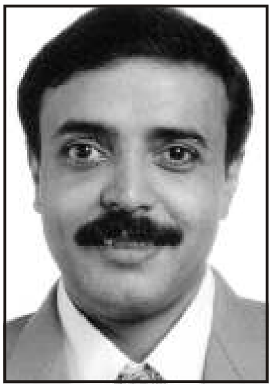
A Practical Approach to Water Supply and Sanitation in Asian Cities

by Subrata Chattopadhyay



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In 1993 he participated in Architecture & Development *an international course in Lund, and in 1996 he was one of the alumni invited to a follow-up course in Istanbul in connection with the second United Nations Conference on Human Settlements (Habitat II). He kept professional contact with HDM and in 2000 spent his sabbatical year doing research and teaching in the department.*

He is the only author of a Building Issue so far who is an expert on cricket.

Contents

Introduction

Problem

Water supply and sanitation top the development agenda in Asian cities. Over one billion people lack access to safe water worldwide, and nearly two billion of them lack safe sanitation. More than three million people die every year from water-related disease, mostly in Asia.

Good quality, easily available and safe water supply and sanitation make a great difference to our life quality. The trend towards urbanization in Asia is posing ever-increasing problems with respect to water supply and sanitation. The rate of population growth in the urban areas far exceeds that of the rural areas in most Asian countries. In several Asian cities, a large part of this urban population, from about a third to a half of the total urban population, lives in slums, derelict areas of towns and cities, and sprawling peri-urban fringe areas. Lack of clean water and proper sanitation are among the most serious health problems in these spontaneous and low-income settlements. While the direct effects of poor water supply and inadequate sanitation are disease, the indirect effects include lost earnings and lost educational opportunity for young people.

This report attempts to compile current knowledge on how to address water supply and sanitation problems with respect to appropriate standards, investment costs, operation and maintenance. The report is intended for those responsible for planning, constructing and operating systems of water supply and sanitation in low-income housing areas. The aim is to provide them a tool to choose an appropriate system.

Population growth, rapid urbanization and industrialization presented a new dimension to the water supply and sanitation problem in the Asian cities from the mid-20th century. Awareness grew that a large section of the population has long been denied easy access to potable water and proper sanitation. Women and children in these cities spend considerable time and energy in collecting the minimum required quantities of water from sources at large distances from home. Sometimes women spend as much as four to eight hours a day to fetch and carry water. It is also common that some inhabitants of these areas buy drinking water, often of bad quality, from commercial companies selling water from tanker lorries. Generally the price per cubic metre is several times higher than for tap water distributed through the municipal water grid. A study by Water Aid, UK, showed that while in the USA the cost of water is about £0.4 – 0.8 per cubic metre, in Jakarta, Indonesia, people pay traditional water sellers up to £5.2 per cubic meter; and in Lima, Peru, people outside the city's water supply grid pay 20 times as much as those connected. The sanitation problem is even worse. Insanitary disposal of human faeces leads to contamination of groundwater and other sources of water. Besides, flies feeding on the excreta lay more eggs, which leads to fly breeding and spread of infection. Many diseases such as cholera, dysentery, gastroenteritis and worm infections are transmitted from one person to another through the contamination of food, water and ground by excreta.

Mahatma Gandhi said, "Sanitation is more important than independence." Truly, provision of water supply and sanitation in these low-income areas is probably one of the greatest challenges for urban planners, engineers and managers. This ought to be an integral part of the socio-economic development process.

Water has always been vital to human health, safety and socio-economic development. The quality of ancient and modern civilizations is not only measured by the grandeur of the monuments they produced. A civilization, especially in the present time, is judged more by the quality of life it offers to its common people. Water resources management played a crucial role in the development of some of the earliest civilizations in the valleys of Euphrates and Tigris, Nile, Indus and Yellow River. Sanitation was of a high order in Mohenjo-Daro and Harappan civilizations, with underground sewers extending about the towns.

Water supply and sanitation was one of the main considerations in ancient town planning in India (Shukla 1995), and location of water bodies was important in selecting sites for settlement planning. A study of the works on town planning of the southern and northern schools of India (700 AD) reveals that ancient town planning was based on several principles: the first was related to examination of on-site and off-site factors before selecting a site for a settlement, and the second was related to soil testing, such as tests for depth of the water table.

Despite this high level of awareness in the past, the present situation of water supply and sanitation is extremely poor in many developing countries and remains a major obstacle to development. This is amply evident from the following.

A WHO study in 1983 showed:

- Less than 1/3 of the people in developing countries have access to sanitation.
- Urban areas are generally better off than the rural in terms of sanitation.
- Only 59% of the urban population in developing countries has adequate sanitation.
- Only 12% of the rural population in developing countries has adequate sanitation.

A study by WHO in 1994 on Indian slums showed the following unmet needs in Delhi:

· Gap in drinking water supply	27%
· Gap in community toilets	67%
· Gap in community baths	91%
· Inadequacy in sanitation	78%

This means that greater attention, better planning, better operation, maintenance and management for water supply and sanitation are urgently needed to improve life quality in these settlements.

Method

This report was written as a desk study. It is based on the author's experience as an urban planner, researcher working at grassroots level with low-income communities, and as a university lecturer. Recent literature was reviewed and interviews were conducted with experts.

Organisation of the Report

The report has three chapters. Chapters 1 and 2 deal with the nature of the problem, outline the basic parameters, major issues and technical aspects. Chapter 3 presents practical recommendations on water supply and sanitation for low-income communities in Asian cities.

General Considerations

Basic Parameters

It is easy to be overwhelmed by the sheer magnitude of the water supply and sanitation problem of Asian cities. The saving grace is that there are some successes in solving the problem. The underlying factor in all these solutions is the idea of empowerment.

It is increasingly realized that those who are most affected by poor water supplies and insanitary conditions should be given the incentive to initiate, carry out and maintain projects. Educating gains importance. The problem can be effectively tackled once people are made aware of how they themselves can take steps to improve their water supplies and sanitation, and more importantly, how an improvement to these can make a difference to their lives. It is also vital to involve local communities in finding their own solutions.

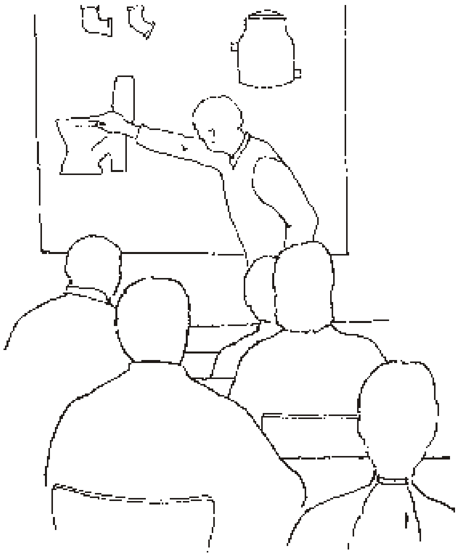

Fig. 1 Heath and hygiene education

Experience shows that typical top-down approaches, where governments or international agencies impose solutions without local agreement and commitment, have failed time and again. A great deal of money is often poured into capital schemes, but insufficient attention is given on the equally important aspects of follow-up and maintenance, training, and education of target groups. It is important to realise that even if a technically sound solution for water supply is provided to a community, “Water is only as clean as the cupped hand of the person who drinks it” (Krishna 1985). This acknowledges the two sides to the problem of water supply and sanitation. On the one hand are the pipes, pumps, treatment stations, and latrines, which may be referred to as the hardware, while on the other hand lies the equally important aspect of health and hygiene education, referred to as the software (Wehrle 1985). The typical attitude of the Asian countries has by and large been to invest in hardware, failing to recognise the importance of the software.

In this report an attempt is made to present both these aspects.

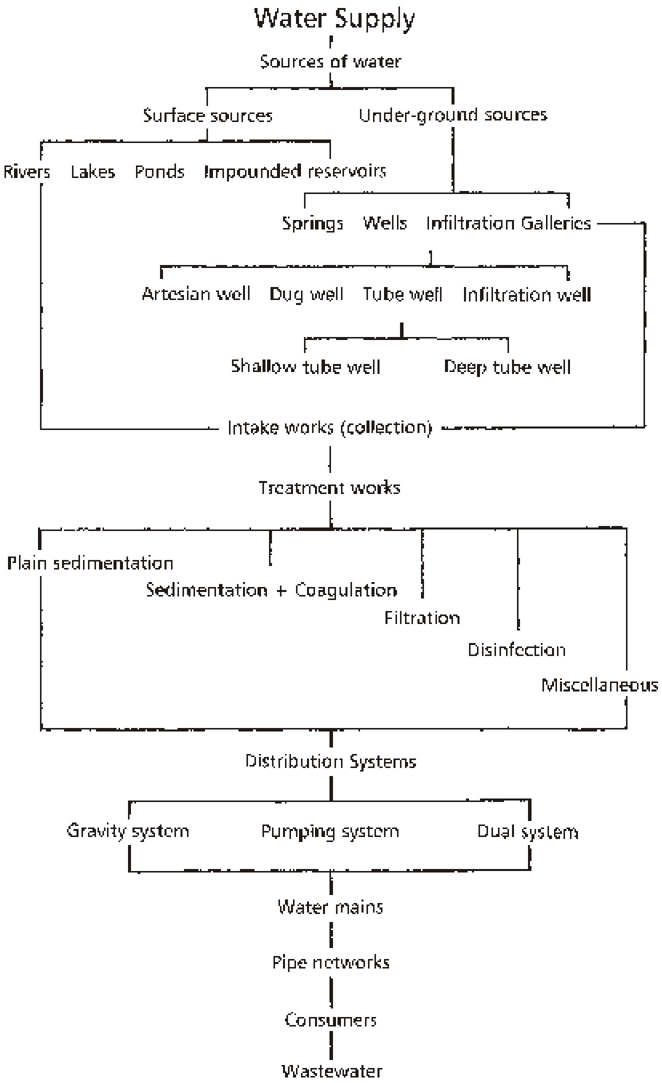

Fig. 2 Flow Diagram of Water Supply Schemes

Water Distribution Solutions

The essentials of water supply, which comprise the hardware side, are shown in the following diagram (Fig. 2).

Quantity and Quality of Water Required

The absolute minimum amount of water needed to maintain the water balance in an adult human is between three to six litres a day. Water is also required for washing, cooking, bathing, etc. The amount of water required also depends upon habits, social status, customs and climatic conditions. Research shows that there are visible benefits to health when people have access to 20 litres of clean water a day for drinking, basic personal hygiene and food preparation. The minimum requirement is 50 litres per person each day including bathing and laundry. Unfortunately in as many as 55 countries the average daily consumption is far below this. In stark contrast the average daily consumption in the USA is 500 litres a day and in the UK it is 200 litres. A breakdown of domestic water consumption in India is shown in Table 1.

Table 1 Domestic Water Consumption

Purpose	*Water consumption (lit/capita/day)*
Drinking	5
Cooking	5
Personal cleaning	10
Cleaning of house & utensils	10
Laundry	30
Flushing water closets	45
Bathing	70
Others	25
Total	200

Source: IS 1172, 1983

Today access to clean water and sanitation is recognised as one of the most basic human needs. Since the mid-1980s various international conventions have reiterated the importance of water as a human right. The UN declared the 1980s as the Water Decade with the mandate to ensure that everyone had access to at least 20 litres of safe water a day. To meet the right to clean water, the following must be addressed:

- How much water should people have a right to?
- How should access to clean water be defined in terms of distance from home?
- What responsibilities should individuals have in securing safe water supplies?

It is also important to note that while water for drinking and cooking should be drinking quality, recycled 'grey' water can be used for cleaning and other purposes, considering the acute water shortage in many Asian cities.

Appropriate Standards and Technology Choice

Choosing appropriate standards and technology, on a case-specific basis, is a decision-making process that should involve all the actors. In the traditional supply-driven approach, the choice was made by professionals. The shift towards demand-responsive approaches means a greater role for the users who pay for the facilities. For a long time the conventional high cost standards for water supply were considered the best solutions, but these were often unaffordable. For instance, the approach during the 1970s and 1980s for water supply and sanitation was largely centrally planned and supply-driven. Experience shows that these projects were not successful. The typical problems of these approaches included that many systems ceased to function over time due to lack of maintenance, and the technology adopted could not be sustained.

The World Bank and bilateral donors are adopting a demand-responsive approach. It is recognised that consulting the stakeholders is necessary for sustainability of a project. A balance is required between three variables: the value of water to the consumer, the user service charge, and the implementation cost. The objectives of water supply projects are being redefined towards lower implementation costs and provision of services which are sustainable. The important questions now are eligibility, choice of technology, cost sharing, and involvement of community for operation and maintenance. The technology chosen should give the community the highest service level that it is willing to pay for, will benefit from, and has the institutional capacity to sustain. In general, technologies offering higher service levels place a higher resource demand on the benefiting community. This implies more capital cost, more operation and maintenance costs and demand for technical skills and materials. For this reason, "It is clear that most of the population in need of improved supplies will have to be provided initially with low-cost solutions, for financial reasons alone" (Arlosoroff 1987). A community may initially opt for tube wells equipped with hand pumps, which are cheap and easy to maintain and repair, even at the local level. These wells may be upgraded incrementally to a potentially higher service level by first replacing the hand pumps with motorized pumps, and then adding a piped distribution system and standpipes. The step-by-step improvement would come as and when the community realises the importance of improved services and is willing to bear the cost.

Sources of Water

The main source of potable water in nature is rainfall, but it is not often used as a direct source of water except on islands, where rainwater is collected, led into cisterns and used as the only fresh water supply. Rainwater runs off into streams or lakes in case of heavy precipitation, forming surface water, or it percolates into the ground through its porous strata until it reaches an impervious layer where it collects forming groundwater. Thus all sources of water can be broadly categorised into surface water and groundwater. Surface water sources are the following:

- Streams
- Lakes
- Ponds
- Rivers
- Impounded reservoirs
- Stored rain water and cisterns

Groundwater sources are the following:

- Springs
- Infiltration galleries
- Porous pipe galleries
- Wells

The quality of water varies a great deal from one source to the other. Surface water might be cloudy due to the presence of suspended impurities; it might also contain bacteria and wastes from households and industry. Groundwater on the other hand might contain a higher concentration of dissolved chemicals. Usually the quality of groundwater is better than surface water as the soil filters out bacteria and non-soluble impurities. Local health authorities and international health organisations such as WHO have established water quality standards that set the concentration levels of different chemical compounds and bacteria, and the physical and chemical properties that can be safely allowed in treated water.

Table 2 gives the standards recommended by the Indian Manual on Water Supply and Treatment for safe water.

Table 2 Characteristics of Safe Water

Physical	
Temperature	10º C – 15.5ºC
Odour	No odour
Colour	10 – 20 in platinum cobalt scale
Turbidity	5 – 10 ppm (parts per million)
Taste	No objectionable taste
Chemical	
Total solids	Up to 500 ppm
Hardness	75 – 115 ppm
Chlorides	Less than 250 ppm
Iron & manganese	Up to 0.3 ppm
pH value	6.5 – 8
Lead	0.1 ppm
Arsenic	0.05 ppm
Sulphate	Up to 250 ppm
Dissolved oxygen	5 – 6 ppm
BOD	Nil
Biological	
E. coli Bacteria	Not more than 1 colony in 100 ml of sample

Extraction of Water

Water is extracted for use from surface water sources or groundwater sources.

Surface Water

Streams: These are created in mountainous regions by runoff. The quality of water is normally good. Streams generally flow in valleys and are often used as a source of water for settlements on the hills nearby.

Lakes: These are natural basins with impervious beds. When the basins fill, lakes are formed. The water quantity depends on factors such as the basin capacity, catchment area, annual rainfall and ground porosity.

Rivers: From ancient times, settlements developed along riverbanks. While they still remain a primary source from which water is extracted, discharge of wastes into rivers is a major cause of concern.

Impounded reservoirs: Some rivers are perennial, while in others the volume of water fluctuates a great deal during the rainy and dry seasons. To cater to the dry periods, an impounded reservoir in the form of a dam or weir is constructed across the river, at a place where the reservoir basin is cup shaped to ensure the greatest depth of water and to submerge as little land as possible.

Stored Water: Rainwater harvesting is an age-old system of storing water. Rainwater is collected from roofs, courtyards, etc. in watertight tanks.

Groundwater

Springs: Sometimes groundwater resurfaces as springs. These can supply a small quantity of water and supplement other water sources. A group of springs together is often used for water supply in small towns.

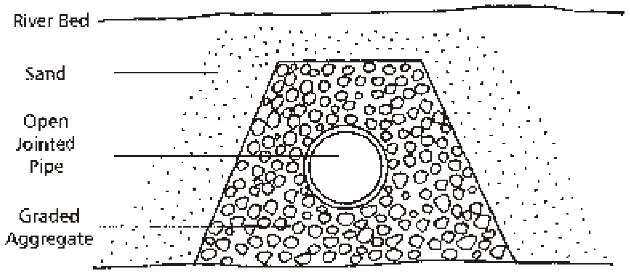

Fig. 3 Infiltration gallery

Infiltration Gallery: The natural flow of groundwater is intercepted by digging a trench or by constructing a tunnel with weep-holes perpendicular to the direction of flow. For maximum yield, these galleries are placed at the full depth of the aquifer with a longitudinal slope ending in a sump well. Infiltration galleries are surrounded on sides and top with gravel or pebble stone to increase their intake capacity.

Porous Pipe Galleries: Groundwater over a large area is cheaply collected by laying porous pipes both in the longitudinal and cross direction of flow of ground water. A slope is given to the pipes ending in a sump well from which water is drawn. The porous pipes are also surrounded by gravel or pebble stone to increase their intake capacity.

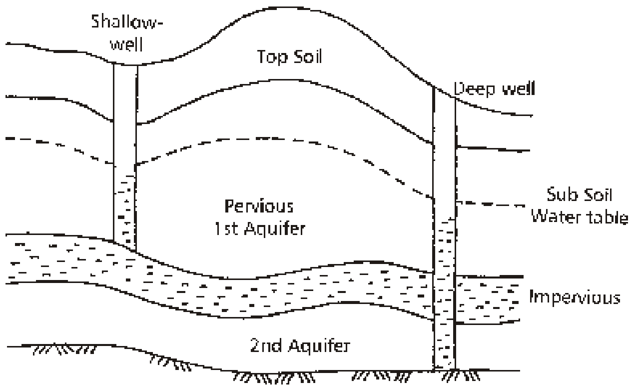

Fig. 4 Shallow and deep well

Wells: Shallow wells are constructed in soft ground, sand or gravel. The diameter is generally 1 – 4 metres, and the depth may be up to 20 metres depending on the water table. These are used for small discharge of about 4 – 5 litres per second in small towns and rural areas. Tube-wells have a greater yield, up to 200 litres per second. The depth of tube-wells varies from 50 – 500 metres.

Conveyance of Water

Water from the source is conveyed to the treatment plant by one of the following methods:

- Open channels
- Aqueducts
- Pipes

Open channels are cheap; they are excavated on the surface of the ground and are lined with concrete or masonry to minimise seepage.

Advantage	*Disadvantage*
Cheap	Used only to carry water under gravity.
Use of local materials	Loss due to evaporation. Unsuitable in high density areas due to possibility of contamination.

Aqueducts are closed conduits used to carry water under gravity.

Advantage	*Disadvantage*
Cheap	No scope of incremental addition as in pipelines
Use of local materials	Affects natural drainage
No corrosion, longer life	Used only to carry water under gravity

Pipelines are circular conduits used for conveyance of water under gravity or under pressure. Pipes are made of different materials. Table 3 shows the selection criteria for pipes of different materials.

Table 3 Selection Criteria of Pipes of Different Materials

Sl. No.	*Pipe material*	*Properties*	*Remarks*
1	Cast iron	High strength, good resistance to corrosion.	Used where soil type and water are of aggressive nature, useful as pressure mains.
2	Steel	Light weight, corrosion resistant, easily affected by acidic or alkaline water.	Useful for high diameter (0.9–3 m) and high water pressure head (70 m +). Suitable in undulating and land subsidence prone areas.
3	Pre-stressed concrete	Resists more pressure than ordinary RCC pipes.	Useful where pressure head is 50–200 m and steel is uneconomical.
4	Concrete pipes (RCC)	Resists moderate pressure. Less frictional loss. Low maintenance and long life, heavy and difficult to repair.	Useful up to pressure head of 30 m.
5	Asbestos cement	Light weight, good resistance to acidic and alkaline water. Brittle, short life.	Useful in low-pressure areas.
6	PVC/plastic	Flexible, easy to join, resistant to corrosion, lightweight, low cost, PVC is resistant to acids, alkalis, salts and chemicals.	Useful in low-income areas, hilly areas, undulating terrains.

Treatment

The main objectives of water treatment are as follows:

- To remove odour and objectionable colour.
- To remove dissolved gases, dissolved and suspended inorganic impurities and harmful minerals.
- To remove suspended and dissolved organic impurities.
- To remove harmful bacteria.
- To make water safe and attractive for drinking.

The treatment plant is generally located as near the town as possible. If the town is very large and water is drawn from several sources, the town is divided into zones and each zone has its treatment plant. When a town is located on the banks of a river, the treatment plant is located near the source to minimize the length of rising mains and also to avoid pumping in muddy water which causes pipe wear.

Treatment is done to purify water from the following impurities:

- Physical impurities.
- Chemical impurities.
- Bacteriological impurities.

The layout of a typical treatment plant is as follows:

1 Intake work
2 Aerator
3 Plain sedimentation
4 Sedimentation with coagulation
5 Filtration
6 Disinfection
7 Storage
8 Pumping plant
9 Distribution system.

Intake works: Water is drawn here from source and screened to eliminate floating matter.

Aerators: Water is exposed to atmospheric air to eliminate gases such as carbon dioxide, hydrogen sulphide, and minerals such as iron. It also improves the taste and removes odours.

Plain sedimentation tank: Removes impurities like silt and clay.

Sedimentation with coagulation: Removes fine suspended particles and some bacteria.

Filtration: Removes very fine particles and colloidal matter, which have escaped the previous stages.

Disinfection: Kills bacteria through chemical treatment.

Storage: Stores pure water.

Pumping plant: Pumps pure water to overhead reservoirs.

Distribution system: Distributes pure water to consumers by pipes.

The degree and nature of treatment depends on the source of water and nature of impurities.

Distribution

This is the last stage of a water supply scheme. A good distribution system satisfies the following:

- The capacity of the system is adequate to meet the peak flow.
- Water quality does not deteriorate in distribution pipes.
- There is sufficient water head at the consumer's tap.
- Maintenance of the system is easy and cheap.
- Elevation of the reservoir allows minimum residual pressure.
- There is provision for fire fighting.
- During repairs or breakdown to a pipeline, water supply is routed through alternative pipelines.
- Distribution pipes are at least one metre away from or above sewer lines.
- Leakage in distribution system is minimal.

Systems of Distribution

The systems of distribution are as follows:

- Gravity system – reliable and economical.
- Direct pumping system – costly, supply stops if power fails, fluctuation in water pressure.
- Combined (gravity + pumping) system – pumping at convenient schedule is possible, uniform pressure can be maintained; water quality improves due to long holding in reservoirs (sedimentation).

Layout of Distribution Systems

- Dead-end or tree system.
- Gridiron system.
- Ring or circular system.
- Radial system.

Dead-end system: Works well in old towns and cities having no definite pattern for roads. It is a relatively cheap system. Determination of discharges and pressures is also easier since it has fewer valves. The disadvantage is that water can become stagnant in the pipes, due to many dead ends.

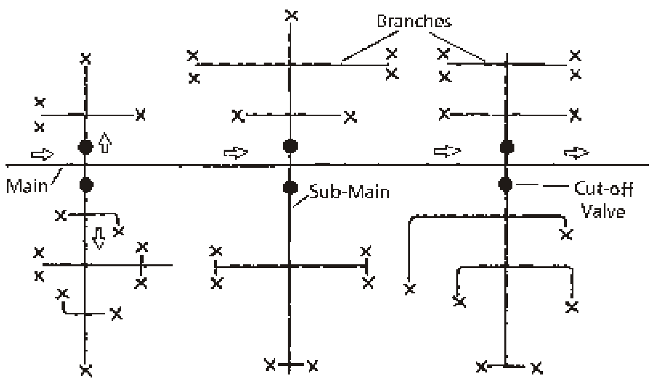

Fig. 5 Dead-end system

Gridiron system: Works well in planned towns and cities having a rectangular layout. The system eliminates dead ends and thus achieves better water circulation. Also, if one segment of the system breaks down, water can still be available from another direction.

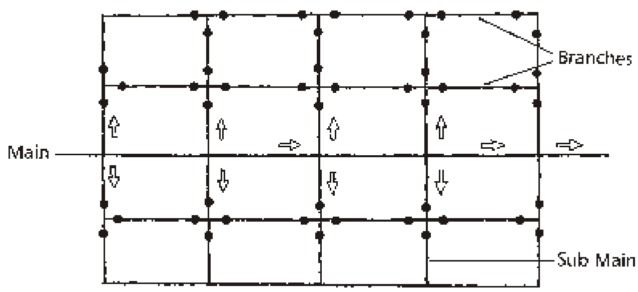

Fig. 6 Gridiron system

Ring or circular system: The supply main is laid all along the peripheral roads with sub-mains branching out from the mains. The advantage of this system is that any point can be served from at least two directions.

Radial system: Works well in large towns. The area to be served is divided into several zones. Water is pumped to the distribution reservoir kept centrally in each zone. Sup-

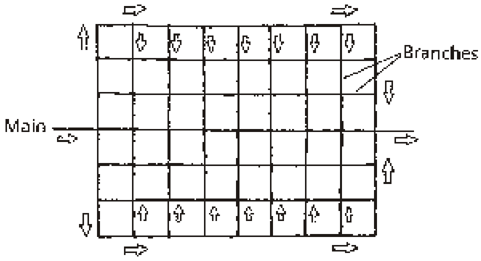

Fig. 7
Ring or circular system

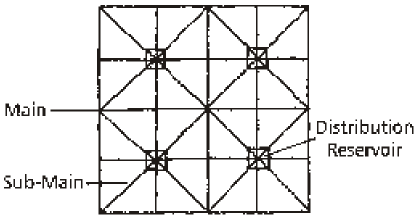

Fig. 8
Radial system

ply pipes are laid in a radial pattern, ending towards the periphery of each zone. The system has several advantages. Zoning of the area to be served can be based on criteria such as population density, topography and socio-economic characteristics. Each zone with an average elevation difference of 15 – 25 metres is catered by a separate system. The layout ensures that the difference in pressure does not exceed 3 – 5 metres within a zone.

Cost for Investment

Though water is a gift of nature, it is a scarce resource. To bring safe water to people requires huge investments, which someone has to pay for. Some theorists believe that like other scarce resources, water can be managed sustainably only through a market pricing system, to ensure the most efficient use of water and discourage wastage. Although in many countries there is a flat-rate annual charge for water, water metering, whereby households pay for what they use, gives a financial incentive to conserve water.

Capital costs of community water supply projects depend on the level of service provided and on the local conditions. The relative cost of different groundwater based technologies varies greatly: US$ 10 – 30 per capita for wells equipped with hand pumps, US$ 30 – 60 per capita for motorized pumps with standpipes, and US$ 60 – 110 per capita for individual taps on the plot. In global terms this implied an estimated cost of US$ 75 – 100,000 million to meet water supply needs by 2001, depending on the choice of technology (Arlosoroff 1987).

Current thinking is therefore shifting from a supply-oriented approach to a demand-oriented one, to what people want and are prepared to pay for, and not what others think they should have. This redefines the “basic human right to water” to “water at an affordable price.” Another school of thought has argued that this could be fatal for the poorest: those who are unable to pay do not get safe water. This raises the important question of “some for all” or “all for some.” Though the primary responsibility of ensuring water supply lies with the state, realistically it is beyond the means of most Asian governments. Due to huge debt burdens, resources are not available to invest in safeguarding people’s right to safe water. Without government funds or international aid, water provision will increasingly have to come from commercial companies within the private sector. But the private sector expects returns from their investments, which could well mean that the poorest would not be able to pay for water supply. It is a fact that solving water supply and sanitation problems depends more on political will than technological solutions. After the UN declared the International Water Supply and Sanitation Decade in 1981, about US$ 10 billion per year was invested in this sector. US$ 50 billion per year were needed to make adequate progress by 2001. However, though a lot of money is spent on capital schemes all over the world, insufficient attention is paid to the necessary follow up.

Use and Maintenance

Success or failure of a system primarily depends on whether the system is sustainable, and for sustainability the maintenance must be done by the community that uses it. This can only come when the community participates at all stages of the project. It may seem that piped water to individual households or community stand-posts and piped sewerage are the best solutions, but they have very low success rates in low-income areas. Such schemes are expensive, and water shortage also makes them unrealistic. Even if the systems are installed with the help of grants, the fixtures and fittings which the household has to buy are mostly beyond their paying capacities. This leads to the common phenomenon of dry taps, or an expensive sewerage system with few connections. When the community is not a party in the decision-making and implementation process, the systems break down and lie unattended, often due to lack of accountability and maintenance. A sewerage system for instance requires a lot of water for efficient running. About 100 litres per capita per day (lpcd) is considered the minimum requirement. This can be a problem in low-income areas with water scarcity and intermittent water supply.

Regardless of the technology chosen, people will take part in operation and maintenance only when they “value” the system. It must therefore provide an appreciable improvement over existing sources and practices, offer greater convenience and better water quality; it should be well designed (such as provided with enough hand-pumps) to reduce queuing and hauling time, and above all should have community inputs in needs assessment, technology choice, design, and execution.

Environmental Impact

Every living thing on earth depends on water. Anything that adversely affects the quality of water threatens the entire ecosystem, but we choose to ignore this fact.

Since the Industrial Revolution man has been steadily dumping wastes into natural water courses, polluting the lakes, streams, rivers and seas. Industrial, agricultural and human wastes pollute the rivers and streams and jeopardise the habitat of animals and plants. This also takes away the livelihood of people dependent on the aquatic plants and animals. But pollution does not only affect surface water, groundwater is also at risk. There are instances in several Asian cities where traces of arsenic above the acceptable limit are found in groundwater. This can cause permanent harm to the people using water from these sources.

Pollution is not the only concern. Diversion of river courses and over-extraction of water can have devastating results. The Narmada Dam in India has raised many such issues. When water is diverted for gainful utilisation up-stream, downstream areas that support wetlands suffer a loss of bio-diversity and become less effective in filtering pollution.

Water should not be taken for granted; 97% of the planet's water is in the oceans. Only 3% is in the form of either ground or surface water. Many of these freshwater supplies are being depleted at rapid rates, as the rate of extraction is higher than the rate of recharge. In southern Delaware, USA, this has led to saltwater intrusion, where fresh groundwater is being contaminated by saltwater. It is our responsibility to conserve the use of water and minimise its waste.

Water Consumption and Water Supply Options

There are several options available for community water supply. It has to be decided which is the best for a community on a case to case basis. These choices could be summarized according to the level of water consumption: low, medium and high.

Water consumption by a community is directly proportional to its socio-economic standard, particularly its level of education, and to the development of the country in general. It is unwise to copy standards of water consumption from developed countries. The average daily water consumption can be as low as 10 – 40 litres per capita per day in some low-income settlements of developing countries to as high as 950 litres per capita per day in some of the affluent areas of the USA.

Low consumption (10 – 40 lpcd)
Many low-income settlements of Asian cities are deprived of any formal water supply system. People traditionally collected rainwater, or fetched water from distant water bodies or springs. The water quality is often poor. There is little cost for operation and maintenance, only purchase and upkeep of collecting vessels/buckets. Indirect cost in terms of time spent is very high. Moreover widespread disease results from consumption of unprotected water, resulting in money spent on treatment.

Community hand pumps are the prime water supply source in other cases. These hand pumps draw groundwater and the quality is good. The amount spent on operation and maintenance is low; most repairs to hand pumps can be carried out by semi-trained local persons.

Standpipes are another option for low-income settlements. If the source is groundwater, the quality is usually good and does not require treatment. However, standpipes also draw from surface water sources and such water may require treatment. Water distribution is either by gravity or using pumps run on some fuel. Capital cost and operation and maintenance costs are high. Trained personnel are required to run the system and to carry out repairs.

Medium consumption (50 – 100 lpcd)
In this category the option is the yard tap. The source of water can be groundwater, surface water or springs. Water drawn from ground or from springs is usually of good quality; water drawn from surface sources may require treatment. Distribution either uses gravity flow or pumps run on fuel. Capital cost and operation and maintenance costs are high. Trained personnel are required to carry out repairs.

High consumption (100 – 150 lpcd)
This category includes individual house connections. Source of water is groundwater, surface water or springs. Capital cost and operation and maintenance costs are high. This could be the most desired water supply solution, but it requires mobilisation of high resources.

Sanitation Solutions

Scope
Having seen the most important aspects and parameters for water supply solutions, the same is now done for sanitation.

Together with safe water, adequate sanitation is now viewed as a fundamental human right. Adequate sanitation is critical in controlling diseases and improving the quality of life in communities. However, it is very difficult to define and quantify what constitutes adequate sanitation. Like the basic water requirement, adequacy depends on socio-cultural factors, traditions, and practices, and needs to be judged with respect to people's priorities. At the basic level, adequate sanitation should ensure safe disposal of human waste and provide adequate water for personal cleaning, to prevent food contamination and health hazards. Also, an integral part of any sanitation programme should include health education and hygiene promotion.

Sanitation practices broadly fall under two categories: "flush and discharge" and "drop and store." The former is largely seen as superior, but in many Asian cities faced with acute shortage of funds and scarcity of water, the flush and discharge system seems unrealistic and unaffordable.

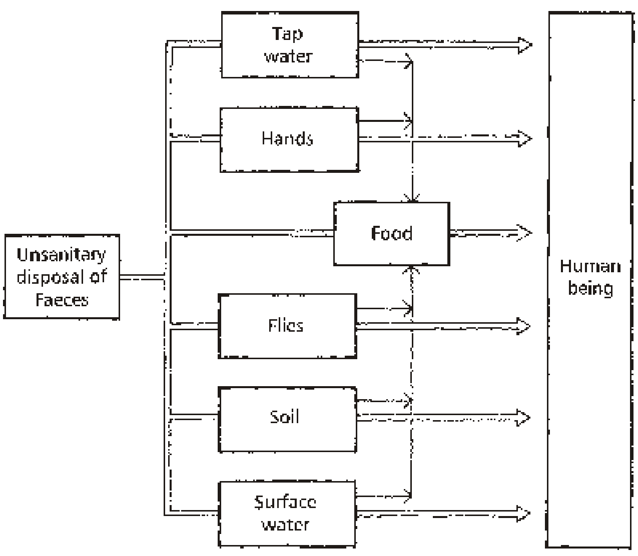

Fig. 9 Faecal-Oral Transmission of Diseases

Health aspects

Poor sanitation leads to diseases and even death, especially in low-income high-density settlements; and in economic terms, it impoverishes the whole community. Excreta disposal is listed by WHO as an important part of environmental sanitation together with provision of adequate and safe drinking water. Human excreta contain disease causing pathogens. Insanitary disposal of human excreta leads to contamination of groundwater and other sources of water supply, promotes breeding of flies and they in turn spread infection. Contamination is also through hands, clothes, utensils, and the fields where crops and vegetables are grown. People are exposed to pathogens and parasites directly or through food as shown in Fig. 8.

Quantity of Sewage Produced in a Community

Where the water supply ends begins wastewater. As soon as the water is used, it becomes wastewater containing human excreta and other kinds of impurities, and it is objectionable from health point of view. There are three main types of sewage: domestic, industrial and storm sewage. The first two are together known as sanitary sewage. In this report we are mainly concentrating on the domestic sewage of communities, which by definition comprises wastes from urinals and latrines, plus sullage, which is the liquid waste from kitchens and bathrooms.

Theoretically, the net quantity of sewage produced is equal to the accounted quantity of water supplied from the waterworks, plus additions due to factors like unaccounted water use from alternative sources, and additions due to infiltration of groundwater through faulty joints of sewer pipes, minus water loss in the supply system. Usually the net value of sewage produced varies between 70 – 130% of the accounted water supplied from waterworks. In India this value is taken as equal to 80%.

Studies also point out that the quantity of human faeces produced varies from one place to the other as shown below:

- Asia 200 – 400 gms per person, per day.
- Europe & America 100 – 150 gms per person, per day.

Appropriate Standards

The basic criteria for a satisfactory excreta disposal system that will be socially acceptable and effective in use are the following:

- There should be no contact by humans with waste materials within the system.
- There should be no access to the waste for insects and animals.
- It should not generate foul odour or insect nuisance.
- It should not contaminate groundwater that may pollute wells and springs.
- It should not contaminate surface water.
- It should not contaminate surface soil.
- The system should be simple to construct and easy to maintain.

In many Asian cities installations often fall short of these objectives. Resource constraint is one major reason for this, but equally important is a general lack of understanding by the community of the health hazards.

For selecting the appropriate standards, the community should be shown all the available options, and with proper counseling, they should be left to choose the best solution for themselves. The prevailing approaches to sanitation services can be categorized into three groups – conventional, informal, and low-cost. A strengths-weaknesses-opportunities-threats (SWOT) analysis of these approaches, which can help a community to select appropriate standards, is given in Table 4. The solution could be a mix of characteristics incorporating in varying degrees the strengths, weaknesses, opportunities and threats of these approaches.

Financing and Cost Recovery

Past experience in Asian cities indicate that traditionally sanitation projects were planned on a grand scale with the assumption that everyone would benefit from them, but the results were a disaster. The economically better off and those with political backing benefited the most; the poorest fell outside most of these projects. Studies also indicate that projects sometimes led to a drop in living standards. Many projects specially targeted for the poor were left without the resources to maintain installations.

Case studies indicate that many poor communities are unable to solve their sanitation problems due to:

- ***Psychological barrier*** – It is a common notion that provision of infrastructure for sanitation is the sole responsibility of the government.

Table 4 *SWOT Analysis of Different Sanitation Approaches*

Approach	*Strengths*	*Weaknesses*	*Opportunities*	*Threats*
Conventional Sanitation	Technically sound, citywide coverage, low health hazards.	High cost, not demand-responsive, poor cost recovery, difficult operation and maintenance, lack of incentive and competition.	Regional overview, consideration of ecological and natural constraints, integration with longterm master plans.	Too expensive for households, high cost installations allow few individual connections, waste of scarce resources.
Informal Sanitation	Adapted to priorities, demand responsive, affordable, self-managed and self-maintained.	Technically poor, piecemeal solutions, limited impact on environment, high health hazards.	Wide coverage of low-income groups.	Isolated solutions, no integration with municipal systems.
Low-cost Sanitation	Moderate cost, limited people's participation, better utilization of available resources.	Isolated solutions, poorest left out, moderate health hazards.	Mobilisation of community groups and community resources, incremental improvement, gradual integration into municipal network.	Supply-driven approach, lacks 'ownership' of projects, poor cost recovery.

- ***Technological barrier*** – Communities think they do not have the technical expertise to construct a sewerage system.
- ***Sociological barrier*** – Communities are not well organized to take collective action.
- ***Economic barrier*** – Communities cannot afford a conventional sewerage system.

Communities generally view improved sanitation as a "public" good, and believe that investment costs for sanitation projects should be paid by the government from taxes. The problem in the Asian countries is further compounded by the huge debts of their governments. Huge sums of money were loaned to these countries by international banks and aid agencies for new sanitation projects, in the hope that the projects would pay for themselves. This assumption was both optimistic and unrealistic. Investment in conventional sewerage is about US$ 1,500 per household, and it generally proves to be unaffordable for poor communities in Asian cities. However, global experience indicates that a demand-responsive approach, attempting to address the needs of all stakeholders, can reduce the cost significantly. One of the best examples of this is the Orangi Pilot Project in Karachi, Pakistan. Cost reductions through simplified design and construction, and elimination of middlemen, meant that a household with a 100 square yard plot could have a toilet connected to an underground sewer line at a cost of US$ 33.

Investment in Asian cities at present has to come from more than one source – the individual or household and an external source/s such as government or donor agency. Coordinating these sources of finance is challenging. The external funds are required to subsidise access to sanitation services for social, public health and environmental reasons. Sanitation facilities are often linked to a central service; and the external funds would finance the trunk facilities to the plot. The household investment would include toilets, fixtures and connections to the trunk facility.

Subsidies to households are also necessary from the perspective of environmental and public health, often outweighing the individual's priorities and perceptions. Thus even if individuals feel that their component of cost for sanitation is too high, subsidies can reduce these costs to an acceptable level. This approach is endorsed by those who argue that basic sanitation is a prerequisite for decent living and that the poorest should not be denied access to it.

Operation and Maintenance

The success of a sanitation project depends on its sustainability. Many projects which were technically sound failed through lack of maintenance. Nobody in the community felt accountable for the upkeep and maintenance of such centrally planned projects. People often rejected the projects for the simple reason that they were culturally not acceptable, socially not justifiable and economically not viable. The supply-driven approach often overlooked these important aspects. The pressure to implement projects on schedule, particularly when donor agencies were involved, was the primary reason for these failures.

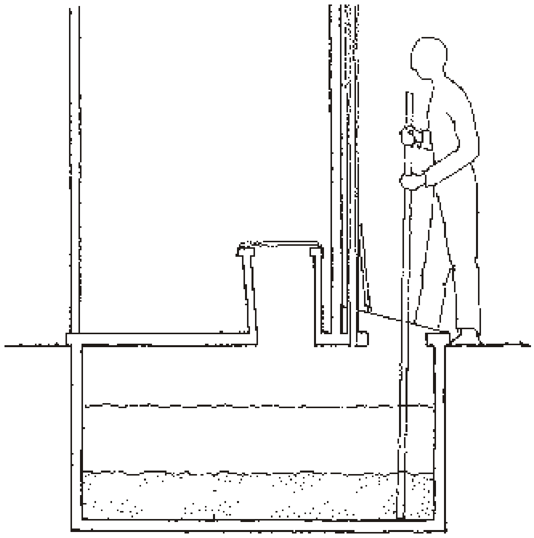

Fig. 10 People's oarticipation in operation and management. Measuring sludge depth

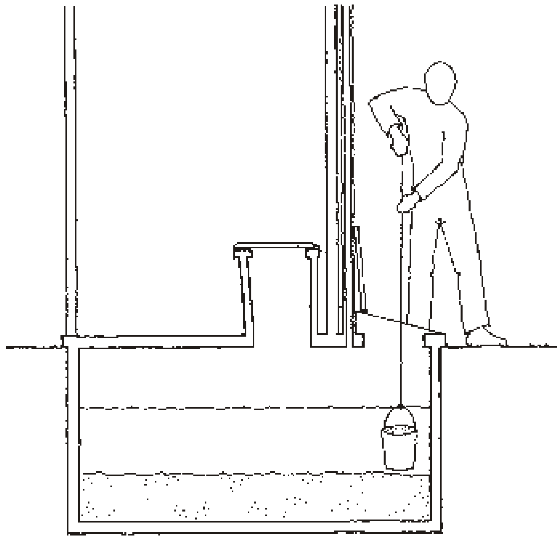

Fig. 11 People's participation in operation and management. De sludging

The assumption that people would change their habits overnight and resort to using an "advanced" sanitation system is also unrealistic. Considerable time and effort is necessary to convince the community of the advantages of improved sanitation – through education, demonstration projects and counselling. The community will use and maintain a project only when it accepts its value.

The outcome of low-cost sanitation strategies has been generally positive. In these projects, technical solutions have been evolved which meet the needs and the ability to pay of low-income households. They have also shown better use of public resources by targeting investments to people's actual demands. User communities have been involved in planning and implementation of sanitation improvements and the subsequent operation and maintenance. However, applying the concept of user participation to government directed projects is not easy. Community mobilization is a difficult and time consuming task, requiring special skills. Thus people's involvement is often limited to just a few meetings. As a result, the communities never take "ownership" of the project, and the projects cease to function due to lack of proper operation and maintenance.

Even if it is understood that good operation and maintenance is essential for the long-term sustainability of a sanitation project, it is difficult to identify the best method. Studies have shown that it may not be possible to get householders to accept the responsibility, especially where sewers are shared by all households in a block. Alternative models are being developed for such cases; for instance, in parts of rural Brazil, a community chooses a representative from among themselves, who is assigned the responsibility for operation and maintenance of the sewers and treatment plants (local oxidation pond). The tasks might also be contracted out to local firms by the states, as in parts of Recife in northeast Brazil. These local firms work in small teams of technical personnel and labourers, and the residents report any problems to them.

The best solution for operation and maintenance of sanitation projects could very well be case specific, and a uniform model may prove to be unnecessary.

Environmental Impact

It has already been pointed out that human excreta are a possible source of infection. The infection route is generally through the soil or groundwater, surface water, and insects like flies. Since a vast majority of the population in Asian cities lack adequate sanitation, open defecation in fields, bushes, and even on roadsides is common and creates an insanitary local environment. Public toilets, when provided, have their own nuisance value as they often are foul-smelling, and infested by insects, resulting in the communities returning to their old practice. Even when sanitation solutions are acceptable to the community, great care is necessary in siting the possible sources of pollution, like pit latrines and soak-pits of septic tanks.

The soil on the surface of ground gets polluted from contact with faeces, but infection travels much further when picked up by animals, flies and insects, or when surface water carries it. The spread of contaminants, either bacterial or chemical, in a pit latrine which has penetrated the groundwater, usually travels in a lateral direction transported by groundwater in the direction of its flow. The vertical penetration is usually not more than 3 metres. Thus arbitrarily located toilets can heavily pollute sources of water supply. Studies point out that bacteria can travel up to 3 metres and chemical substances can travel up to 30 metres from the point of entry to the ground water.

Many Asian cities are also subject to severe environmental degradation due to indiscriminate sewage discharge into water bodies, polluting the water and its aquatic life. People are exposed to infection when using these water bodies for bathing, laundry, drinking or eating fish and vegetables grown there. Seepage from sewers, septic tanks, and pit latrines pollutes the groundwater, and people are exposed when using such groundwater sources for domestic purposes.

Sanitation Technology

Excreta disposal systems can be classified as follows:

- On-plot
- Off-plot
- Community
- Ecological.

The essential characteristics of these technologies are now discussed in brief.

On-plot

The safe disposal of excreta takes place on or near the housing plot. Pit latrines and septic tanks fall under this category. Different types of pit latrines include dry pit and pour-flush-twin-pit.

Pit latrines: In its simplest form these consist of a hole in the ground about 1.5 metres deep, covered with logs or a concrete slab with an opening. The walls of the pit are lined and a roof is often provided to the latrine for privacy. At the rudimentary stage of design these used to be foul smelling and were infested with flies and cockroaches. Later designs suggested a seat cover, which could be

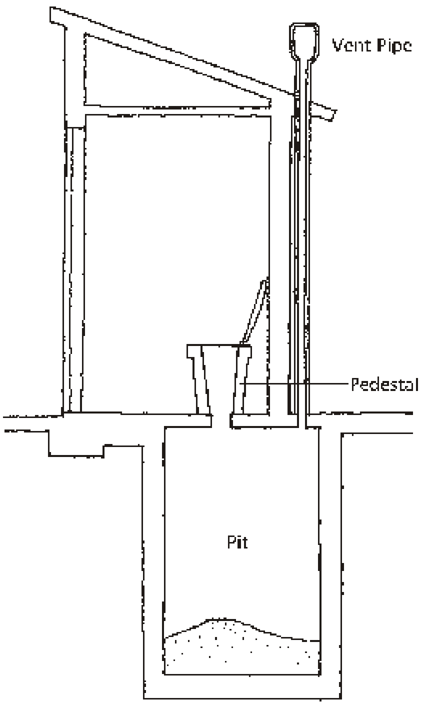

Fig 12 Ventilated improved pit latrin

closed when the pit was not in use. These are not used in conjunction with flush toilets and very little liquid is allowed into the pit. Excreta and anal cleansing materials get deposited in the pit. The liquid seeps into the surrounding ground while the excreta undergo decomposition into humus-like solids, liquids and gases. Due to its long retention period, the pathogens in human excreta die. Usually the pit-life varies between 3 – 10 years. When one pit gets filled up, it is covered with an earth cover of 0.5 metre, and another pit is dug. These are particularly used in areas with a low water table and where population density is low, especially in rural and peri-urban areas.

Pour-flush, twin-pit latrines: The life span of pit latrines is severely lowered if water enters the pit. Considering the practice of using water for anal cleansing in many Asian cities, the pour-flush, twin-pit type latrine may be more suitable. It generally has the latrine and the pit in different locations connected by a sewer pipe. It consists of a squatting pan, a trap with a water seal (usually 20 mm) to prevent smells and to check the nuisance of flies and mosquitoes, and two leaching pits. The liquid and gaseous contents of excreta are allowed to leach in the ground through the holes in the pit lining, while the solids are retained. One pit is used at a time, and when it fills up, excreta are led into the second pit. The contents of the filled pit are emptied after a lay off of about one and a half years during which time the pathogens are inactivated and the organic matter is decomposed. The two pits are used alternately in this manner.

Septic tank & Aqua-privy: This system was first developed in Zambia (then Northern Rhodesia) in the 1960s. Following its success there, it was then tested in Australia and Nigeria in the mid 1960s, USA in the mid 1970s, and parts of Latin America and South Africa in the 1980s. In this system excreta are transported through sewer pipes from water closets and are retained and partially treated in the septic tank. These tanks hold a large volume and are capable of accepting sullage, though in many Asian cities sullage is

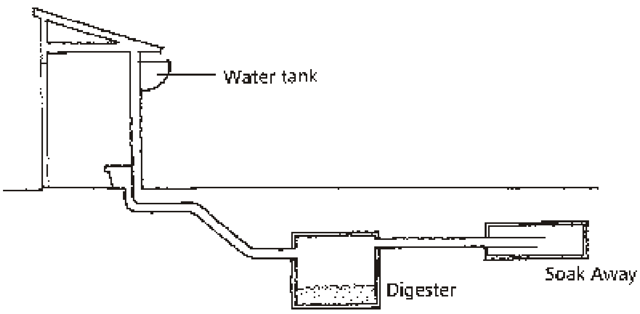

Fig. 13 Aqua-privy

directly led into storm water drains. Where water is scarce, the aqua privy is an alternative. A small septic tank is placed under the latrine. An aqua-privy allows excreta to fall directly from a squatting plate into a septic tank, without passing through a water seal. The solids in a septic tank settle down due to gravity and undergo anaerobic decomposition producing water, gas, sludge and scum, and a par-

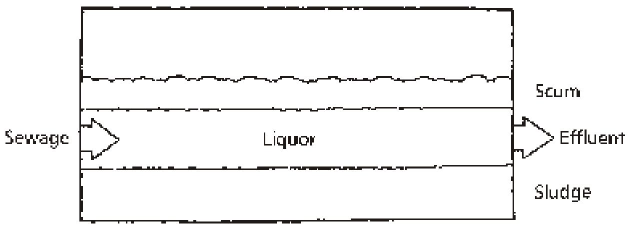

Fig. 14 Separation of solids in a septitank

tially treated effluent is discharged into a soak-pit. The second stage of treatment of effluent is its biological breakdown and takes place in the soak-pit.

These systems are not low-cost solutions and may not be affordable to poor communities.

Off-plot

Excreta are collected from individual houses and carried away from the plot to be disposed of. Sewerage system is the most important option in this category; this system is also referred to as the water-carriage system. Sewerage system can be the conventional sewerage system and shallow sewerage system.

Conventional sewerage system: This system requires a large volume of water for transporting sewage, which includes excreta and sullage. Since it is mainly a carriage system, it should lead the excreta to a sewage treatment facility. After suitable treatment, the effluent is safe to be disposed of into water bodies or to an oxidation pond (if cheap land is available). Some studies on Asian cities have indicated that a sewerage system is cost effective only when the population density is more than 350 persons per hectare. Investment in conventional sewerage is in the range of US$ 1,500 per household and it generally proves to be unaffordable for poor communities in Asian cities.

Shallow sewerage system: This system was developed to

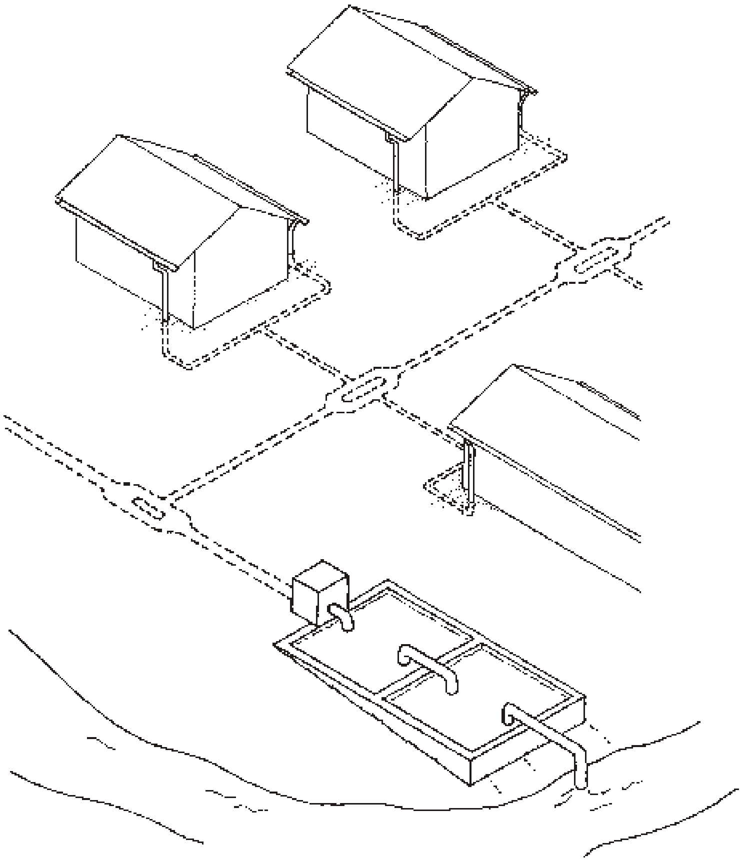

Fig. 15 Shallow sewer system

find a cheaper alternative to the conventional sewerage system. It has now been tried by several international aid agencies, including the World Bank. The shallow sewers were especially designed for high-density, low-rise, low-income areas, such as slums and squatter settlements. This system can accept both sullage and sewage and has most of the advantages of the conventional sewerage system. It basically comprises a network of narrow diameter pipes laid at flat gradient, located in areas where there is no heavy traffic load. The design is based on “high frequency usage” concept, and so it does not require large volumes of flush water for operation.

Community

Keeping in view the huge investment costs required for providing individual latrines, governments adopting the supply-driven concept were in favour of providing community latrines to low-income communities in the Asian cities.

In India for instance, under the ***slum improvement*** and ***slum up-grading*** projects, the standards indicated one toilet seat for 20 – 50 persons, or 4 – 10 households respectively. In practice however, this was seldom met. The community latrines had other intrinsic problems as well. They lacked the "ownership" of the communities. As a result, the operation and maintenance of such latrines was extremely poor. Most of these community latrines were abandoned in no time, with people returning to open defecation.

Pay and use toilets: To overcome the problem of operation and maintenance of community toilets, the pay and use type community toilets were conceived. They have been quite successful in India and China. The "Sulabh" toilets in India have gained considerable popularity not only in low-income communities but also in various public places like bus and railway stations. In this system, private persons are assigned the responsibility of operation and maintenance of these toilets. They in turn charge the users a small amount of money. The money collected is used to pay for the caretaker and the sweepers and to purchase cleaning supplies.

Ecological

Ecological sanitation, also known as ecosan, was developed on the principle of recycling. It keeps the eco-cycle in the sanitation process closed. It is a low-energy process using natural processes.

A conventional sanitation process disposes of the nutrients thus breaking the natural cycle. According to the ecosan principle, excreta is not viewed as a waste product. It recycles sanitised human urine and faeces by returning them to soil. The concept is borrowed from old traditions and practices, and in China for instance, ecological sanitation has been used for thousands of years.

This principle should not be viewed as an inferior low-cost sanitation approach, and it could be applied across a range of socio-economic conditions (Esrey et al. 1998). In this system it is essential to sanitise human excreta before it can be recovered and reused. Urine is largely sterile and has most of the fertilizer value of human excreta. The ecosan concept dwells upon three ways to recover the resources in urine: diversion (urine is diverted away from faeces), separation (urine and faeces are collected together and later separated), and combined (urine and faeces are collected together and processed). Since human faeces is responsible for the spread of diseases, it is important to sanitize it, either by dehydration (when faeces is not mixed with urine or water) or by decomposition.

It is important to weigh the pros and cons of the system and its acceptability by a community, since the system requires some handling of the products at the household level. Another cause of concern is whether these toilets would function properly where water cleaning after defecation is a traditional practice. Adding additional water might disrupt dehydration.

Recommendations

General Guidelines

The following guidelines are designed to offer a broad perspective to water supply and sanitation projects:

- Consult with and encourage community participation, especially by women, to formulate objectives and identify key health and hygiene issues related to water supply and sanitation.
- Formulate clear objectives based on people's priorities and demands.
- Phase the project according to the needs, addressing immediate needs first and gradually attaining minimum standards with respect to water supply and sanitation.
- Coordinate and monitor projects so that priorities are met, gaps are avoided and necessary adjustments are done.
- Involve community representatives and a gender-balanced cross-section of the community in all aspects of decision-making, design, layout, implementation, and operation and maintenance of projects.
- Consider local conditions: customs and practices, available materials and resources – while planning and implementing projects.
- Be sensitive to the needs of the different social groups: ethnic groups, castes and religion, at household and community levels.
- Plan for immediate betterment of living conditions with a long-term incremental perspective.

Needs Assessment Based on Sustainability – A Key Issue

The 1980s promoted the concept of "sustainability." To make water supply and sanitation sustainable for low-income communities, a better appreciation of the complex interrelationships between environmental, social and economic issues is vital. Water supply and sanitation projects ought to reflect these interrelationships with a view to provide sustainable and not piece-meal solutions.

Before undertaking any project, a multidisciplinary team should be constituted with representatives of all stakeholders, including the project promoters and funders, government and international aid agencies (where applicable), local extension workers, members of the community and the end users. The team should commission or conduct a baseline KAP (knowledge, attitudes and practices) study to assess the existing water and sanitation situation in a community. A questionnaire survey should be conducted taking a representative sample of the community. The survey should also include respondents from the local government and health authorities. The report should include the following information.

General

- What is the size of population affected by poor water supply and sanitation?

- What water and sanitation related diseases do the community face? (Time-series data for last 3 – 5 years desirable).
- What is the status of community organisations and who are the community representatives?
- Is the community gainfully employed? (Details of employment/unemployment).
- What is the age-sex ratio of the community?
- What is the literacy level of the community?

Water supply

- What is the current source of water?
- How much water per capita, per day, is currently available?
- What are the hours of water supply? (In case it is provided).
- Is the amount of water available adequate?
- Where and at what distance are the water collection points?
- How reliable is the present source of water supply and how long would it last?
- What kinds of storage containers do people use?
- Is the water source contaminated, or does it run a risk of contamination?
- What kind of water treatment is necessary?
- Are there convenient alternative sources of water supply available?
- What are the key hygiene issues related to water supply?
- How aware is the community of hygiene issues?
- How much is the community prepared to invest for quality water supply?

Sanitation

- What are the current defecation practices?
- What kinds of facilities for defecation exist in the community?
- If some facilities exist, are they sufficient in number? Are they correctly used and maintained? Are they adaptable to local needs and customs?
- What are the major drawbacks of the existing facilities?
- Does the current defecation practice threaten the users, the environment, or sources of water?
- What are the main diseases faced by the community due to insanitary conditions? (Time-series data for last 3 – 5 years desirable).
- What is the level of awareness of the community with regard to sanitation?
- Are the people ready to adopt better sanitation practices?
- How much are the people willing to invest for better sanitation and better health?
- What are the beliefs, customs, and practices of the community with respect to excreta disposal?
- What is the density of the community?
- What is the nature of soil and depth of water table?
- What is the slope of the terrain?
- What are the locally available materials suitable for constructing toilets?
- Do people have access to personal cleansing facilities? (Soap, paper, etc.).

Equity and Demand Responsive Programming

Needs assessment in water supply and sanitation should be backed up by a demand responsive programme based on fundamental considerations of equity and distribution of benefits.

Instead of choosing target groups, projects should focus on the following:

- Eligibility. Set the eligibility criteria for communities to get services, such as through applications and payments. Information about these rules should get wide circulation, through media coverage, handouts, etc.
- Technology choice. Offer a range of technology and service levels to communities with clear information on their costs and recurring financial or management implications for the community. The community then selects an appropriate technology according to its paying capacity.
- Cost sharing. The community can pay in cash, kind, labour or a mix of these, to cover a portion of the investment cost. The community could for instance pay a small amount, about 5 – 20% and the rest could be subsidised. Or the government could set a ceiling on subsidy, above which the community has to pay. Thus the community makes a financial choice for the level of services and technology they want.
- Operation and maintenance. For sustainability, the community should be made responsible for operation and maintenance, and it in turn could undertake the operation and maintenance itself or appoint private parties.

Technology Choice

A community should be encouraged to evaluate the different technology options, to make an appropriate choice for themselves. It is evident from Figure 3 that a more sophisticated system requires more resources, and most communi-

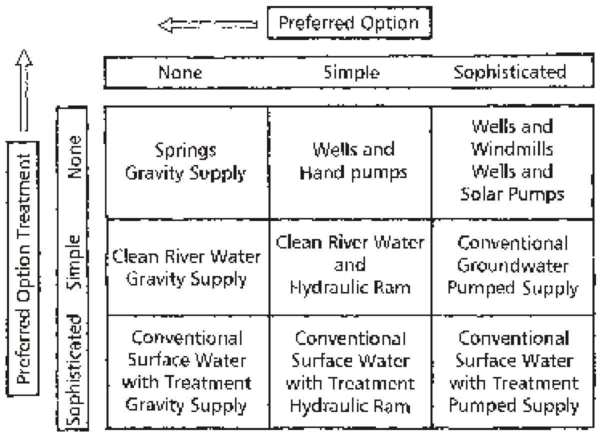

Fig. 16 Preferred Water Supply Options for a Community

ties may start from the bottom of the line and incrementally upgrade their systems.

The different options of water supply for a community should be presented with their advantages, disadvantages and implications (Table 5). The community can then select the option best suited to their demand.

A similar methodology should be adopted for selection of an appropriate sanitation system for a community. The various sanitation options with their advantages, disadvantages and other implications should be presented to the community. With good technical advice, the community should be encouraged to select the best option for itself.

Table 6 below compares the different sanitation systems.

While the community is encouraged to take decisions for ifself, the role of the government and aid agencies should be that of facilitators. They should not only present all the various options available but also give technical guidance to the community. In terms of choice of an appropriate sanitation system, the following technical factors should be borne in mind:

- For areas with fissured rock like limestone, a watertight excreta disposal system is appropriate. The septic tank or aqua privy are suitable. These should at least be 30 metres downhill from a water supply source. If this is not possible, the effluent from the septic tank should be conveyed through leak-proof pipes to a point of secondary

Table 5 *Options for Community Water Supply*

Sl	*Type of service*	*Source*	*Quality*	*Quantity lpcd*	*Energy*	*Operation & Maintenance*	*Cost*	*Remarks*
0	Traditional source (unprotected)	Surface water Groundwater Spring Rainwater	Poor Poor Variable Variable	10 – 40	Manual	General upkeep	Low Collection time very high	Starting point of improvement.
1	Improved traditional (partially protected)	Groundwater Surface water Spring Rainwater	Variable Poor Variable Good if protected	10 – 40	Manual	General upkeep	Very low O&M and Capital Collection time high	Improvement required if source is contaminated.
2	Hand pumps	Groundwater	Good	10 – 40	Manual	Trained repairer, few spare parts	Low O&M and Capital Collection time high	Access to safe water, good for rural areas.
3	Standpipes	Groundwater Surface water Spring	Good Needs treatment Good	10 – 40	Gravity Electric Diesel Wind Solar	Trained operator, fuel, chemicals, spare parts	Moderate O&M and Capital Collection time high	Good access to safe water.
4	Yard taps	Groundwater Surface water Springs	Good Needs treatment Good	50 – 100	Gravity Electric Diesel	Trained operator, fuel, chemicals, spare parts	High O&M and Capital	Very good access to potable water, Institutional backup required.
5	House connection	Ground water Surface water Springs	Good Needs treatment Good	100 – 150	Gravity Electric Diesel	Trained operator, fuel, chemicals, spare parts, waste-water disposal	High O&M and Capital required	Most desirable High resources.

Source: Adapted from World Bank

Table 6 *Options for Community Sanitation*

Sanitation system	*Low population density*	*High population density*	*Cost*	*Technology*	*O&M skills*	*Flushing water*	*Health hazards*	*Nuisance (odour, insects)*	*Remarks*
Pit latrine	Suitable	Not suitable	Low	Low	Low	Nil	Medium	Medium	Temporary solution, maintenance problem.
Bored hole	Suitable	Not suitable	Low	Low	Low	Nil	Medium	Medium	Temporary solution, maintenance problem.
Ventilated pit	Suitable	Not suitable	Low	Low	Low	Nil	Low	Low	Temporary solution, maintenance problem.
Compost	Suitable	Not suitable	Low	Low	Low	Nil	Medium	Medium	User awareness required.
Pour flush	Suitable	Not suitable	Medium	Medium	Low	Medium	Low	Low	Effective soak pit essential.
Vault & vacuum tanker	Suitable	Suitable	High	Medium	Medium	Moderately high	Low – medium	Low – medium	Efficient management essential.
Septic tank	Suitable	Not suitable	High	High	Medium	High	Low	Low	Effective soak pit essential.
Aqua-privy	Suitable	Suitable	Medium	High	Medium	Medium	Low	Low	Effective soak pit essential.
Pay & use	Not Suitable	Suitable	High	High	High	High	Low	Low	Private partnership essential.
Sewerage system	Not suitable	Suitable	Very high	Very high	Very high	Very high	Nil	Nil	Most desirable, but high resource requirement.

treatment, and finally to a point of disposal that is well clear of sources of water supply.

- The pit latrine is suitable in areas that do not have fissured rock formation. It is recommended that if the pit latrine is located downhill, it should be at least 8 metres away from a water supply source; and if located uphill from the source of water supply, it should be at least 30 metres away.
- On flat lands, the disposal system should be at least 30 metres away from the water source.
- The disposal system should always be above the flood level.

Investment and Cost Recovery

From the high estimated costs for improving water supply and sanitation, it is evident that funds must be used more effectively and that users must start paying for services. Rehabilitation of defective systems, reduction in wastage and unaccounted for water (UFW), recycling, improved operation and maintenance are often more effective than new services. Widespread promotion of the concept that water is not a free good is also essential.

Investment in new works and infrastructure should be complemented by a matching investment in training and education. In other words, there should be equitable distribution of resources for the hardware and the software components of water supply and sanitation.

The United Nation's 20/20 model is worth noting, where governments invest 20% of their budget in basic services including water supply and sanitation, and this is matched by 20% of international development funds. Participation of the local communities in the decision-making process is necessary to ensure best utilisation of the funds.

The private sector can also be involved in investing in this sector. Since they will look for returns, the government's role will be to protect the poorest sections through subsidised water and sanitation connections/schemes. Aid agencies could provide technical know-how and forge partnerships to provide the resources to help local communities find appropriate, sustainable ways of meeting their needs.

Control of Wastage

In the Asian cities that operate under tremendous resource constraints, it is not enough to do only a systematic needs assessment and analysis, followed by appropriate technology choice and execution of projects. There should also be a feedback and monitoring of projects. A lot of good work is lost if the feedback and monitoring is weak. For instance, water wastage in some Asian cities is sometimes as high as 50%. By contrast the Helsingborg Water Supply Authority in Sweden keeps wastage to 6%. Wastage can be controlled by the following ways:

- Water Metering. This has shown good results round the world. However, metering an entire apartment building and dividing the cost of water among the apartments does not always give good results (Tel-Aviv, 1955). Metering individual apartments showed much better results in the UK. Individual metering gives better control to the user and provides incentives to detect faults and leakages.
- Household Retrofitting. Considering the tremendous water shortage in Asian cities, there must be efforts to conserve water. This can be done in the following areas. *Toilet flush:* A toilet flush accounts for the largest volume of domestic water consumption. Installing a modern flush taking about 6 litres in place of the conventional flush can result in considerable saving. A dual-action flushing cistern (using 3 or 6 litres per flush) can save even more water. These modern fixtures have resulted in savings of up to 40% of domestic water consumption. *Showerheads:* Introduction of flow-controlled showerheads using 8 – 10 litres/minute can save considerable water. In Israel these are reported to show a saving of 7 – 8%.
- Checking Unaccounted for water (UFW) – Unaccounted for water is the result of leakage, inadequately metered supplies, absence of user service charges, pilferage, etc. Investing in leak detection and timely repairs can substantially reduce the UFW component.

Developing Appropriate Indicators

It is important to develop appropriate indicators for water supply and sanitation programmes, backed up by periodic monitoring and feedback. The indicators could be as follows:

Water supply Indicators

- A minimum of 20 litres of potable water per person per day.
- Minimum rate of flow of water at each collection point of 0.125 litres per second.
- At least one water point per 250 persons (WHO).
- Maximum walking distance between dwelling and water collection point not over 200 metres (WHO).
- One hand pump serves at most 150 persons or 30 households.
- Each household has at least two water-collecting vessels and at least one storage vessel with a capacity of not less than 20 litres. Vessels should have covers or lids.
- A vessel with a long handle used to draw water, and hands do not touch the stored water.
- In community baths there are separate cubicles for men and women, and the hours of water supply are convenient to the users. The community, especially the women, should be consulted for their preferences.
- Washing areas for utensils and clothes are in hygienic condition.
- Water is treated with a residual disinfectant such as chlorine if the source is not well protected and to avoid risks of post-collection contamination. Several point of use (POU) techniques are available, people should be made aware of these.
- Water has no objectionable taste and odour.
- For untreated supplies no more than 10 faecal coliforms per 100 ml at the point of delivery.

- Total dissolved solids in water no more than 1,000 mg per litre.
- In acute shortage conditions, adequate quantity of intermediate quality should be preferred over inadequate quantity of potable quality. The water should then be treated with residual disinfectants at home.

Sanitation Indicators

- A toilet seat serves a maximum of 20 – 30 persons or 4 – 6 households.
- Segregation of male and female users is possible in community toilets.
- Toilets are located not more than 50 metres from dwelling units.
- Toilet design encourages their use by people, especially children and females; for instance with light point, hand washing facility, privacy for personal cleaning for females, and with no nuisance of odour and insects.
- Toilets and soak-pits are located at least 30 metres away from groundwater sources and are at least 1.5 metres above the water table.
- Effluent does not flow towards surface water sources.
- Use, cleaning, and maintenance of toilets are proper and regular. Target group is involved in deciding about sharing of responsibility for cleaning and maintenance.
- Proper hand washing with soap is practiced after defecation.
- People associate a sense of ownership with the toilets. They should be involved in decision-making, design and construction of toilets. Toilets should not be too big and are close to where people live to encourage regular cleaning.

The main problem of water supply and sanitation in Asian cities is not a lack of available technology. Rather, it is the fact that stakeholders are largely unaware of the alternatives available and how difficult it is to assess the suitability of one technology over the other in their given situation. The major challenge is to select an appropriate technology, considering the multi-faceted issues including technical feasibility, affordability, customs and practices, preferences and institutional support available. What is necessary is a bottom-up approach, presenting no single and absolute solution, but offering a comparative analysis of various options, and encouraging the communities to adopt the one best suited to their needs.

Promoting safe latrines in Bangladesh

A pioneering social mobilizing programme was started in Bangladesh by its Public Health Department and UNICEF in 1990 to promote better hygiene practices based on people's needs, culture and practices. The main features of the programme included:

- Mobilization of senior government officials, politicians, NGOs, media and the community.
- Enumeration of how the entire society was at risk from water-borne diseases due to pathogen overload.

The programme was well received. A village-based organization of four million people, Ansars, trained its officers in sanitation. The Islamic clergy allowed UNICEF officers to address mass religious gatherings and distribute leaflets on sanitation. Since 1994 a National Sanitation Week was organized to work towards a goal of providing a sanitary latrine to each household by the turn of the century. Sanitation promotion material highlighted women's preferences and cultural values. Community meetings were organized in courtyards attended by 25 – 30 households at a time. They resolved to adopt a participatory planning approach. A strategy of incentives was also worked out in which groups of ten families had to show they had installed latrines to receive the benefits of a tube well.

The results were very encouraging. Between 1990 to 1994.

- Rural families with sanitary latrine rose from 10% to 35%.
- Overall use of sanitary latrines rose from 4% to 24%.
- Hand washing after defecation rose from 5% to 27%.
- Commercial latrine producers rose from 700 to 2500.

Emerging Models on Water Supply and Sanitation in Asia

China: Water supply, sanitation and hygiene education are currently viewed as a 3 in 1 package. A 'push–pull' strategy is worked out.

Push includes advocacy meetings with officials to formulate regulations, chalk out R&D areas on affordable technology and promotion of inter-sectoral linkages (education, women, poverty and environment).

Pull includes social mobilization, communication and social marketing, demonstration (through mass media) of affordable and culturally acceptable latrines. Primary schools are targeted as entry points for promoting community behavioural change and participation.

India: To motivate rural and peri-urban communities to construct toilets without subsidy, Rural Sanitation Marts (RSM) are established as commercial enterprises with a social objective. This includes a production centre and credit mechanism, supported by information, education and communication. The objective is to promote zero subsidies, stimulate demand generation, and create awareness for sanitation and hygiene. RSM are cost effective, economically viable, self-sustaining and have employment generation potential. It is currently being felt that these should be integral parts of all future sanitation schemes.

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