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Rain Water — An Alternative Source in Developing and Developed Countries*

by *D. H. Waller,*
Centre for Water Resources Studies
Technical University of Nova Scotia
P.O. Box 1000, Halifax, Nova Scotia
Canada

ABSTRACT

This paper reviews current application of Rain Water Cistern Systems and results of related research, in both developed and developing countries. Particular note is made of practices and research in Nova Scotia, Canada, and of applications in Bermuda. Differences in considerations involved in applications of the technology in developing and developed countries are reviewed. Construction practices, capacity design, water quality considerations, and institutional considerations are discussed. Rain water cistern systems are considered a safe and reliable source of domestic water supply that is an appropriate technology in many parts of the world.

INTRODUCTION

A rain water cistern system (RWCS) collects direct runoff of rainwater from roof or other surfaces and conveys it to some form of storage from which it can be withdrawn for use when needed.

Collection and storage of rain water for use is as old as recorded history.

The concept of collection and storage of rain water for use is as old as recorded history. Although it has been overshadowed by other sources and more sophisticated technologies, this concept is receiving increasing recognition as a viable and important water source for many areas of the world.

Evidence of the recognized importance of this source are proceedings of major international conferences dedicated to rain water cistern systems: [1-3]. These documents include presentations by most of the individuals and agencies that have been active in the study of, and promotion of the use of, rain water cistern systems. They also include references to a much wider literature on the subject, eg., Latham and Schiller [4], review 267 references.

Rainwater cistern systems, traditional and modern, are found in all parts of the developed and developing world. Situations in which rain water systems are used vary from those where no other sources exist to those where available ground or surface supplies are contaminated from natural or man-made sources.

Applications of rain water have been summarized as: to provide the major source of water supply; to provide a supplementary supply in an area where the major supply is from another source; to provide a supplementary non-potable supply; to provide a potable source in a dual system; and as a supply for other uses such as fire fighting [5].

The scale on which rain water systems are used also varies widely.

In most parts of the world rain water systems serve individual dwellings. Water may be collected from roofs or from ground level catchments. Storage may be in tanks below roof level, in jars, cisterns, or ponds at ground level, or in buried tanks. Public rain water systems, involving larger catchments and more sophisticated cisterns, are in use, for example, in Iran, Bermuda, and formerly in the U.S. Virgin Islands. The scale on which rain water systems are used also varies widely: in Nova Scotia, Canada, rain water is an important source for a few hundred dwellings; in Thailand, a rain water jar program was expected to provide jars to 3 million households by the end of 1987.

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EXPERIENCE AND RESEARCH IN NOVA SCOTIA

The Canadian province of Nova Scotia includes a population of approximately 900,000 in an area of 52,840 km². About one-half of this population is served by municipal systems, and most of the remainder are served by private wells.

In some areas of the province, however, groundwater is not an acceptable source. In several areas that are underlain by gypsum deposits, mineral concentrations make the water unusable for domestic purposes, and excessive iron and manganese concentrations occur in other areas. Salt water intrusion is another problem in some coastal regions. Recent testing programs have revealed unacceptable concentrations of arsenic and uranium in other parts of the province.

Recognizing roof water as a small but important water source, in 1982 the Nova Scotia Department of Health published guidelines for system construction and operation. Research initiated by the Technical University of Nova Scotia, and later conducted jointly by the University and the Department of Health, has aimed at producing knowledge that can be used to improve the guidelines.

Initial studies focused on descriptions of existing systems in Nova Scotia. Subsequent research has considered both quality and yield of domestic rain water systems, with results, summarized in later sections of this paper, that will be incorporated into design guidelines.

RAINWATER AS A SOURCE IN BERMUDA

The island of Bermuda probably represents the most complete and sophisticated example of a country dependent on rain water cistern systems. This small (53 km²), densely populated (12.1 persons/ha), country depended entirely on rain water until the 1930's. Rainwater still provides almost all of its domestic supplies, and approximately 50 percent of its total water demand. Development of fresh groundwater lenses, and desalination of brackish groundwater and seawater, today produce supplies for hotels, other commercial establishments, and public uses.

Bermuda probably represents the most complete and sophisticated example.

Mean annual rainfall in Bermuda is 147 cm; the recorded 12 month minimum is 77 cm. The average Bermuda cistern system, which includes a roof area of 139 m² and a cistern capacity of 68,000 L, is capable of supplying 106 L/cap/day for an average household of 3.5 persons during extreme dry periods [6]. Systems with smaller-than-average roofs and cisterns, and/or larger household populations, experience shortages that are satisfied by trucked water.

The 1949 Public Health Act and subsequent regulations require that cistern storage be provided in every new building, and regulate cistern sizes and system design and maintenance. Most domestic roofs are constructed of local limestone block, which is sealed with non-toxic latex paint. Wedge-shaped limestone "glides" form gutters that direct rain water to vertical leaders that empty into cisterns under the houses. Electrically driven pumps with pneumatic tanks raise water from the cisterns into plumbing systems.

Rainfall is also collected from surface catchments, which supply hotels and augment the government-operated groundwater supply. These catchments, formed by removing shallow soil cover and sealing the limestone rock surface with mortar, represent about 9 percent of the total rain water catchment area on the island.

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The importance of rain water in Bermuda is indicated by the fact that rain water catchments cover 5 percent of the land area of the island, and that the volume of rain water cistern storage on the island is 1.12×10^6 m³, compared with 0.023×10^6 m³ in government reservoirs.

OTHER APPLICATIONS IN DEVELOPED COUNTRIES

Most of the other examples of applications in developed countries are in regions that are undeveloped to the extent that they do not have access to a central water system, but increasing thought is being devoted to use of rain water as an auxiliary source to more conventional supplies.

In Canada, rain water is known to be used in some rural areas, but the only documented usage outside of Nova Scotia is in Saskatchewan [4]. Proposed revisions to a manual on cold climate utility systems include rain water as a seasonal or supplementary source in the Artic and sub-Arctic, particularly for schools and other isolated structures with relatively large roof areas and limited water needs [7].

Use of rain water is widespread in many rural areas of the United States (67,000 systems in the State of Ohio alone [8]). Some states regulate construction, and both state and national agencies provide instructional materials on system construction [4].

Recent examples of consideration of rainfall as a supplementary source in the United States are: proposals for use of airport runoff as an economic alternative to municipal water for non-potable uses at the Honolulu International airport [9]; consideration of the use of roof water at the Kennedy Space Center in Florida as a cooling water source [10]; an experiment in Arizona where urban surface runoff is harvested as a source for garden irrigation in a municipal area [11]; and proposed use in Southern California of rain water and grey water for domestic landscape irrigation, which represents up to 40 percent of household usage [12].

Rain water has long been recognized as a domestic source in the United States Virgin Islands, where building codes require incorporation of cisterns in dwellings. More recently, experimental PVC-covered ground level catchments have been evaluated for agricultural supplies [13].

There are a few examples of domestic roof catchment systems in Japan. Use of rain water from roofs of multi-story residential buildings in Osaka as a supply for toilet flushing has been examined and found feasible [14].

One million people in Australia rely on rain water as their primary source of supply.

One million people in Australia rely on rain water as their primary source of supply [15]. The government of South Australia has promoted increased use of rain water cistern systems, and has provided information on cistern sizing, materials, and maintenance [16].

In Europe, rain water, which historically was an important source, is still used in Germany. Gibraltar requires roof top collection where central service is not available [4].

RAIN WATER HARVESTING IN DEVELOPING COUNTRIES

Rain water cistern systems are a traditional water source in many parts of the developing world, and extensive efforts are being made to extend the use of such systems in areas where reliable supplies of clean water remain a problem. Locations where such systems are used, or have been proposed for use, include Bangladesh, Botswana, Caribbean Islands, India, Indonesia, Kenya, Malaysia, New Guinea, South Pacific Islands, Sri Lanka and Thailand.

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The potential for extensive use in developing countries is typically in rural areas that do not have access to safe, adequate, or reliable supplies of surface water within a reasonable distance because surface sources are polluted or seasonally dry, or because ground water is not available or is highly mineralized, or shallow wells are seasonally dry or polluted.

One indication of the potential impact that cistern systems can make to the solution of these problems is a government program in Thailand that aimed at providing rain water storage jars to three million households by the end of 1987 [17]. In Malaysia, an estimated 3.5 million people, who live in rural areas without pumped water or potable well water, could benefit from use of rain water systems [18].

Considerations involved in applications of roof water cistern systems in developing countries appear to differ in a number of respects from those in developed countries:

1) In developed countries the criterion for evaluation of a satisfactory supply is likely to be quality or quantity that is comparable to that attainable from a conventional public system. In many situations in developing countries, where alternative supplies are non-existent or grossly contaminated, the selection of a rain water system can be justified by the fact that it provides a supply of clean water that would not be available otherwise. In some developing countries the quality of cistern water, although a matter of concern, may not be a primary consideration if alternative sources are highly contaminated and/or boiling is an accepted practice. In developed countries the quality of cistern water is normally judged by the same standards applicable to public supplies.

The prime objective of water . . . is provision of an adequate, reliable, safe supply for drinking and cooking.

Lack of other available sources is an important reason . . . but other reasons have been cited.

2) Consumers' expectations of rain water cistern systems in a developing country are generally different from those of consumers in a developed country. A North American customer expects his supply to meet all household demands -- which may even include lawn irrigation -- continuously and at an undiminished rate. The prime objective of water supply in developing countries is provision of an adequate, reliable, safe supply for drinking and cooking.

3) In many developed countries, deficiencies in conventional sources that prompt use of rain water are localized, and when dry periods occur water can be trucked from other sources. In most developing countries where cisterns are used they must completely meet dry period demands.

4) In Canada the urban population is 82% of the total, and about 80% of the population is served by community water systems [19]. In many underdeveloped countries the urban population is a smaller proportion of the total (Africa, 32%; Asia, 25%; South America, 69% [20]) and even in major population centres a large proportion of the population may not have access to piped water supplies.

5) The economic circumstances of rain water users in developing countries are generally much worse than those in developed countries. Ability to pay is usually not a serious consideration in decisions about cistern systems in a developed country; the fact that a cistern system costs more than a public supply or a private ground water supply is irrelevant if these alternative sources are not available, and the cost of water supply is a small proportion of the capital and operating costs of a single-family dwelling. In developing countries most potential users have minimal disposable income, which limits their ability to purchase water systems.

Lack of other available sources is an important reason for reliance on rain water cistern systems in developing countries, but other reasons have been cited for choices in specific situations: ease of construction, versatility in that capacity can be varied to suit individual needs and local rainfall; reliability; satisfactory water quality; low capital cost; labour intensive, thereby permitting local construction with primarily local materials; failure or contamination of an individual system does not affect the whole population; they are autonomous, and can be used in remote areas and difficult terrain; they receive a large percentage of rainfall in comparison with surface or groundwater sources that are more subject to effects of evaporation and infiltration.

Another measure of the significance of rain water systems, as an appropriate technology for rural areas of India, is their ability to satisfy the following criteria [21]:

"(1) Solace to the sufferings of people with the availability of additional quantity of water within their easy reach;
(2) availability of safe drinking water at a nominal cost;
(3) reduction of hardship and drudgery of womenfolk; and
(4) release of time for womenfolk to take-up some income augmenting activities."

CONSTRUCTION METHODS AND MATERIALS

Major elements of a rain water cistern system are a collection surface and a storage container. In most situations rain water is collected from a roof, but ground level catchments are used to serve institutional and public buildings and community supplies.

Storage containers may be at or above ground level, in basements, or below ground. Appurtenances include gutters and piping systems to intercept and convey water to storage, and may include overflows from storage, and devices to divert to waste unclean water collected at the beginning of a storm event. Water may be removed from storage by a dipper, bucket, or pump, and be carried or piped to the point of use. In Nova Scotia, as in many other parts of North America, most roofs are covered with asphalt shingles. In Bermuda, roofs are constructed of limestone sealed with non-toxic latex paint [6]. In many other parts of the world use of corrugated galvanized iron roofs is common. Thatched roofs have also been used for rainfall collection.

Cistern storage in developed countries is common-

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ly provided by poured concrete or mortar-lined concrete block tanks. In undeveloped countries considerable emphasis is placed of use of indigenous materials and local labour-intensive storage containers.

Bamboo-reinforced water tanks were widely used in many countries, but have been found to deteriorate rapidly over time due to the deterioration of the reinforcing [22]. Ferro-cement tanks (made from thin walled reinforced concrete using closely spaced wire mesh in a rich cement-sand mortar) are widely used [23-26]. They are being introduced in Botswana to replace commonly used galvanized corrugated metal tanks [27]. Tank sizes have ranged from 5 - 20 m^3.

A 2 m^3 cement jar, which can be constructed with local labour, is the basis for a government campaign in rural Thailand. To provide more storage, cost comparisons favour 6 and 12 m^3 ferro-cement tanks, which are being promoted for schools and other public buildings. Ultimately these tanks are expected to supercede jars for many households in northeast Thailand, where the minimum household storage requirement is 6 m^3, because they provide storage which is more permanent and uses less space (but is more expensive), compared with use of three 2 m^3 jars [23].

Possible combinations of indigenous materials applied for rain water collection and storage appear almost endless. A system used in rural India includes a well 3 to 4 m deep and 1 to 2 m in diameter, lined with brick and mortar. A circular area of about 100 m^2 around the well is sloped toward the well to provide a catchment area. "A suitable site is selected for construction of these cisterns keeping in mind distance from the village, altitude, natural depression, etc. During rainy season (May - July), water is collected in these cisterns and is covered with branches of tree and dry bushes and surrounded with thorns for protection from stray cattle. When all other sources of drinking water exhaust, people consume water from this cistern. The water is drawn in buckets with rope. One such cistern meets the drinking needs of five - six families." [21]

CAPACITY DESIGN

The yield of a rain water cistern system depends on available precipitation, the size of the collection surface, the fraction of the precipitation that is recovered, and the volume of the cistern. In some circumstances losses by evaporation and seepage must also be considered. Precipitation can be characterized by the total annual depth, by its distribution throughout the year, and in colder climates, relative amounts of rainfall and snowfall. Examples of the range of precipitation in areas where cisterns are used are: Nova Scotia, with a relatively uniform precipitation ranging from 100 to 160 cm per year (20 - 40 cm as snow); northeastern Thailand, with a seven-month dry period and annual precipitation exceeding 97 cm in 95 percent of recorded years; and most of South Australia, with an average annual rain fall less than 25 cm per year (Table 1).

TABLE 1

Water Demands and Availability of Precipitation in Typical Regions

Where Rain Water Systems are Used

Location	Design Demand L/cap/day	Annual PPT mm	Dry Period	Reference
South Australia	200-400*	250		[28]
South Bangaladesh	52	3280	Nov - Apr	[29]
Botswana	8 to 13	250 to 650	May - Oct	[27]
Southwest India	17	40 to 750	Dec - March	[21]
Indonesia	4 to 5	840 to 3230	3 to 8 mo	[30]
Jordan	28 to 225*	68 to 616	May - Sept	[31]
Nova Scotia Canada	91	1000 to 1600	none	[32]
North East Thailand	5	1000	Nov to Apr	[17]

* Calculated availability per household

Recovery of rain fall from a collection surface may be as high as 90 to 95 percent, but values as low as 53 percent have been estimated for a Nova Scotian house with a steeply sloped mansard roof, and 43 percent for Indonesian dwellings with gutters considered too small to completely capture intense rainfalls [33-35].

Storage capacities for affluent users may be selected, as a design parameter, but in many situations are determined by economics and local technology. The objective of government programs in Thailand is to provide a minimun of one 2 m^3 cement jar per family. In Nova Scotia, cistern capacities as large as 75

Sizes of roof surfaces are also functions of local economics and technology.

m^3 are used for domestic systems [34]. Sizes of roof surfaces are also functions of local economics and technology. Examples range from an average of 35 m^2 for a Malay home [36] to 171 m^2 for an affluent residential area in Nova Scotia [34].

Design procedures for determination of yield where system characteristics are given, or for selection of storage capacity to meet a specified yield from a given roof area, have been reviewed by Schiller and Latham [37]. Analyses are commonly based on mass curves of precipitation, and increasing use is made of microcomputers for individual designs or production of regional design charts. Two widely used algorithms are based on assumptions described as yield before storage (rainfall is added to initial storage, demand is satisfied, and any balance in excess of net capacity is spilled), or yield after storage (rainfall added to initial storage, in excess of tank capacity, is spilled before demand is subtracted). Most calculations are based on monthly data, which is more readily available in most regions, although there is evidence to suggest that use of daily rainfall produces more accurate results [31]. System yields, determined by design of a specific system or accepted de-facto by the user as a result of his roof area and available storage, vary greatly. Reported demands range from 3 L/cap/day in Malaysia as a minimum for cooking [18], to 17 L/cap/day used for system designs in southwest India, to 50 L/cap/day in Bangladesh, to 91 L/cap/day suggested in Nova Scotia for guidelines for design of rain water cistern systems (see Table 1).

In northeast Thailand, 5 L/cap/day is considered adequate for drinking and cooking for a family of six persons. The 200-day dry period, lasting from November to March, would require 6 m^3 of storage. This amount is a small proportion of 77 m^3 discharged from an average roof of 80 m^2 during the remainder of the year [35].

WATER QUALITY

As potential new applications of rain water cistern systems have been recognized, increasing attention has been paid to water quality from such systems. Considerations that may effect the quality of water consumed from a rain water cistern system are:
— quality of precipitation
— deposition on catchment surfaces
— contaminents introduced into cisterns
— contributions from systems materials
— effects of treatments
— effects of maintenance practices

References previously cited deal with many of these items, and available space does not permit a detailed review. It is the author's perception, however, that rain water cistern systems, if properly designed, constructed, and maintained, can provide a safe supply of water for any domestic purpose, including drinking.

Precipitation does not represent a contamination source in predominatly rural areas where rain water use is seriously considered, and analyses of cistern water in areas exposed to industrial emissions have not exceeded drinking water standards. The only exception to the foregoing statement is that pH values in areas where acid precipition is a problem have been significantly below acceptable limits.

Wasting of the first flush of runoff may be important where prolonged dry periods occur.

Deposition on catchment surfaces may include atmospheric fallout in dry periods, bird droppings, leaves and other tree materials, moss accumulations, and insect eggs and larva. Total and fecal coliforms counts found in most of samples taken from cisterns and household faucets in 18 systems in Hawaii were attributed to feces of birds and rodents [38]. Concentrations of potential contaminants in runoff in the cisterns increase with the duration of dry periods, and wasting of the first flush of runoff may be important where prolonged dry periods occur. Regular cleaning of roofs may also be advisable.

Collection surfaces may contribute tastes, colour, or chemicals orginating with unsuitable or uncured paints, corrosion from metal roofs, or materials leached from thatched roofs or shingles. These problems can be minimized or eliminated by material selection, maintenance, and waste of runoff from newly painted surfaces.

Contaminants introduced into cisterns include materials washed from catchments, or insects and rodents that deposit excrement, eggs, and larva, or die in cisterns. Filtration and/or screening of water entering a cistern and protection of over-flows and vents can reduce these problems. Where leaves or organic materials accumulate in cisterns, water quality deter-

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ioration can be avoided by judicious location of cistern outlets and by regular cleaning. In larger cisterns partitions can maintain supply when the cisterns are drained and cleaned. In some situations, clean cistern water has been contaminated by supplementary supplies added in dry weather. If cistern surfaces are not covered, the open storage may provide a breeding place for mosquitoes which may act as vectors for diseases including hemorrhagic fever. Exposure to sunlight may promote algae growth.

When water is withdrawn from jars or small tanks by dipper or bucket, these utensils may introduce contaminants into the cistern. Results of analyses of samples of rain water at various points within cistern systems in Thailand did not meet WHO standards [39]. It was concluded that the possible route of contamination is from both unclean collecting systems (roof and gutter) and unclean storage containers. In some cases it has been recognized that introduction of a safe drinking water source must be accompanied by health education for a population not aware of the need for, or methods of, hygiene. One author has pointed out that health education is particularly important in areas where the amount of available rain water is small, alternative sources are contaminated, and women who recognize that rain water, which is very soft, is ideal for washing and laundry purposes may use it for these purposes instead of for human consumption.

Cistern materials that effect water quality may include paints, coatings, liners, corrosion products from metals, and materials leached from concrete and mortar surfaces. Where atmospheric inputs are acidic, concentrations of metals like lead and cadmium may be dissolved from plumbing systems. It has been found that materials leached from concrete cistern walls neutralize the acid and decrease the aggressiveness of cistern water, and for this reason lined tanks are discouraged in areas where acid rain is a problem.

Treatment of cistern water has included disinfection by occasional additions of hypochlorite, boiling, or by continous disinfection using ultraviolet light or chlorine. Chlorination may not be effective at high pH levels found in some tanks. Filtration devices have been used in some systems, but should be unnecessary if systems are properly constructed, designed, and maintained. The bacteriological quality of cistern water should be such that disinfection is not required; nevertheless the author has recommended that Nova Scotia guidelines include a recommendation that disinfection be adopted, to assure a continued safe supply in the event of chance contamination.

Water collected from ground catchments will require boiling unless extreme precautions to exclude animals, and careful maintenance, are practiced.

Concentrations of minerals in rain water are low compared to those in surface and ground waters, and therefore contribute little to human nutritional requirements. Attention has been drawn to the possibility that long-term consumption of rain water, in situations where intake from minerals is deficient or marginal, may contribute to negative health effects [40].

INSTITUTIONAL CONSIDERATIONS

In Nova Scotia, rain water cistern systems are an important source for a small number of situations where alternative reliable sources of potable water are not available. The role of the responsible government agency has been to provide prospective users with guidelines that will enable them to properly design, construct, and maintain their systems, i.e. to provide information, rather than encouragement, to potential users.

In areas where governments and other agencies recognize that rain water cistern systems offer effective solutions to supply of water for whole communities, programs must be more intense and more pro-active. In South Australia, rain water is an important alternative source, government agencies have actively promoted use of cistern systems by information booklets and media campaigns. No financial encouragement is provided [15]. California in 1980 adopted a law providing tax credits for water conservation measures that include cisterns (for non-potable uses only) [5]. Tax credits, requirements by building codes, and promotion of use in housing projects are all possible means of encouraging use of cistern systems in other water-short areas [5], [41].

"When installed on a large scale, particularly in developing countries, a host of issues, of social-economic, and even cultural nature can influence the implementation strategy." [42].

Following an experiment in Thailand in which a pilot project for promotion of latrines was used in one village and another village was used as a control, it was concluded that the essential features of a successful program were preparation of the community, training of craftsmen, organization of a village committee and establishment of a revolving fund [43].

Implementation strategies adopted for the government of Thailand program to provide water jars to 3 million household by 1990 (at least one jar to each household by 1987, and 3 jars per household by 1990) include: involvement of villagers from the beginning including information, involvement in finances and involvement in construction; provision by government of a revolving fund for materials purchases, with a realistic repayment rate; provision by government agencies of training for village technicians, who are expected to train other villagers; and provision by government agencies of tools and materials, while villagers provide free labour and repay materials costs [17]

Villagers do not perceive rain water as wholesome.

Goh and Ramli [36] reviewed reasons why properly designed cistern systems, which could play an important role in providing safe water supplies in rural Asia, have not been widely adopted when promoted by government: villagers do not perceive rain water as wholesome, because authorities have overemphasised development of piped water systems; cisterns benefit individual households while installation of piped systems supplies larger groups simultaneously; and cisterns are perceived as being more expensive and relatively less convenient when compared to piped water.

Appan and Wing [44] proposed a total approach to large scale introduction of rain water cistern systems, integrating technological, socio-cultural and economic components, and recognizing the existing state of knowledge of cisterns in the region, to assure that the final outcome is long lasting, simple, inexpensive, and manageable by rural communities. Case studies of application of this approach in the Philippines and Indonesia are presented. The importance of financing schemes is emphasised, as is recognition that programs totally financed by external sources lead to progressive lack of interest resulting in poor operation and maintanence, compared with self-help involving community participation. Appan [42] described a unique financing system that is applied in Indonesian villages:

"Two she-goats are lent to the family that needs the RWCS and when they bear (normally) four young ones, two of these are returned to the owner and the other two belong to the borrower. The borrower then looks after the two young ones and when they have grown up uses them as payment for the RWCS."

An approach taken by a Village Industry Research and Training Unit in Papua, New Guinea is based on production of 4 m^3 ferro-cement tanks, considered to be considerably cheaper than commercial alternatives. The organization provided a process and equipment package, including fiberglass molds and training, to local entrepreneurs, who were expected to meet equipment and materials costs. [24].

Fok [45] proposed that area-wide drinking water management policies should be established for periods of water shortage, so that emergency water supply can be made available.

RWCS AS AN APPROPRIATE TECHNOLOGY

"Appropriate technology" is a phrase that is widely used but seldom defined. It is the author's impression that the "appropriate" in this context means:

(1) appropriate with respect to level of service - which in turn can be related to design objectives such as health, convenience, aesthetics, etc.
(2) appropriate with respect to ability to pay - which relates to the economic circumstances of individuals and/or the society in which they live, and includes their ability to pay both in monetary terms and/or contributed services.
(3) appropriate with respect to willingness to pay, which reflects the importance which individuals attach to various levels of service, and is a reflection, at least in part, of cultural norms.
(4) appropriate with respect to cultural or behavioural constraints - an example might be preference in some countries for ground water versus rain water for drinking purposes.
(5) appropriate with respect to local conditions - which might include urban versus rural; climatic factors such as temperature and precipitation; soils and geology; availability of electricity, central water systems, or alternative supplies.

"Appropriate technology" is a phrase that is widely used but seldom defined.

It is also the author's impression that many people associate appropriate technology with small-scale projects, in developing countries, where the term is used to emphasize solutions that are within the capabilities of the recipients to construct, pay for, use, and maintain them. Many of these solutions are intended for the economically deprived, and design objectives are often related entirely to improved health by providing clean water for cooking and drinking.

The nature and extent of the applications of rain water cistern systems suggests that the dimensions of at least this appropriate technology go beyond this narrow definition:

— Appropriate technology need not be limited to the "third-world" or developing countries. Reference need only be made to the examples of rain water cisterns in Bermuda, the U.S.A., and Australia.

— Appropriate technology is not only for the disadvantaged, or economically deprived, in any country. Reference can again be made to very expensive homes, hotels, and public buildings in Bermuda, and expensive houses in Nova Scotia, that are supplied by rain water cistern systems.

— Appropriate technology does not mean second-best solutions in terms of quality of service; non-conventional solutions can often provide levels of service that equal or approach service provided by conventional systems. Rain water cistern systems can provide water quality that often exceeds that of any available alternative source, and can provide reliable supplies in terms of quantity that are consistent with the ability of users to pay and their expectations in terms of service.

Rain water cistern systems provide an example of a truly appropriate technology.

In summary, rain water cistern systems provide an example of a truly appropriate technology, which is playing an increasing role in provision of safe reliable supplies of water in many parts of the developed and developing world.

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