the risk level of such practices. (2), on reuse practices where health protection measures are in effect. This is to test the effectiveness of individual protection measures or of combinations of measures in avoiding excess risks from the reuse practice. It will allow to accumulate knowledge about optimum "mixes" of measures for particular, local conditions.

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[1] Double-pit or vault latrines are an important "tool" to facilitate excreta use, as they allow for pathogen die-off during the storage of the faecal material in the pit or vault at rest.

ANNEXES

ANNEX 1	Basic Information on Excreta-Related Infections
ANNEX 2	Institutions Dealing with Public Health Aspects of Excreta and Wastewater Use

ANNEX 1 Basic Information on Excreta-Related Infections

Table A1.1 lists the important pathogens excreted in faeces, truncated according to the kind of organism, i.e. viruses, bacteria, protozoa, and helminths. Table A1.2 presents the excreted pathogens according to "environmental categories" (Feachem et al. 1983). The categories allow to differentiate the excreted, gastrointestinal infections by their "behaviour" in the environment, i.e. after having been passed in the excreta, and by their epidemiological features. These characteristics can be described by considering the latency[1], infective dose[2], persistence[3], potential for multiplication[4], and transmission paths of the pathogens. The classification allows to judge whether, how and for which pathogens specific excreta disposal methods are likely to bring about a reduction in the spreading of particular infections. Careful evaluation of the classification reveals that helminths and bacteria are likely to be the pathogens of major concern when considering the health implications of excreta and wastewater use. Fig. A1.1 shows the transmission cycles and intermediate hosts for soil and water-transmitted helminths. Fig. A1.2 specifically illustrates the transmission path of those helminthic infections which have fish as intermediate hosts.

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[1] the length of time between the excretion of a pathogen and its potentially becoming infective to a new host; applies to helminths only because all viruses, bacteria and protozoa have zero latency (Feachem et al. 1980).

[2] the number of pathogens required to infect a host

[3] the length of time between the excretion of a pathogen and its death or inactivation in the environment

[4] Although, as a general rule, all pathogens eventually die or become inactivated upon excretion, some pathogens may multiply under favourable conditions. This holds for the trematodes (flukes), the larvae of which undergo multiplication in the intermediate host (aquatic snails). Certain bacteria may multiply on suitable substrates (Salmonella on food, e.g.). Viruses and protozoa do not multiply once they are excreted.

The environmental categories as introduced by Feachem et al. (1983) are defined as follows:

- Category I:
  - viral and protozoal infections
  - low infectious dose ($ID_{50} < 10^2$)[1]
  - zero latency
  - mainly and most easily spread from person to person under conditions of low levels of personal and domestic hygiene
  - excreta disposal methods have little effect on incidence of these diseases

- Category II:
  - bacterial infections
  - medium to high ID_{50} ($\geq 10^4$)
  - zero latency
  - bacteria are relatively persistent and some can multiply on a suitable substrate
  - person-to-person transmission less likely than for category I, importance also of relatively long transmission routes such as water or crops contaminated with faecal material
  - effective methods of control: improved personal and domestic hygiene, improved storage, handling and reuse of excreta

- Category III:
  - soil or crop-transmitted helminths (nematodes) without intermediate host
  - long latency and persistence
  - improved excreta disposal is the most important control measure; personal hygiene little relevant because the eggs are not immediately infective

- Category IV:
  - soil or crop-transmitted helminths (tape-worms) with cows and pigs as intermediate hosts
  - long latency and persistence
  - improved excreta disposal methods avoiding contamination of soil and crop will reduce transmission; thorough cooking of beef and pork is an alternative control

- Category V:
  - water-based helminths (trematodes) with one or two intermediate aquatic hosts
  - long latency and persistence
  - multiplication with intermediate host
  - effective control by avoiding untreated excreta or wastewater reaching the water where the intermediate hosts live

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1 ID_{50} is the dose required to infect half of those exposed

Table A1.1 Important Pathogens Excreted in Faeces[1]

Agent	Disease or major symptoms
Viruses	
• Enteroviruses	
Polio-	Poliomyelitis, paralysis, meningitis, fever
Echo-	Diarrhea, fever, meningitis and others
Coxsackie A and B	Meningitis, respiratory disease, fever, and others
New enterov.	Encephalitis, meningitis, conjunctivitis and others
• Hepatitis A virus	Infectious hepatitis
• Rotaviruses, Norwalk agent and other viruses	Gastroenteritis (diarrhea, vomiting etc.)
Bacteria	
• Campylobacter fetus ssp.[2] jejuni	Diarrhea, vomiting
• Pathogenic Escherichia coli	Gastroenteritis (diarrhea)
• Salmonella	
S. Typhi	Typhoid fever
S. paratyphi	Paratyphoid fever (incl. diarrhea)
other Salmonellae	Food poisoning and other salmonelloses
• Shigella species	Shigellosis (bacillary dysentery) (incl. diarrhea)
• Vibrio	
V. cholerae	Cholera (diarrhea)
other vibrios	Diarrhea
Protozoa	
• Entamoeba histolytica	Colonic ulceration, amebic dysentery, liver abscess
• Giardia lamblia	Diarrhea, malabsorption

Agent	Disease or major symptoms
Helminths	
Nematodes (Roundworms)	
• Ancylostoma duodenale, Necator americanus (Hookworm)	Hookworm (anemia)
• Ascaris lumbricoides (Roundworm)	Ascariasis (respiratory, digestive or abdominal disturbances, bowel obstruction)
• Enterobius vermicularis (Pinworm)	Enterobiasis (anal itching)
• Strongyloides stercoralis (Threadworm)	Strongyloidiasis (often asymptomatic; skin inflammation; lung or abdominal disturbances)
• Trichuris trichuria (Whipworm)	Trichuriasis (often asymptomatic; bloody stool, diarrhea)
Cestodes (Tapeworms)	
• Hymenolepis nana (Dwarf tapeworm)	Hymenolepiasis
• Taenia saginata (Beef tapeworm)	Taeniasis (often asymptomatic; digestive disturbances)
• Taenia solium (Pork tapeworm)	Taeniasis (often asymptomatic; digestive disturbances) Cysticercosis[3] (disturbances e.g. of eye, heart, central nervous system)
Trematodes (Flukes)	
• Chlonorchis sinensis (Chinese liver fluke)	Chlonorchiasis, Opisthorchiasis (often asymptomatic; diarrhea, abdominal and liver disturbances)
• Opisthorchis	
• Schistosoma	Schistosomiasis, bilharziasis
S. haematobium[4]	(obstruction, blood urination, bladder tumors)
S. japonicum S. mansoni	(dysentery-like symptoms, liver cirrhosis)

[1] after Feachem et al. 1983
[2] ssp.-subspecies
[3] infection with larvae of T. solium, formation of cysts
[4] excreted in urine

Table A1.2 BASIC EPIDEMIOLOGICAL FEATURES OF EXCRETED PATHOGENS BY ENVIRONMENTAL CATEGORY[1]

Pathogen	Excreted load[a]	Latency[b]	Persistence[c]	Multiplication outside human host	Median infective dose (ID_{50})[d]	Significant immunity?	Major nonhuman reservoir?	Intermediate host
Category I								
Enteroviruses[e]	10^7	0	3 months	No	L	Yes	No	None
Hepatitis A virus	10^6(?)	0	?	No	L(?)	Yes	No	None
Rotavirus	10^6(?)	0	?	No	L(?)	Yes	No(?)	None
Balantidium coli	?	0	?	No	L(?)	No(?)	Yes	None
Entamoeba histolytica	10^5	0	25 days	No	L	No(?)	No	None
Giardia lamblia	10^5	0	25 days	No	L	No(?)	Yes	None
Enterobius vermicularis	Not usually found in faeces	0	7 days	No	L	No	No	None
Hymenolepis nana	?	0	1 month	No	L	Yes(?)	No(?)	None
Category II								
Campylobacter fetus ssp *jejuni*	10^7	0	7 days	Yes[f]	H(?)	?	Yes	None
Pathogenic *Escherichia coli*[g]	10^8	0	3 months	Yes	H	Yes(?)	No(?)	None
Salmonella								
S. typhi	10^8	0	2 months	Yes[f]	H	Yes	No	None
Other salmonellae	10^8	0	3 months	Yes[f]	H	No	Yes	None
Shigella spp	10^7	0	1 month	Yes[f]	M	No	No	None
Vibrio cholerae	10^7	0	1 month(?)	Yes	H	Yes(?)	No	None
Yersinia enterocolitica	10^5	0	3 months	Yes	H(?)	No	Yes	None
Category III								
Ascaris lumbricoides	10^4	10 days	1 year	No	L	No	No	None
Hookworms[h]	10^2	7 days	3 months	No	L	No	No	None
Strongyloides stercoralis	10	3 days	3 weeks (free-living stage much longer)	Yes	L	Yes	No	None
Trichuris trichiura	10^3	20 days	9 moths	No	L	No	No	None
Category IV								
Taenia saginata and *T. solium*[i]	10^4	2 months	9 months	No	L	No	No	Cow (*T. saginata*) or pig (*T. solium*)
Category V								
Clonorchis sinensis[j]	10^2	6 weeks	Life of fish	Yes[k]	L	No	Yes	Snail and fish
Diphyllobothrium latum[j]	10^4	2 months	Life of fish	No	L	No	Yes	Copepod and fish
Fasciola hepatica[i]	?	2 months	4 months	Yes[k]	L	No	Yes	Snail and aquatic plant
Fasciolopsis buski[i]	10^3	2 months	?	Yes[k]	L	No	Yes	Snail and aquatic plant
Gastrodiscoides hominis[i]	?	2 months(?)	?	Yes[k]	L	No	Yes	Snail and aquatic plant
Heterophyes heterophyes[j]	?	6 weeks	Life of fish	Yes[k]	L	No	Yes	Snail and fish
Metagonimus yokogawai[j]	?	6 weeks(?)	Life of fish	Yes[k]	L	No	Yes	Snail and fish
Paragonimus westermani[j]	?	4 months	Life of crab	Yes[k]	L	No	Yes	Snail and crab or crayfish
Schistosoma								
S. haematobium[i]	4 per millilitre of urine	5 weeks	2 days	Yes[k]	L	Yes	No	Snail
S. japonicum[i]	40	7 weeks	2 days	Yes[k]	L	Yes	Yes	Snail
S. mansoni[i]	40	4 weeks	2 days	Yes[k]	L	?	No	Snail
Leptospira spp	urine(?)	0	7 days	No	L	Yes(?)	Yes	None

[1] *Source:* FEACHEM, F. G. ET AL. *Sanitation and disease: health aspects of excreta and wastewater management.* Chichester, John Wiley, 1983

[a] Typical average number of organisms per gram of faeces (except of *Schistosoma haematobium* and *Leptospira* species, which occur in urine).
[b] Typical minimum time from excretion to infectivity.
[c] Estimated maximum life of infective stage at 20–30°C.
[d] L Low ($< 10^2$); M medium ($\approx 10^4$); H high ($> 10^6$); ? uncertain.
[e] Includes polio-, echo-, and coxsackieviruses.
[f] Multiplication takes place predominantly on food.
[g] Includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli*.
[h] *Ancylostoma duodenale* and *Necator americanus*.
[i] Latency is minimum time from excretion by man to potential reinfection of man. Persistence here refers to maximum survival time of final infective stage. Life cycle involves one intermediate host.
[j] Latency and persistence as for *Taenia* species. Life cycle involves two intermediate hosts.
[k] Multiplication takes place in intermediate snail host.

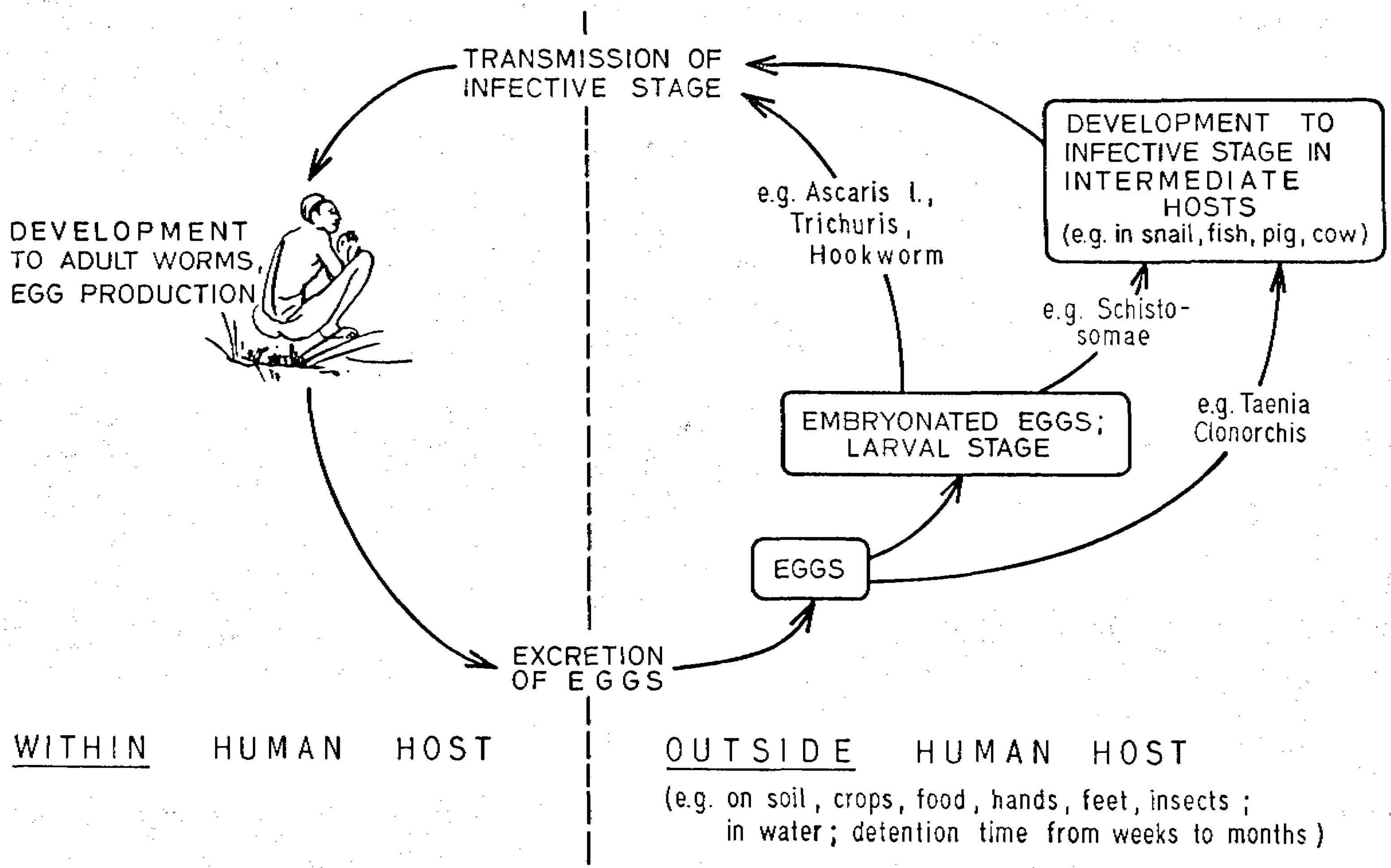

Fig. A1.1 Typified Pattern of Helminth Infection Cycles

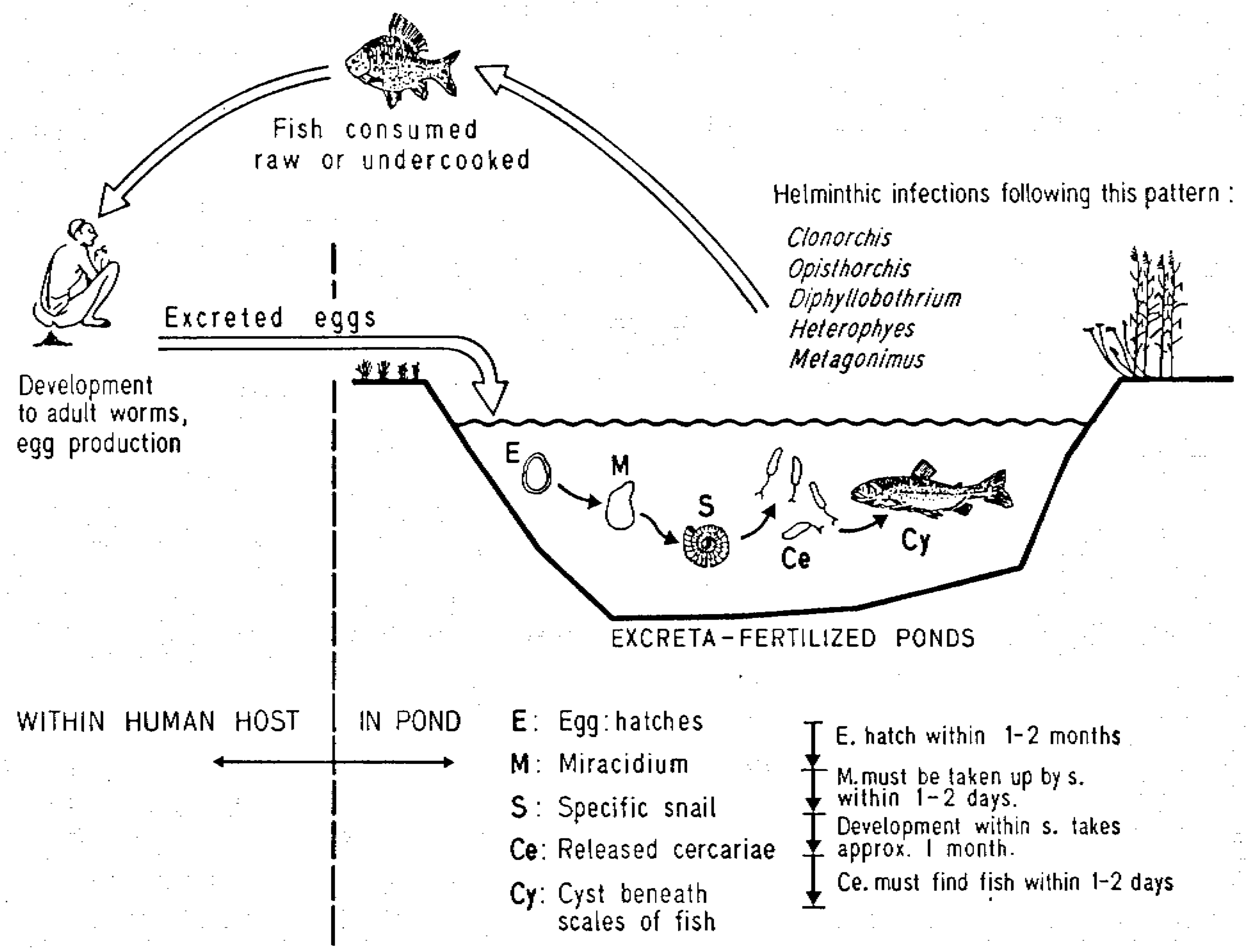

Fig. A1.2 Transmission Path of Helminthic Infections Having Fish as an Intermediate Host

ANNEX 2 Institutions Dealing with Public Health Aspects of Excreta and Wastewater Use.

The following Institutions are actively involved in the various aspects of wastewater and excreta recycling, particularly with respect to public health protection. The list below does not claim to be exhaustive, but contains those government, private and aid organisations as well as research institutions, with which, in recent years, the IRCWD and LSHTM have been in close collaboration on aspects of human waste use.

In Latin America	Activity	Contact persons
- CEMAT, Centro Mesoamericano de Estudios sobre Tecnología Apropiada Apartado Postal 1160 Guatemala GUATEMALA C.A.	Community development; latrine technology and microbiol. aspects of dry fertilizer latrines	Ms A. M. Xet M. Mr J. G. Flóres G.
- CEPIS, Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente P.O. Box 4337 Lima 100/PERU	Applied research and development in wastewater treatment and reuse	Ing. A. Flórez M.
- Instituto Mexicano de Tecnología del Agua Insurgentes Sur No. 2140 Col. Huerta del Carmen S. Angel Del. Alvaro Obregón 01070 México, D.F. MEXICO	Planning, monitoring, research	Ing. H. Romero Alvarez
- Instituto Mexicano de Tecnología del Agua CIECA-IMTA Ave. San Bernabé No. 549 Col. San Jerónimo Lídice 10200 México, D.F. MEXICO	Research and monitoring	Dr C. Enriquez Enriquez
- Secretaría de Salud Dirección General de Salud Ambiental, Ocupacional y Saneamiento Básico S. Luis Potosi No.192, Col. Roma CP 10200 México, D.F. MEXICO	Monitoring and enforcement	Dr F. Hurtado
- Instituto Nacional de la Nutrición Calle Vasco de Quiroga 15 Delegación Tlalpan 14000 México, D.F./MEXICO	Research on epidemiological aspects of wastewater reuse	Prof. G. Ruiz-Palacios Dr E. Cifuentes

In North America

- IDRC, International Development Research Centre Health Sciences Division 60 Queen Street P.O. Box 8500 Ottawa K1G 3H9/CANADA	Community-based research support	Dr. G. Forget
- US Env. Protection Agency Environmental Monitoring Systems Laboratory Cincinnati, Ohio 45268/USA	Health effects monitoring; epidemiological aspects	Dr W. Jakubowski
- The World Bank Department for Infrastructure and Urban Development 1818 H Street, N.W. Washington, D.C. 20433/USA	UNDP/World Bank Resource Recovery Project (applied research, development and technical assistance)	Dr C. Bartone
- University of Arizona Dept. of Microbiology and Immunology Building No. 90 Tucson, Arizona 85721/USA	Development of analytical methods for virus and protozoa detection in wastewater	Dr Ch. P. Gerba Dr J. Rose
- International Association on Water Pollution Research and Control: Specialist Group on Wastewater Reclamation, Recycling and Reuse c/o Dr T. Asano 1125 Dartmouth Place Davis, California 95616/USA	Research, development and information transfer on wastewater reuse technology and health effects	Dr T. Asano (Chairman)

In Mediterrania

- Ministère de la Santé Public Département de l'Hygiène de l'Environnement Cité Welvert, Bab Saadoun Tunis/TUNISIA	Law-making, monitoring, enforcement	Mr S. Atallah
- Ministère de l'Agriculture Centre de Recherches du Génie Rural B.P. No.10 Ariana 2080/TUNISIA	Agricultural research; microbiological monitoring of wastewater-irrigated crops	Mr A. Bouzaïdi Mrs M. M. Trad-Raïs
- Agricultural Research Institute P.O. Box 2016 Nicosia/CYPRUS	Applied research in treated effluent use in agriculture	Dr C. Serghiou Dr J. Papadopoulos
- Water Authority of Jordan (WAJ) Directorate of Central Operation P.O. Box 150793 Amman/JORDAN	Wastewater treatment for effluent reuse; applied research on pathogen removal in conventional plant and in pond systems	Dr S. S. Alsalem
- The Hebrew University School of Public Health and Community Medicine Jerusalem/ISRAEL	Research in epidemiological aspects of reuse in agriculture and aquaculture	Prof. H. Shuval

In Asia

- AIT, Asian Institute of Technology Div. of Env. Engineering P.O. Box 2754 Bangkok 10501/THAILAND	Applied Research and development of treatment and reuse options	Dr Ch. Polprasert
- AIT, Asian Institute of Technology Div. of Agricultural & Food Engineering P.O. Box 2754 Bangkok 10501/THAILAND	"	Dr P. Edwards
- NEERI, National Environmental Research Institute Wastewater Agriculture Div. Nehru Marg Nagpur-440 020/INDIA	Applied research and development in engineering and agronomic aspects of wastewater reuse	Dr G.B. Shende
- Padjadjaran University Institute of Ecology Jalan Sekeloa Bandung/INDONESIA	Epidemiological aspects of excreta use in aquaculture	Dr B. Abisudjak

In Europe

- University of Leeds Dept. of Civil Engineering Leeds LS2 9JT/U.K.	Applied research and development in WSP treatment & in microbiological aspects of reuse	Prof. D.D. Mara
- University of Nancy Faculté des Sciences Pharmaceutiques et Biologiques 5, rue Albert Lebrun F-54000 Nancy/FRANCE	Development of analytical methods for parasite detection in wastewater	Prof. J. Schwartzbrod
- University of Newcastle upon Tyne Dept. of Civil Engineering Claremont Road Newcastle upon Tyne NE1 7RU/U.K.	Research and technical assistance in planning and implementation of wastewater reuse	Prof. M.B. Pescod
- Universidad Politécnica de Cataluña ETS de Ingenieros de Caminos Gran Capitán, s/n. E-08034 Barcelona/SPAIN	Applied research in wastewater treatment and reuse	Prof. R. Mujeriego
- Dott. Ing. F. Croce Studio Ambiente Via dei Cantieri, 58 I-Palermo 90142/ITALY	Design and implementation of reuse schemes	
- Division of Sanitary Engineering Laboratório Nacional de Engenharia Civil (LNEC) P-1799 Lisbon Codex/PORTUGAL	Applied research on crop cultivation with treated effluent	Ms M.H. Marecos do Monte
- World Health Organisation Div. of Env. Health CH-1211 Geneva 27/SWITZERLAND	Sector guidelines and technical assistance	Dr W. Kreisel Dr I. Hespanhol

- Food and Agriculture Organisation FAO Land and Water Div. Via delle Terme di Caracalla I-00100 Rome/ITALY	Sector guidelines and technical assistance	Dr. A. Arar
- London School of Hygiene and Tropical Medicine Dept. of Epidemiology & Population Sciences Keppel Street London WC1E 7HT/U.K.	Research in epidemiological aspects	Dr U.J. Blumenthal
- IRCWD/EAWAG Ueberlandstrasse 133 CH-8600 Duebendorf/ SWITZERLAND	Applied research and technical assistance in human waste use	Mr M. Strauss