SEARO REGIONAL HEALTH PAPERS No.4

low-cost water supply and sanitation technology: pollution and health problems

world health organization
regional office for south-east asia
new delhi, 1984

The SEARO Regional Health Papers are intended to make generally available material that for economic, technical or other reasons cannot be included in SEARO's regular publications programme and would otherwise receive only limited distribution.

ISBN 92 9022 173 9

Printed in India

FOREWORD

This publication was originally prepared for ESCAP and presented at the Tenth Session of its Committee on Natural Resources, held in October 1983 in Bangkok, Thailand. Since various national agencies concerned with water and sanitation have an interest in this subject, it was decided to publish it in its present form for wider distribution.

In many developing countries, low-cost and simple technologies have generally been found "appropriate" and are being adopted on an increasing scale. Their simplicity and dispersed nature, however, can lead to poor construction and lack of maintenance at the community level. Incorrect applications and ill-maintained facilities are fraught with danger, as they can cause pollution and health problems.

It is hoped that this publication will stimulate greater awareness of the health aspects of these technologies, in keeping with the goals of the International Drinking Water Supply and Sanitation Decade.

Ko Ko

Dr U Ko Ko
Regional Director

ACKNOWLEDGEMENT

The contribution of Dr T.R. Bhaskaran, who acted as Temporary Adviser, and Mr S. Arceivala, WHO Regional Adviser on Environmental Health, in preparing this paper for the WHO Regional Office for South-East Asia is acknowledged.

CONTENTS

		Page
1.	INTRODUCTION	1
2.	OVERVIEW	3
3.	COVERAGE HIGH, HEALTH STATUS LOW	7
4.	LOW-COST TECHNOLOGY APPLICATIONS IN WATER SUPPLY	11
5.	LOW-COST TECHNOLOGY APPLICATIONS IN SANITATION	19
6.	SUMMARY AND RECOMMENDATIONS	29
Annex -	Pollution and Health Problems Related to the Use of Simple, Appropriate and Low-cost Technologies in Water Supply and Sanitation	31

1. INTRODUCTION

Simple, low-cost technologies have been used in the Region[1] for a long time, particularly in the provision of water supplies to rural communities. Several applications have also been designed for excreta disposal. However, over the last few years governments and public authorities have begun to consider their use not only in rural but in urban areas as well. Such technologies could accelerate the coverage of unserved and underserved populations.

Thanks to the efforts of various governments, and with support from UNICEF, WHO, World Bank and other international and bilateral agencies, demonstrations and field studies have been carried out, guidelines for design and operation developed, and schemes prepared for application. In India, schemes for providing nearly 200 towns with low-cost sanitation facilities are under preparation. In Indonesia and Thailand, projects are under way for providing hundreds of rainwater storage systems. Over 3 000 000 hand pumps are in use in the countries of the Region. In China, over 7 000 000 biogas digesters in operation; India has over 70 000.

Their low per-capita cost and simplicity of operation have made these technologies irresistible. Many have proved to be socially acceptable and economically viable and, therefore, have come to be called "appropriate technologies". As with all technologies, however, their health implications must be given careful consideration. Being simple, and generally implemented on an individual basis, they are apt to be poorly conceived, constructed and maintained. Simplicity can breed complacency, with the result that the full health benefits implied in a wider coverage of rural and urban populations may not accrue. After all, the provision of water and sanitation has a dual purpose - improved environmental health and public convenience. Equal attention should be paid to both aspects.

---

[1]"The Region" is defined inside the front cover.

DISEASES RELATED TO THE IMPROPER USE OF LOW-COST TECHNOLOGIES

	TECHNOLOGY	WATER-BORNE DISEASES 1	WATER-RELATED DISEASES 2	SOIL POLLUTION 3	FLY-AND INSECT-BORNE CONTAMINATION OF FOOD
WATER SUPPLY	RAINWATER HARVESTING AND SUPPLY	■	■		
WATER SUPPLY	GROUND WATER FROM WELLS AND SPRINGS	■			
WATER SUPPLY	SURFACE WATER SUPPLIES	■			
WATER SUPPLY	STAND PIPES	■	■		
WATER SUPPLY	STORAGE OF WATER	■	■		
SANITATION	PIT LATRINE	■			
SANITATION	POUR/FLUSH	■			■
SANITATION	VENTILATED IMPROVED PIT	■			■
SANITATION	VAULT AND CARTAGE	■	■	■	■
SANITATION	TRENCHING			■	■
SANITATION	AQUA PRIVY AND SEPTIC TANK	■	■		
SANITATION	WASTE STABILIZATION POND				■
SANITATION	REFUSE DISPOSAL				■

1. Includes diarrhoea, dysentry and typhoid
2. Includes malaria, filariasis dengue and schistosomiasis
3. Includes hookworm, rand worm and other helminths.

Figure 1

2. OVERVIEW

The low-cost technologies commonly used in water supply and sanitation and the health problems that can arise from their improper use are summarized in Figure 1. Since human excreta are the source of nearly 50 infections that are transmitted through various direct and indirect routes, the list includes water-borne and water-related diseases as well as others resulting from soil pollution and food contamination. The incidence of these diseases is high in the developing countries of Asia, where the major health problems are diarrhoeal diseases, nematode infections, filariasis, malaria and other mosquito and fly-borne infections.

Figure 2 shows the infant mortality rates prevailing in some South-East Asian countries plotted against the percentage of their populations without adequate sanitation. Since infant mortality is the result of a number of factors (unsafe water and lack of sanitation being only two among them), the graph in Figure 2 merely indicates the general situation, and should not be taken as implying any cause-effect relationship. However, the larger the percentage of population without sanitation, the greater the infant mortality rate.

The task of providing water and sanitation to the unserved populations is so immense that it would be almost impossible to accomplish it without resort to low-cost technologies. If the International Drinking Water Supply and Sanitation Decade targets of the countries of the Region are to be met, nearly half a million people would have to be given access to new water supply and sanitation facilities every day! It would be impossible to achieve this using conventional technologies alone, owing to their high-cost

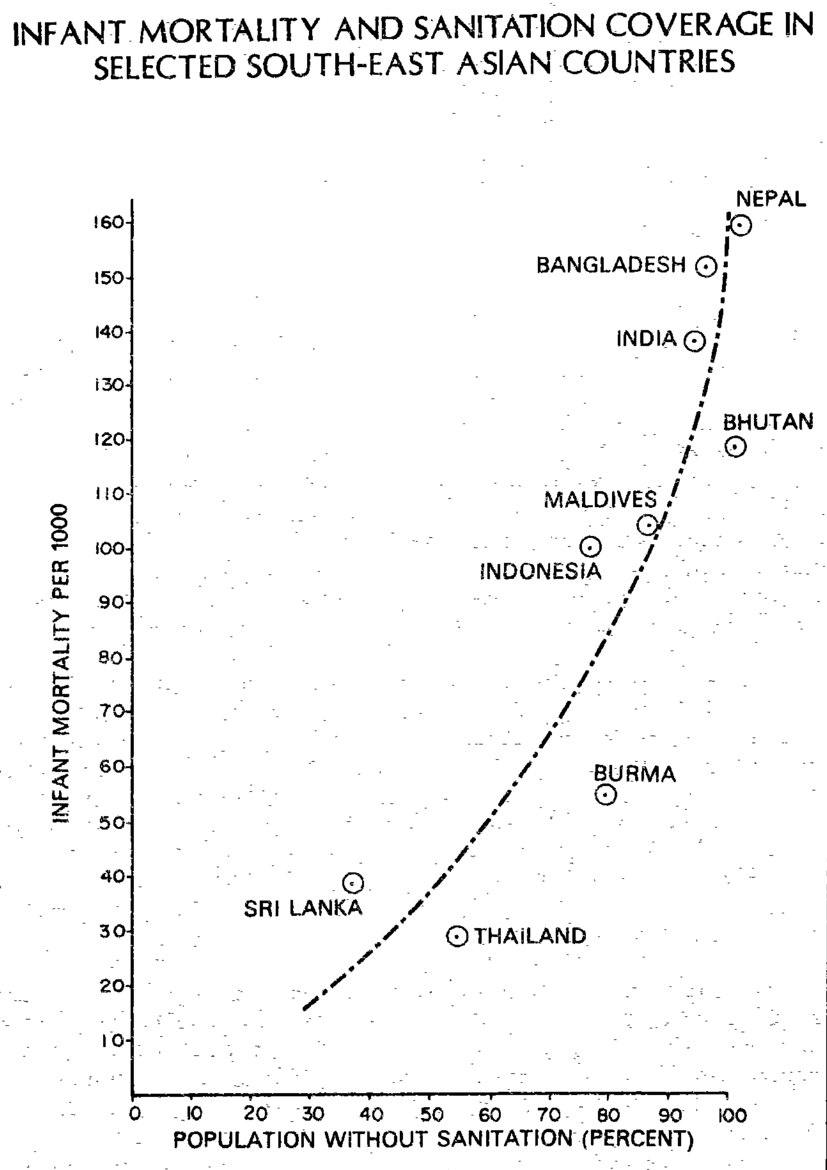
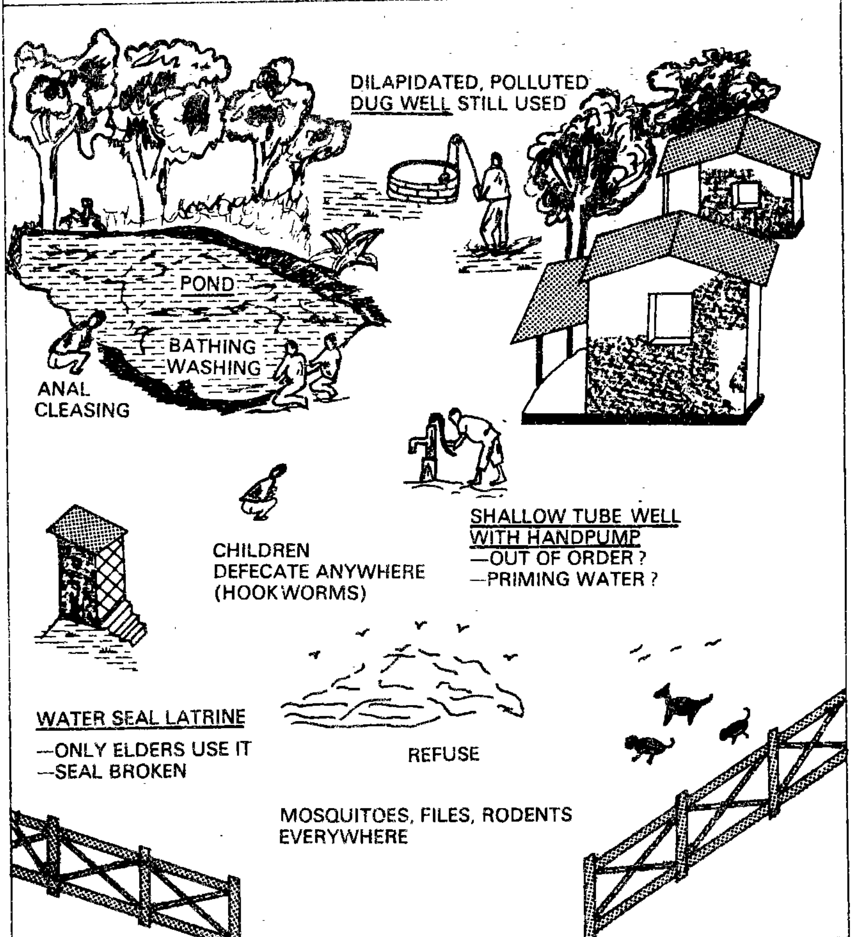


Figure 2

Source *IDWSS Decade Commencement Report*, WHO/SEARO, December 1982 and the level of skills required. However, the provision of low-cost technology on a wide scale will have a favourable health impact only if due regard is given to a variety of local factors. Unlike conventional technologies, where centralized design, construction and operation are possible, the application of low-cost technologies is by its very nature decentralized. Low-cost technologies are generally applied at the peripheral level, where construction, operation, maintenance and surveillance may vary greatly from one location to another; such applications are greatly affected by the level of community motivation and participation.

100 PERCENT COVERAGE BUT LITTLE IMPACT ON HEALTH STATUS



NOTE HOW THE VILLAGE HAS BEEN PROVIDED WITH THE REQUIRED WATER AND SANITATION FACILITIES. THERE IS THEREFORE 100% COVERAGE OF THE POPULATION AS REGARDS THESE FACILITIES, BUT THEIR MAINTENANCE AND USAGE ARE UNSATISFACTORY AND NO HEALTH BENEFITS ARE LIKELY TO OCCUR.

Figure 3

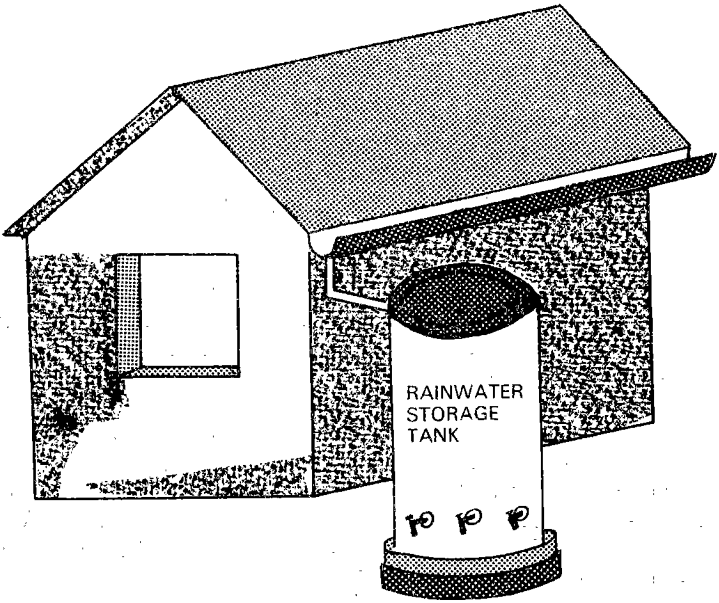
3. COVERAGE HIGH, HEALTH STATUS LOW

A typical scenario commonly found in many developing countries of Asia is given in Figure 3 to illustrate how the health benefits of low-cost technologies can fail to materialize in the rural setting.

The typical family lives in a mud hut with a thatched roof. Their compound is near a coastal belt, and the land becomes waterlogged during the short periods when there is heavy rain. For food, the family depends on seasonal rice cultivation and sea fishing. The house is located in an extensive compound that has a large pond. The pond is used by the family for bathing in and for washing clothes and household utensils, and one section of the pond is also used for anal cleansing after defecation. There is a shallow tube well fitted with a hand pump and a dilapidated dug well with little sanitary protection. These wells are used as a source of water supply by the family. The tube well pump often needs priming water and is also out of order for considerable periods of time, during which the family depends entirely on the dug well for its water supply. Water is drawn from the dug well with a bucket and rope that are always kept near the well. When the pump needs priming, both well and pond water are used.

The family also has a pit latrine with a pour-flush squatting plate and water-seal. This is located close to the dug well. Only the elders use this latrine, while the children defecate in the open - all over the compound. The water-seal of the squatting plate is not maintained because the trap was once broken in order to remove a blockage. Kitchen waste and waste food are discarded in the compound and left without any cover, and this leads to flies breeding

RAIN WATER COLLECTION AND STORAGE



NOT JUST A STRUCTURAL ENGINEERING PROBLEM! MANY OTHER DETAILS NEED ATTENTION:

- —ADEQUATE ROOF SURFACE AND AREA
- —ADEQUATE CAPACITY BASED ON HYDROLOGICAL DATA
- —BYPASS ARRANGEMENT FOR INITIAL RUN-OFF
- —COVER ON STORAGE TANK (AEDES MOSQUITO)
- —TAPS TO WITHDRAW WATER; NO DIPPING BUCKETS
- —DRAINAGE AROUND TANK (CULEX MOSQUITO)
- —NO BITUMINOUS PAINTS INSIDE
- —CLEANING AND EMPTYING ARRANGEMENT
- —EDUCATION OF THE USERS

Figure 4

profusely during certain seasons of the year. During the rains, the latrine gets flooded, creating pools of dirty water that harbour plenty of culex mosquitoes (see Figure 4).

The family living in the house consists of the parents and four children between the ages of one and ten. Occasionally relatives visit the family for short periods, at which time they are also exposed to the poor sanitary conditions prevalent in the compound.

It is easy to see that the level of environmental sanitation in a scenario of this kind will adversely affect the health of the people living in the house. Although a tube well with hand pump and a water-seal latrine have been provided, all members of the family and the occasional guest will suffer from diarrhoeal diseases. Although they may obtain some relief by visiting the doctor at the local health centre, they are likely to be reinfected. Bacillary dysentery with painful diarrhoea and blood in stool may not be uncommon. The children are prone to infection with hookworm, ascaris and other helminths, which will sap away what little nutrition they may be getting. They will be anaemic and also manifest other effects of worm infestation. The elders may also become infected with worms. The environment around the house provides an ideal breeding ground for flies and mosquitoes. The flies will help in transmitting some of the diseases mentioned earlier. The culex mosquito can spread filaria in the family. Individuals will eventually have blockages of the lymph circulation which culminate in elephantiasis in the elders. This scenario may be grim, but it is nonetheless likely.

4. LOW-COST TECHNOLOGY APPLICATIONS IN WATER SUPPLY

Low-cost technologies for water supply and sanitation are no longer in an experimental stage but have been sufficiently tested in the field. From the economic, environmental and health standpoints, they can provide a satisfactory solution to the problem. However, if this technology is to yield satisfactory results, adequate attention should be paid to the proper design, construction and maintenance of the system, as well as to community education.

Faulty conception and design often arise from a lack of understanding of the rural setting. It is dangerous to extrapolate experiences from the urban to the rural setting as behavioural patterns differ. The lack of adequate operation and maintenance facilities imposes another severe constraint.

The designer is thus called upon to simplify further his already simple, low-cost technology, and adapt it to the local situation. In such circumstances, the selection of a water supply source and site becomes even more critical.

While a community dug well may serve 100 people, a latrine is often meant to serve only a family of 5 or 6 persons. Thus, in a community that is provided with both water supply and sanitation facilities, there may be 15 to 20 latrines (potential sources of pollution) for each drinking-water well.

In order to highlight the situation in the Region, only a few principal applications of low-cost technology in water supply will be discussed:

- Rainwater harvesting and supply;
- Groundwater supplies from wells and springs, and
- Surface supplies.

The problems mainly stem from three causes: contamination at sources; contamination in pumping, piping, manual transport, and storage in the home; and fly and mosquito breeding in accumulated water.[1]

RAINWATER SUPPLIES

In some areas, rain water may be the only source of drinking water for a community, and either individual-household or community-sized units may be installed. Rain water per se is safe, but its collection, storage and use may be fraught with danger (see Annex).

First, if the rainwater storage capacity is not adequate, the community may be forced to supplement its rainwater supplies with other, probably unsafe, sources of water that may be available in the vicinity. Thus, proper hydrological design is crucial. Second, during the dry season, the rainwater collecting surfaces (roof or ground) are, in most cases, polluted by dirt, bird droppings and the like, and it is necessary to provide suitable arrangements for by-passing the run-off from the first showers of the rainy season (see Figure 4). The access of animals and humans to the ground-level collecting surfaces would also need to be restricted.

It is a good technological design to include further steps to protect the storage tank from contamination as well as to inhibit mosquito and insect breeding (as indicated in the annex). A sand filter is sometimes provided at the inlet of the storage tank. Facilities are needed for drawing water from the tank, either through taps or hand pumps, so as to prevent contaminants from entering into the stored water. Thus, even a relatively simple rainwater supply system must be carefully planned, designed and constructed, if it is to

[1] Small Community Water Supplies, Technical Paper Series No.18, International Reference Centre for Community Water Supply and Sanitation, The Hague, Netherlands (1981).

protect the health of the community. The community should also be educated, in order to secure their participation in the correct operation and maintenance of the system.

Special attention must be paid to the potential for breeding the aedes mosquito in the clean water stored in the reservoir. This can occur if the reservoir is not closed very tightly. The mosquito can readily enter through a mesh or netting. Household containers for storing drinking water can also provide breeding grounds for these mosquitoes. One mode of control in this case is to make the containers in a size small enough to require consumers to refill them every day or two. The users should also be taught to clean the containers each time before they refill them so as to destroy the larvae before they develop into adult mosquitoes.

GROUNDWATER SUPPLIES

Groundwater supplies are generally provided through either dug wells, tube wells or springs, and may be on-site or piped to community standposts or individual houses. As in the case of rain water, the ground water may be free from pathogenic organisms because it has undergone filtration in its passage through soil; however, its abstraction, storage and supply may introduce various pollution and health hazards unless precautions are taken (see Annex).

Many things can go wrong, even in a simple system consisting of a covered dug well or tube well with a hand pump. There are thousands of out-of-order hand pumps awaiting repairs on any given day in the countries of the Region; in the meantime, people use whatever other sources are available to them - most of them unsafe. The choice of pump is consequently of particular importance. Technological improvements are needed and research (executed by the World Bank with UNDP funding) is under way to develop a hand pump that can be easily operated and maintained at the village level.

Even when a pump does work, it may not be adequate for the number of people who have to depend on it, as inadequate norms and design criteria might have been used. The same situation may be found with regard to standposts.

The task of keeping hand pumps in proper repair has proved a challenge to planners, engineers and operators, and various ideas have been tested, some with success, in the Region.

Many wells now in use do not have the desired degree of sanitary protection, which would be secured by correct choices regarding site, distance from pollution source, well lining and covering, and the provision of an impervious platform and surface drain around the well. Many technological requirements are, in fact, well known (see Annex), but are at times neglected, under-rated or complied with as regards equipment, but this is allowed to fall into disuse.

Water-borne diseases can occur in such a situation. However, often even rudimentary health facilities are not available, nor is training given to ensure that disinfection is performed, either at the source or in the home, at least during epidemics.

Spring sources, however pure, may become contaminated unless adequate engineering measures are taken to protect them from surface run-off, humans, animals and insects. These measures are also well known.

The development of low-cost technology has also embraced treatment of ground water for iron, manganese, fluorides, etc. The operation of such technology generally involves a certain degree of skill (sometimes including the use of a chemical) although the installed plant may be relatively low in cost and simple in conception compared with conventional ones.

SURFACE WATER SUPPLIES

Surface water available in rivers, lakes, ponds and canals is invariably polluted and, unless it is purified, dangerous and not fit for human use. The treatment necessary to render such water safe is often not practicable for small communities because of the high cost of treatment and the need for constant skilled supervision of the treatment plants. For this reason, surface water is not easily amenable to low-cost technology applications and is generally not recommended as a source of water supply for small communities.

However, a number of simple methods involving a few items of mechanical equipment have been developed for the purification of surface water. The slow-sand filter, for example, can be adapted to provide a simple, efficient and reliable method for the filtration of water. The filter can remove 99 per cent of bacteria, including all pathogens. Work is now in progress on standardizing this technology for wide application in the rural areas of developing countries.

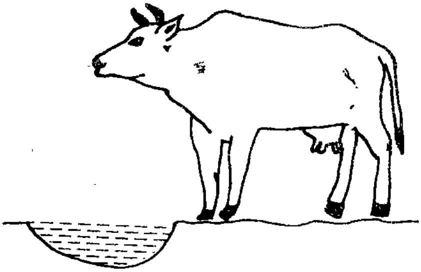
PIPED SUPPLIES

On-site supplies as well as supplies provided through standposts require the consumers to collect water in their own containers, transport it to their homes and store it. Here, the general health awareness of people regarding the need to protect their water from contamination determines their behaviour. In such circumstances, health education and the promotion of personal hygiene become more important than the technological design of the system. Behavioural studies have been, and are being undertaken to determine community-specific behavioural patterns prior to formulating appropriate community education interventions.

The improper design and installation of pipelines and standposts can also lead to various problems, including short supply, leakage, wastage, and seepage of polluted ground water into the piping system during hours when water is not being supplied. The use of inappropriate design norms can lead to overcrowding at standposts and hand-pumps, which may encourage people to seek other, perhaps unsafe, water sources. Inadequate drainage around standposts and hand pumps may lead to the formation of stagnant pools of water which, in turn, promotes mosquito breeding (see Annex).

SURVEILLANCE

All systems need some surveillance

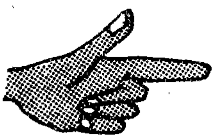


LOW-COST SYSTEMS PRESENT SPECIAL PROBLEMS DUE TO

- —DISPERSED SITES
- —LACK OF SKILLED MANPOWER
- —LOGISTIC DIFFICULTIES
- —POOR CONSTRUCTION
- —LACK OF OPERATION AND MAINTENANCE

ALL TOO OFTEN, LOW-COST TECHNOLOGY APPLICATIONS ARE NOT BACKED UP BY PROPER SURVEILLANCE MEASURES REQUIRED BY THE VERY NATURE OF THE TECHNOLOGY USED:

- —COMMUNITY EDUCATION
- —TRAINING OF COMMUNITY LEVEL WORKERS
- —CAREFUL SELECTION OF WATER SOURCE AND WASTE DISPOSAL SITES
- —PROTECTION OF WATER SOURCE FOLLOWED BY PERIODIC SITE INSPECTION (SANITARY SURVEYS)
- —OCCASIONAL SAMPLING AND ANALYSIS
- —INSTITUTIONAL SUPPORT, ESPECIALLY IN TAKING REMEDIAL MEASURES



The challenge lies in involving the community in its own surveillance work.

Figure 5

Various materials have been used to make piping for water supplies. Among the traditional materials, steel, cast-iron and copper are still in wide use. The use of lead has generally been discontinued, as a result of economic and health considerations (lead is soluble in soft waters). The use of asbestos cement is declining in some countries, owing to the health hazard asbestos presents to the workers engaged in the manufacture of such pipes. PVC and polyethylene are increasingly being used. Their potential health hazard has been investigated and shown to be negligible. Bamboo pipelines are still common in some countries, although pollution by infiltration is probable with such piping, especially where make-shift arrangements are made for its repair.

WATER-QUALITY SURVEILLANCE

Water-quality surveillance is just as essential with low-cost systems as it is with the more mechanized, urban ones in order to ensure the hygienic safety of the supplies. Low-cost systems, however, pose several problems as regards surveillance owing to their dispersed nature, logistics, generally poor quality of construction, operation and maintenance, as well as the lack of skilled manpower and laboratory facilities to assess quality.

Thus, with low-cost technologies, greater reliance has to be placed on the careful selection of the water source, its continued protection, periodic inspection (i.e., sanitary survey) and training of the community health worker. It may be necessary to sample the water occasionally in order to assess its bacterial quality or detect any suspected changes in chemical quality resulting from changes in land-use patterns in the vicinity. Therefore, careful attention needs to be given to institutional aspects, which should be built into the programme plan at the initial design stage. All too often, low-cost technology applications have not been backed up by proper surveillance measures required by the very nature of the technology used (see Figure 5).

5. LOW-COST TECHNOLOGY APPLICATIONS IN SANITATION

In the countries of the Region, applications of low-cost sanitation technology are mainly found in the following systems:

- On-site excreta disposal systems, consisting of individual or community latrines discharging into pits, tanks, cesspools, digesters or ponds;
- Community sewered systems, with subsequent use of low-cost treatment and disposal methods such as oxidation ponds and land irrigation;
- Drainage of storm and sullage water;
- Refuse disposal systems.

The pollution and health problems arising from poor sanitation are mainly due to fly and mosquito breeding, human contact with faeces, pollution of surface and ground waters by sewage, and food contamination. Furthermore, the personal hygiene and health benefits of improved sanitation in a community are difficult to assess and document.

As in the case of water supply technologies, the pollution effects and health problems related to low-cost technology applications in sanitation are a result of faulty conception, lack of awareness, incorrect application of technology, poor operation and maintenance and, in some cases, lack of field experience in designing, installing and operating low-cost systems.

Most Asian cities manifest the two extremes of sanitation: modern sewer systems for relatively small, affluent areas, and the most primitive possible manual systems (such as bucket latrines) for many other areas. To date, very few low-cost technologies have been applied in these cities. In a few cases where enough water supply is available, the undesirable manual scavenging systems have been replaced by septic tanks and soakage pits. However, by and large, experience with low-cost, on-site excreta disposal latrines is yet limited. There is a real need to evaluate the few systems already installed on a large-enough scale and draw lessons from them. Various technological precautions based on sound engineering judgement can be incorporated into designs and implementation programmes. This is discussed further in the following sections.

ON-SITE EXCRETA DISPOSAL SYSTEMS

Over the last 30 years, several studies have helped to determine user acceptance and provide better insights into design and construction practices, operational problems and health aspects of various excreta disposal methods in developing countries. Notable among them is a UNDP/World Bank study covering small townships in 14 countries including Bangladesh, Bhutan, India, Indonesia, Nepal, Philippines and Thailand - which aims to identify appropriate technologies and develop projects and programmes for wide implementation. The results of these and other studies have been reviewed in several publications.[1,2]

As a result of studies and experience gained over the years, the older concept of pit and borehole latrines has yielded place to newer ones, such as those of the ventilated

---

[1]<u>Health Aspects of Excreta and Sullage Management</u>. R.C. Feacham, D.J. Brodley, H. Garlick and D.D. Mara. World Bank (1980).

[2]<u>Appropriate Technology for Water Supply and Sanitation - A Planner's Guide</u>. J. Kalbermatten, G. Feachem, J. Bradley, Garlick and D.D. Mara. World Bank (1980).

improved pit (VIP) and the Reed Odourless Earth Closet. These reduce the problems of smell and flies and increase acceptance by communities that do not use water for anal cleansing. Pour-flush latrines incorporating improved pan designs are being provided where water is available and used by people for anal cleansing. Similarly, the pits that receive excreta are now being provided in duplicate, so as to enable alternate use by the community. Much more attention is now being paid to the potential for groundwater pollution by latrines. Aqua-privies have been made safer by making them self-topping. Biogas digesters are being fed with waste materials other than just excreta. Oxidation ponds have been designed to accept even raw excreta and nightsoil, and pond effluents are used for pisciculture. Better engineering concepts have been brought to bear upon the recycling of wastes. However, all these low-cost technologies have to be applied with adequate precautions of an engineering and educational nature in order to promote health benefits and prevent pollution. Some of these precautions are detailed in the Annex.

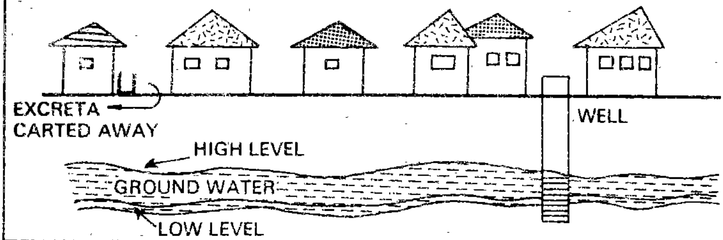
PIT LATRINES

The control of the fly nuisance is one of the principal objectives of good latrine design. In pour-flush latrines, the water seal prevents flies from entering into the pit and odours emerging from it. This water seal must be of adequate depth and must remain intact at all times. In trying to remove blockages, the seal may be broken and its whole objective defeated. In the VIP-type latrines, where there are no water seals, the odour and fly nuisance is controlled by the use of a vent pipe of sufficient diameter and height to generate an upward draft, and a screen on the top to trap the flies. General cleanliness on the part of the user is, of course, important.

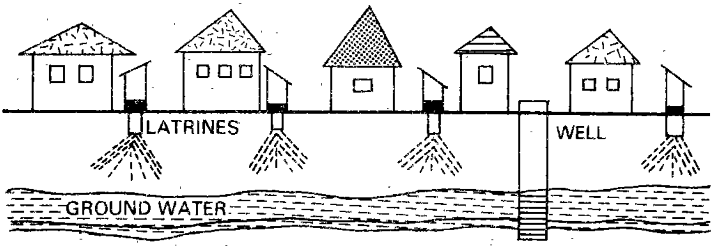
The survival time of pathogens in the pit must also be given due consideration. The provision of two pits for alternate use helps retain the excreta in a pit for a year or two after it is filled up and taken out of use. During this time, all viable pathogens and most helminths,

TRADITIONAL DRY SCAVENGING SYSTEM REPLACED BY LOW-COST, ON-SITE EXCRETA DISPOSAL LATRINES

This traditional dry scavenging system has its own set of problems and urgently needs to be replaced



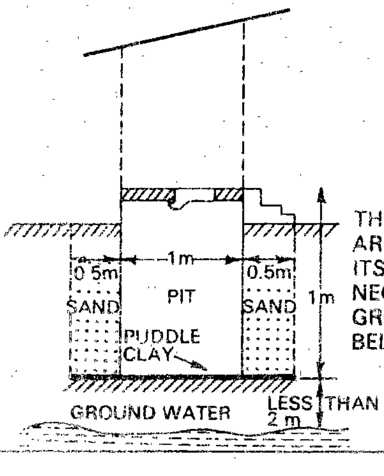
When dry scavenging is stopped and pit latrines are introduced



A NEW SET OF PROBLEMS MAY ARISE, SUCH AS CHANGES IN NITRATES AND BACTERIAL AND VIRAL QUALITY OF GROUND WATER

THIS DEPENDS ON:

—HYDRAULIC LOAD
—TYPE OF SOIL
—DEPTH OF GROUNDWATER



THE PROVISION OF A SAND ENVELOPE AROUND THE PIT LATRINE AND SEALING ITS BOTTOM WITH PUDDLE CLAY MAY BE NECESSARY ESPECIALLY WHEN THE GROUNDWATER LEVEL IS LESS THAN 2m BELOW THE PIT

Figure 6

including the resistant ascaris, are destroyed. The public health risk involved in handling the digested excreta after this long storage underground is minimal and the material can safely be used as manure in agriculture. This safety would not be assured if only one pit was provided.

GROUNDWATER POLLUTION

Ground water pollution has been studied in some detail in many countries and particularly in India and the United States. All the data available on the problem have been critically reviewed recently by the WHO International Reference Centre for Waste Disposal.[1] These studies provide valuable conclusions regarding groundwater pollution arising out of on-site disposal of excreta envisaged in most low-cost technologies (see Figure 6). The main conclusions of these studies may be summarized as follows:

- The extent of pollution of ground water arising from pit latrines and other low-cost technologies depends on many factors, such as the characteristics of the soil where the pit is located, the groundwater table and the velocity of flow of ground water (which determines the residence time of the pathogens under the ground). There can be no general or arbitrary limits for a "safe distance" between latrines and sources of water supply.

- The removal of pathogens from the pit is partly through filtration and partly through absorption by the soil. When the pit has been in operation for some time, the soil pores become clogged and this provides an effective defence mechanism for filtration. The

---

[1]The Risk of Ground Water Pollution by On-site Sanitation in Developing Countries, W.J. Lewis, S.D. Foster and S. Draser, WHO International Reference Centre for Waste Disposal, Switzerland (1982).

pollution potential is greatly reduced thereafter.

- The extent of polluted flow from latrines located in unsaturated zones with at least 2m of soil between the pit and the maximum water table is indeed very limited in soils that are predominantly silt and clay with file sand (effective grain size up to 0.2 mm). Under these conditions, the latrines can be located as close as 3 m from the well used as water supply. Under saturated soil conditions, a distance of 10 m may be necessary between the latrine and water supply.

- In coarser soils, an envelope of file sand (effective grain size 0.2 mm) of suitable thickness (0.5 m) should be provided all around the pit, sealing the bottom of the pit with clay or a polythene sheet to give the necessary protection from pollution.

It is evident from the studies already carried out that the pollution of groundwater supplies through pit latrines may not pose a serious problem in most soil conditions provided that the soil is free from chalk formations, gravel, fissures, root channels and rodent holes and provided that some precautions are taken in the location and construction of the latrines.

SEPTIC TANKS

Many septic tanks are used in Asia without sufficient care and precautions being taken. Such tanks do not work satisfactorily and are responsible for soil and water pollution and filthy environmental conditions in their neighbourhood. For example, they may be built with no sub-surface tile field or with a leaching area that is inadequate for the underground disposal of the effluent from the septic tank. The effluent from the tank, which is dangerous, is often let out in open drains, with attendant health risks. Regular de-sludging of the septic tank, which is necessary for its proper functioning, is often not carried out, with the result that the effective capacity available in the tank for removal of solids by sedimentation is greatly reduced. This results in direct carry-over of fresh solids, along with the pathogens, in the effluent, making it more dangerous.

AQUA-PRIVIES

Aqua-privies are essentially septic tanks with the toilet mounted directly on the tank. Important health aspects related to the aqua-privy include the proper maintenance of the water seal, with the periodic addition of water to the tank, and its location in soil conditions that can effectively leach out the effluent from the tank. If these two factors are not properly taken care of, the privy will be filthy, with bad odours and profuse fly breeding. The tank contents may also flood the area if there is not proper leaching from the tank. The attendant health risk can be serious.

WASTE-STABILIZATION PONDS

Although this is a simple technology, some attention is still required if waste-stabilization ponds are to be used without introducing health risks. One of the important health aspects relating to badly maintained stabilization ponds is the breeding of mosquitoes and insects that are vectors of disease. This problem can be taken care of by preventing the growth of any vegetation in the ponds and on the banks by properly designing the pond and protecting the embankments. If, in spite of this, some vegetation grows in the pond, it should be periodically removed to keep the water surface and embankments clear at all times. The design of the ponds should also provide adequate capacity. A cells-in-series arrangement is preferable, so that there is good removal of pathogens in the effluent of the pond. It is desirable to use a final maturation pond in the system if the effluent from the pond is to be used for irrigation or aquaculture.

FISH PONDS

Ponds enriched with sewage and nightsoil are often used for fish culture. The sewage is used after some pre-treatment or dilution and the nightsoil added to the pond directly in regulated doses. The health problems associated with this practice include the possible passive transmission of pathogens by the contaminated fish to people who handle and prepare it and others who eat it raw or partially cooked, and transmission of helminthic diseases such as fish tapeworm and schistosomiasis, where the required intermediate hosts are present in the pond (see Annex).

BIOGAS DIGESTERS

A large number of biogas plants using animal and human excreta are in operation in Asia. The main health problem associated with biogas plants is the risk involved in using the slurry in agriculture or fish ponds. Since excreta stay in the digester only for short periods (typically 5 to 30 days), the pathogens present in the excreta are not removed from the slurry. The slurry needs further treatment before it can be safely applied on land or fish ponds. The techniques of drying and storage for a period of one year or treatment in stabilization ponds can be used for this purpose. The slurry can also be composted along with refuse in order to obtain compost manure that is safe for use on land. However, if human excreta were excluded from the biogas plant, the slurry obtained would not pose this problem.

NIGHTSOIL DISPOSAL SYSTEMS

In these systems, nightsoil is periodically removed and carted away from bucket or vault privies. The bucket system is the oldest method, and is odourous, most unhygienic and not at all desirable from the public health point of view. This technology has therefore not been recommended for adoption as a low-cost technology.

However, the vault privy, with a water-seal squatting pan and vent pipe with a fly screen on top, can be a hygienic latrine, free from bad odours and flies. It is suitable for use in certain conditions such as rocky soil, high-density habitation, and where there is flooding. However, adequate care is necessary in the collection and transport of excreta from the vaults to the treatment site in order to minimize health risks. This can be achieved by using good equipment and well-trained personnel for operating the trucks used for the purpose. The outlet pipe in the vault and the suction pump and fittings on the trucks should always be maintained in good repair.

After collection, the excreta have to be properly treated before disposal. Sometimes the excreta are buried in trenching ground without any attempt being made to re-use them. Poor operation can often turn these trenching grounds into a major health risk to the community. A badly operated trenching ground that is not adequately supervised will not only be a serious health hazard for those who work in the trenching ground but also for others, particularly the children who come in contact with the trench. People thus exposed may also transmit the disease to others in the family and the community. Adequate precautions are necessary to make this technology safe. The trenches should be located far from residential areas and in soils that will not permit groundwater pollution. The trenches should be at least 0.6 m deep and filled with nightsoil only up to half their depth. They should then be covered by filling the pits with packed earth and erecting mounds over them, and be left undisturbed for a period of at least two years before being dug out.

Nightsoil is often re-used in agriculture. Untreated nightsoil should not be directly applied on land because there is conclusive evidence that this practice can produce serious health hazards. This practice should be condemned and discarded. The most appropriate technology for re-use of nightsoil in agriculture is to mix it with suitable proportions of domestic refuse and compost it. The compost manure can safely be used in agriculture.

LAND IRRIGATION SYSTEMS

From the health viewpoint, it is not safe to apply sewage directly to land without any treatment. The effluent from a waste stabilization pond, which is a recommended low-cost sewage treatment method, is generally satisfactory from the point of view of pathogen load for use as irrigation water in agriculture. Pathogen removal, including the removal of helminths, is invariably very satisfactory when the pond is designed in two or three cells in series, and when an adequate retention period is allowed.

REFUSE DISPOSAL

There are two main low-cost technologies used for the disposal of garbage, refuse and other household wastes; manure pits for the rural areas, and sanitary landfills for urban settlements.

The health problems associated with these technologies relate to the exposure of the material during collection and transport and the breeding of flies, cockroaches and rodents at the disposal sites. These hazards can be avoided by providing properly covered bins for the collection of refuse, using fully covered containers during transport and by covering each day's deposit of refuse at the disposal site with kitchen ash or earth so that the dumpings are not directly exposed to vermin. The location of the sanitary fill should not allow the leachates from the fill to endanger the ground water.

6. SUMMARY AND RECOMMENDATIONS

The task of providing water supply and sanitation to all people in the Region within the period of the International Drinking Water Supply and Sanitation Decade (1981-1990) is a great challenge. It is fortunate that there are low-cost technologies that work and are satisfactory from the health aspect and that are also within the reach of the economic resources of most communities.

However, the faulty application of these technologies can lead to health risks. The pollution and health hazards arising from faulty design and use of the technologies and the preventive measures necessary to forestall them are well understood, although not generally known. There is an urgent need to stress and disseminate this information at all levels in the various agencies concerned with the implementation of water supply and sanitation programmes. Planners, administrators and the health and engineering staff executing the programmes should be given this education through intersectoral cooperation and integration. If this is not done, the technologies may not be applied properly, resulting in their failure and the technology itself falling into disrepute. In consequence, the entire programme may be adversely affected. This is crucial at this time, when governments are beginning to allocate more funds for sanitation and to apply low-cost technologies in preference to traditional ones.

Two of the important requirements for the success of low-cost technologies are social acceptance by the user and proper operation and maintenance of the systems. An educational programme on health and maintenance aspects designed for the users would motivate them to demand the technology and lead to their satisfactory maintenance of the system.

Local governments are often weak and need support if they are to function well as a framework for organizing community participation in the implementation and maintenance of these technologies. Carefully planned training programmes for trainers will be needed for operational staff at all levels and in order to carry the message down to the village-level health workers and volunteers, and the general public.

Along with the implementation of the technologies, systematic monitoring and evaluation of the systems are necessary to assess performance and the utilization of the facilities by the community. Such monitoring will give the users the necessary security and confidence, and will also indicate areas where improvements and research are necessary.

Research and development in the field would greatly benefit if socio-behavioural scientists and health educators were included in the study teams. Technical cooperation among the countries of the Region themselves would be advantageous, as much field experience has already been gained in some of these countries.

National and international agencies funding water supply and sanitation projects involving the application of low-cost technologies should ensure that proper support programmes for community education and follow-up monitoring form an integral part of the project.

ANNEX

POLLUTION AND HEALTH PROBLEMS RELATED TO THE USE OF SIMPLE, APPROPRIATE AND LOW-COST TECHNOLOGIES IN WATER SUPPLY AND SANITATION

System component	Likely nature of pollution or health problem	Precautions/remedial measures
WATER SUPPLIES		
Rainwater collection from roofs and ground surfaces followed by storage in tanks or reservoirs	Wash-down of dirt, bird droppings, etc., from roof and ground surfaces	Provide bypass arrangements for the initial run-off of the season
		Educate householders
	Contamination of stored water	Provide cover on storage tank
		Provide taps for tanks above ground and hand pumps for underground tanks
		Provide cleaning/emptying arrangements
		Avoid the use of bituminous paints on the inside surface of tanks
		Teach people not to dip buckets or hands in stored water, and not to use unclean utensils at home
		Provide slow-sand filters

(continued)

(continued)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
	Mosquito nuisance	Provide drainage around tank and netting on any overflow pipe (<u>Aedes</u> mosquito is known to breed even in covered tanks)
	Use of other water sources of unsafe quality to supplement meagre rain-water supplies	Based on hydrological data, provide adequate capacity of rainwater collection systems Educate householders
Shallow or deep wells with hand pumps	Entry of pollution from nearby pollution sources through sub-strata	Generally, wells should be lined and located at least 10 m away from and upstream of pollution sources Tap the water from deeper and more favourable water aquifers Adopt precautions in the construction of latrines (provide a thicker unsaturated zone, use impervious materials on pit bottom, etc.) Need to raise latrine platform if water table high

(continued)

(continued)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
	Pollution from surface run-offs	Proper drainage and protection from surface run-offs. Construction of water-tight platforms and well casings (3 m deep)
	Entry of contaminants (e.g., dirt), as a result of handling water	Provision of tight lid/cover. Handling by rope and bucket should be rendered impossible
		Provision of hand pumps (self-priming or with pump cylinder under water). Avoiding use of contaminated water for pump priming
	Contamination of water during collection, transport and storage	Health education of community
		Clean container and utensils (provide tap on water-storage basins)
		Practice of personal hygiene
		Disinfection in the home
	Poor drainage and resulting mosquito nuisance	Provide an impervious platform around well and proper drainage to carry away spillage and clothes-washing water

(continued)

(continued)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
	Use of unsafe water supplies available more conveniently in vicinity	Ensure depth of well is adequate to provide water throughout the year Provide adequate number of wells and at convenient locations (according to accepted norms in the area) Check for taste and odour problems in wells Educate the community
Water supply from surface-water sources generally unprotected (village ponds, water holes, rivers, etc.)	Contamination from surface run-off and through improper handling	Select point of collection in the river (to be as distant as possible and upstream of sources of pollution) Collection container to be cleaned and protected during transport Simple water treatment may be essential (sand filtration and/or chlorination on individual or community basis Train community leaders in periodic surveillance of water source through sanitary inspection

(continued)

(continued)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
		Remove any sources of pollution located within the catchment area
		Educate the community
Spring-water sources	Contamination of spring sources by surface run-offs	Spring outlet to be located and encased by concrete spring box
		Diversion channel around spring site to be provided
	Entry of contaminants and insects	All openings (overflow pipe, etc.) in the spring box should be provided with netting
Water supplies from public taps (standposts)	Improper design and installation of pipelines and standposts, leading to short supply, over-crowding, and contamination and possible use of unsafe water supplies available more conveniently in the vicinity	Ensure water-tightness to prevent leakage/wastage and possible entry of polluted ground water during non-supply hours
		Provide an adequate size of pipeline and intermediate storage, and a sufficient number of conveniently located taps (according to accepted norms in the area) to serve community throughout the year

(continued)

(continued)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
	Contamination of water during collection, transport and storage	Health education, promotion of personal hygiene
		Use of clean containers and utensils
		Disinfection of drinking water stored in the home
	Poor drainage and resulting mosquito nuisance	Provide impervious platform around standposts and proper drainage to carry away spillage and clothes-washing water
SANITATION		
Pit Latrines		
Pour-flush with water seal, or ventilated improved pit (VIP) type	Odour, fly-borne diseases	Keep latrine pan clean and free from adhering excreta
		Ensure adequate water seal
		Prevent blockage of pan by proper flushing, avoid extraneous materials going into the pan
		Drums used for storing water outside the latrine should not be left open

(continued)

(continued)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
		For VIP latrine, use vent pipe 100-150 mm in diameter with fly screen on top. Locate vent pipe on the sunny side of the latrines and paint it black.
	Pollution of ground water	Sites for pit should be free from chalk formation, gravel, fissures, root channels and rodent holes
		Locate latrine pit at safe distance from well, depending on soil and ground water. Provide sand envelope for pits in coarse soils (see page 23 for details)
	Health hazards in handling and use of pit contents/worm disease	Allow contents to remain at least two years before removal
Vault toilet and cartage	Odour, fly-borne diseases	Keep latrine clean
		Provide vent pipe with fly screen

(continued)

(continued)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
	Spillage during transport	Empty vault at regular intervals
		Maintain vault outlet pipe and fittings in truck and pump in good repair
Burial of nightsoil in trenches	Exposure of excreta to flies/human contact	Locate trenches away from residential areas
		Trenches should be at least 0.6 m deep
		Provide adequate soil cover (half the trench depth)
		Leave the trenches undisturbed for at least two years before removal
Aqua privy	Odour, fly-borne diseases	Keep squatting pan clean and free from adhering excreta
		Ensure adequate water seal in drop pipe; provide self-topping arrangement if possible
		Avoid flooding of tank by providing adequate soakage area for effluent

(continued)

(continued)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
Septic tank	Fresh solids carry over, ponding of effluent, soil and ground-water pollution	De-sludge the tank regularly Provide adequate sub-surface tile field area for soakage Do not discharge effluent in open drain or water bodies without further treatment
Waste stabilization ponds	Mosquito breeding	Keep the pond and embankments free from vegetation Clear floating vegetation from water surface periodically Examine pond water for mosquito lervae and use larvicides if necessary
Biogas digesters	Presence of pathogens in slurry	Dry and store slurry for one year before use, or treat slurry in stabilization ponds or compost before use
Fish ponds	Pathogen transfer by contaminated fish to fish handlers and others who eat raw and partially cooked fish	Use stabilization pond effluent Allow fish to stay in clean water for some days before Harvesting Discourage consumption of uncooked fish

(continued)

(concluded)

System component	Likely nature of pollution or health problem	Precautions/remedial measures
Refuse	Nuisance, fly, cockroach and rodent-borne diseases	Use covered bins for collection and covered container for transport Provide adequate earth cover after each day's dumping Locate disposal site suitably to prevent ground water pollution from leachate