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International Training Network Centre
for Water Supply and Waste Management

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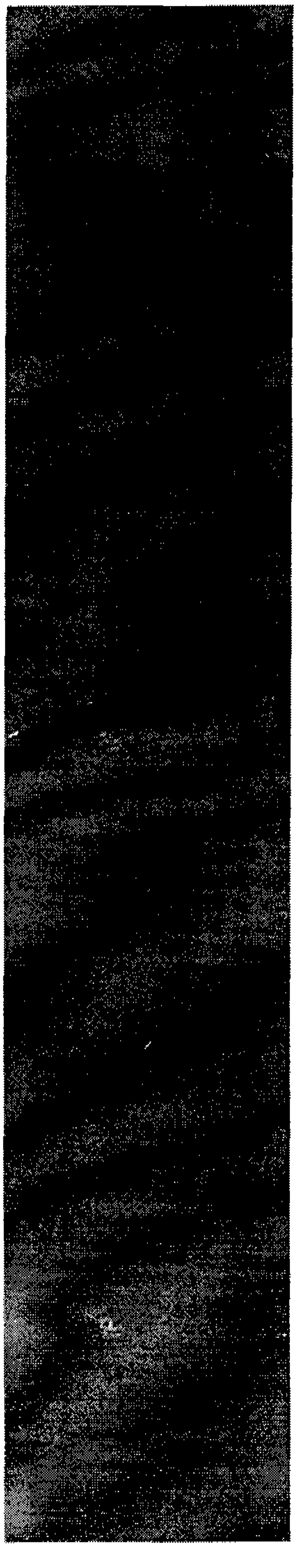

Students' Training Course on Water Supply and Waste Management

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET), DHAKA

ITN Bangladesh

International Training Network Centre
for Water Supply and Waste Management

Students' Training Course
on
Water Supply and Waste Management
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PARTICIPANTS' NOTES

BIT-Dhaka, Gazipur

International Training Network Centre
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Water, Waste and Health

Importance

Water supply and safe disposal of human wastes are most important for the protection of health. Table 1 shows human's lines of defence against diseases. It may be observed that water supply, sanitation, waste management provides human's first line of defence.

Table.1 : Human's line of defence against diseases

I. **Environmental Management : Human's First Line of Defence against Diseases**

- Safe water supply*
- Natural water quality management*
- Proper human waste disposal*
- Solid and hazardous waste management*
- Rodent and insect control*
- Food sanitation*
- House sanitation*
- Recreational sanitation*
- Occupational health practice
- Air pollution control
- Noise control
- Radiation control
- Environmental safety and accident prevention
- Land use management
- Environmental planning*

II **Public Health : Humans Second Line of Defence against Diseases**

- Nutritional level
- Personal Health and hygiene practice*
- Routine health check-up

III. **Preventive Medicine : Human's Third Line of Defence**

- Phagocytosis (a natural process)
- Immunity (natural and induced)

IV. **Curative Medicine : Human's Fourth Line of Defence against Diseases**

- Administering medicine and radiation
- Surgical intervention
- Corrective therapy

* *Water and waste related lines of defence*

The high rate of incidence of diarrhoeal diseases and infant mortality in developing countries is attributed to lack of waster supply and sanitation. Every year 3 million children under five years' of age die of diarrhoea in developing countries. Every child in the third world countries suffers an average of three diarrhoeal attacks a year. **Figure 1** shows a good correlation between infant mortality and sanitation coverage in developing countries produced by the World Health Organization in 1981.

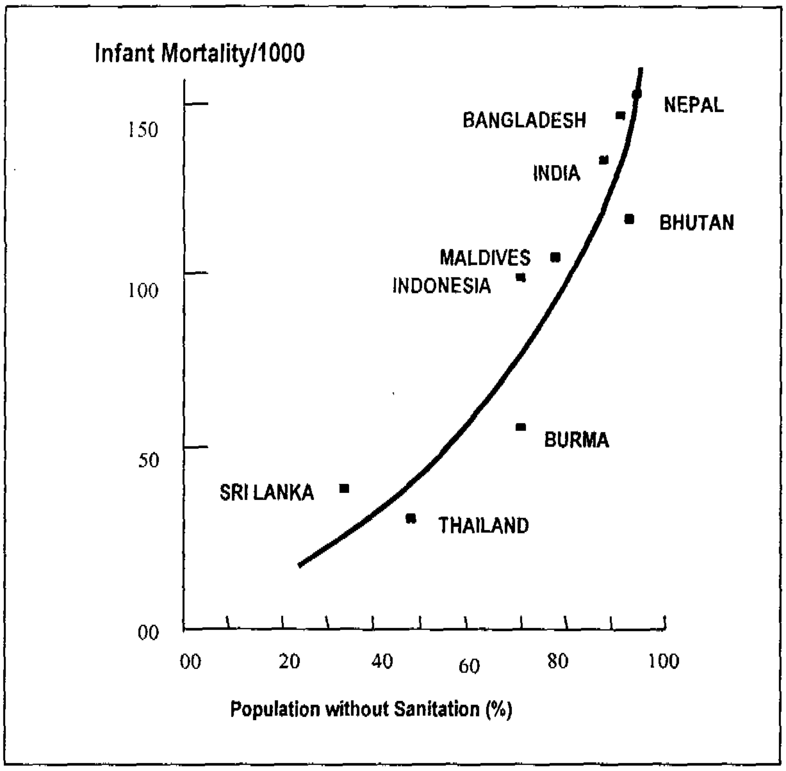


Figure 1 Infant Mortality and Sanitation Coverage in Selected South East Asian Countries (WHO,1981)

Mode of Transmission

The diseases related to water supply, sanitation and waste management may be classified into five groups according to their transmission routes.

Group I : Diarrhoeal Diseases, Dysentries, and Enteric Fevers
Group II : Disabling Enteric Viruses. Hepatitis A and Poliomyelitis
Group III : Worm Infections
  a. Worm infections with no intermediate host
  b. Worm infections with aquatic intermediate hosts
  c. Worm infections with animal as intermediate hosts
Group IV : Water-Related Insect –Borne Diseases
Group V : Skin, Eyes and Other Diseases

There are many ways in which disease producing micro-organisms from faeces can reach the mouth and then into human body. The most common faecal-oral routes have been shown in **Figure 2**.

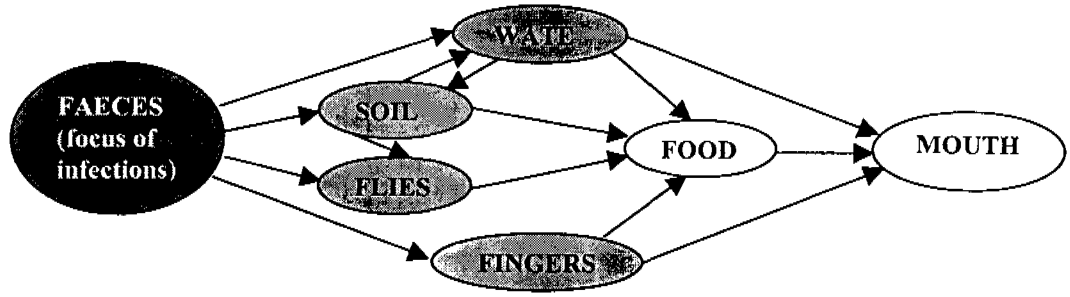


Figure 2 Faecal-Oral Routes of Transmission of Diseases

Open defecation contaminates water and soil in rainy season. Flies and other insects feeding and breeding on faeces transfer pathogens from faeces to food and utensils. Fingers become unclean and contaminated when hands are not washed after defecation and after handling faeces of babies. Contaminated water, soil, flies and fingers contaminate food. Thus disease producing micro-organisms enter into human body taking the oral route through contaminated water, food and fingers. The diseases under Group I and II are mostly transmitted by faecal-oral routes.

A model showing dose-response relationship of a community under varying exposure of enteric pathogens has been shown in **Figure 3**. The model shows that incidences of both mild and severe diarrhoea are low if the dose is low and remain constant upto certain ingestion of enteric pathogens. The incidence of both mild diarrhoea increases with the increase in dose and then it becomes constant. The incidence of severe diarrhoea also increases with the increase in the ingested dose of enteric pathogens and it also becomes constant at a relatively higher dose.

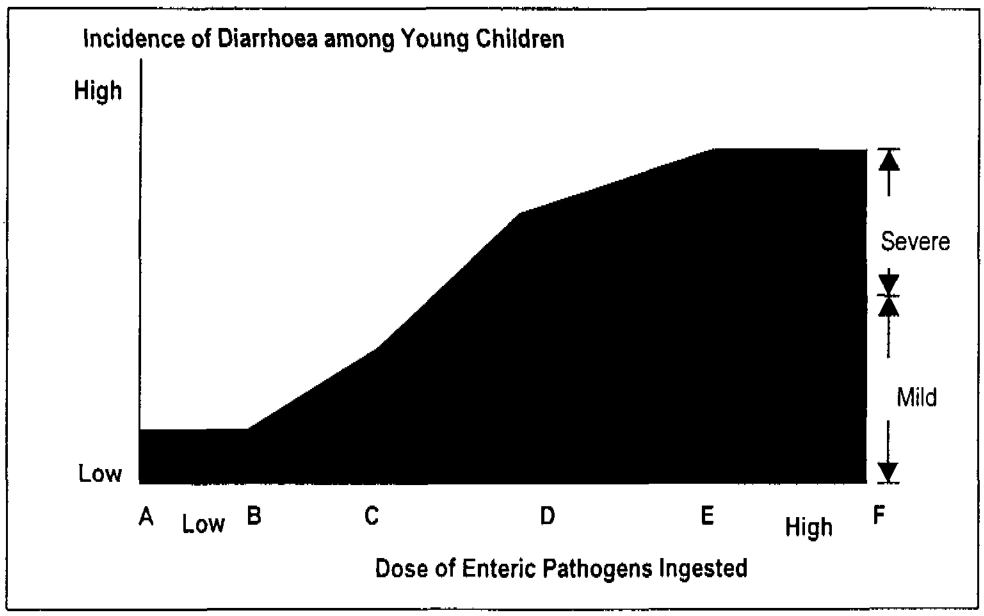
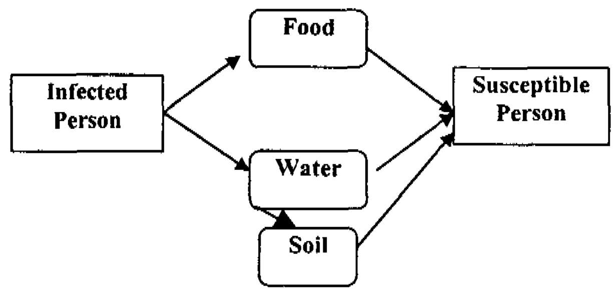
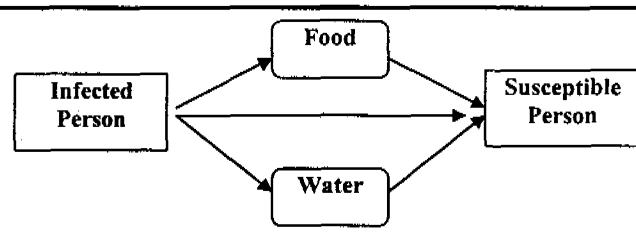
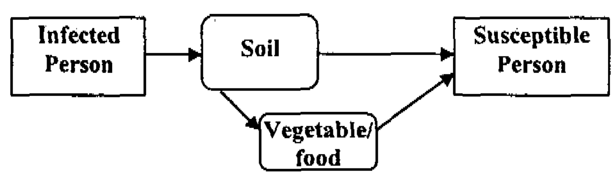
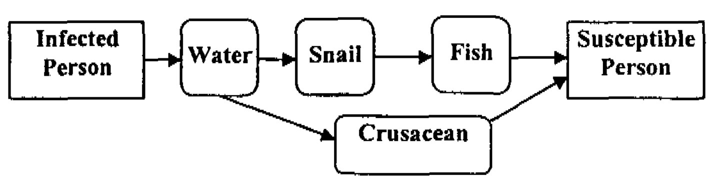
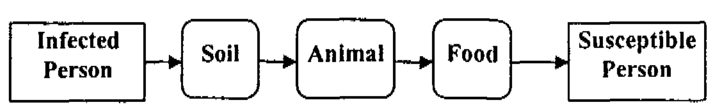
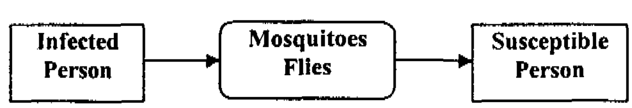


Figure 3 The Dose-Response Relationship under Varying Exposure to Enteric Pathogens (Esrey et al, 1985)

Parasitic worm infections under Group III are common in Bangladesh and transmit through different routes. Ascariasis transmit by faecal oral route and hook worms enter into the skin of bare feet from contaminated soil. Others passes a part of their life cycle into an aquatic host or animal host before infecting humans. The diseases under Group IV are transmitted by water related insect vectors. The last group of diseases are related to the use of enough water are termed as water washed diseases. The relevance of water to these diseases is that it is an aid to maintenance of personal cleanliness and hygiene. The availability and use of enough water are more important than the quality of water.

The detailed transmission routes of these five groups of diseases are shown in Table 2. The table presents a list of diseases related to water and wastes and a clear picture of modes of propagation of these diseases.

Table 2 Transmission Routes of Water and Waste Related Diseases.

GROUP	DISEASES	TRANSMISSION ROUTE
I	**Diarrhoeal Diseases:** • Cholera • E.Coli Diarrhoeas • Viral Diarrhoeas • Other Diarrhoeas **Dysenteries:** • Amoebic dysentery • Bacillary Dysentery **Enteric Fever :** • Typhoid • Para-typhoid	
II	Viral Diseases • Poliomyelitis • Hepatitis-A	
III	**a. Worm Infection with no intermediate host:** • Ascariasis (round worm) • Pinworm • Hookworm **b. Worm Infection with aquatic host:** • Schistosomiasis • Guinea Worm **c. Worm Infection with animal host:** • Tape Worm	  
IV	**Water/Waste related insect-borne diseases:** • Malaria • Dengue & Yellow Feber • Kalazar	

	• Filariasis • Sleeping Sickness	
V	**Skin, Eye and other diseases:** • Skin Infection • Scabies • Eye Infection • Louse-borne typhus	**Infected Persons** → **Susceptible Persons**

Control

The uncontrolled waste is the focal point of pollution of the environment. If the environment is polluted, it ultimately affects the population. The different routes of transmission of diseases and the interventions against such propagation of diseases have been shown in **Figure 4.**

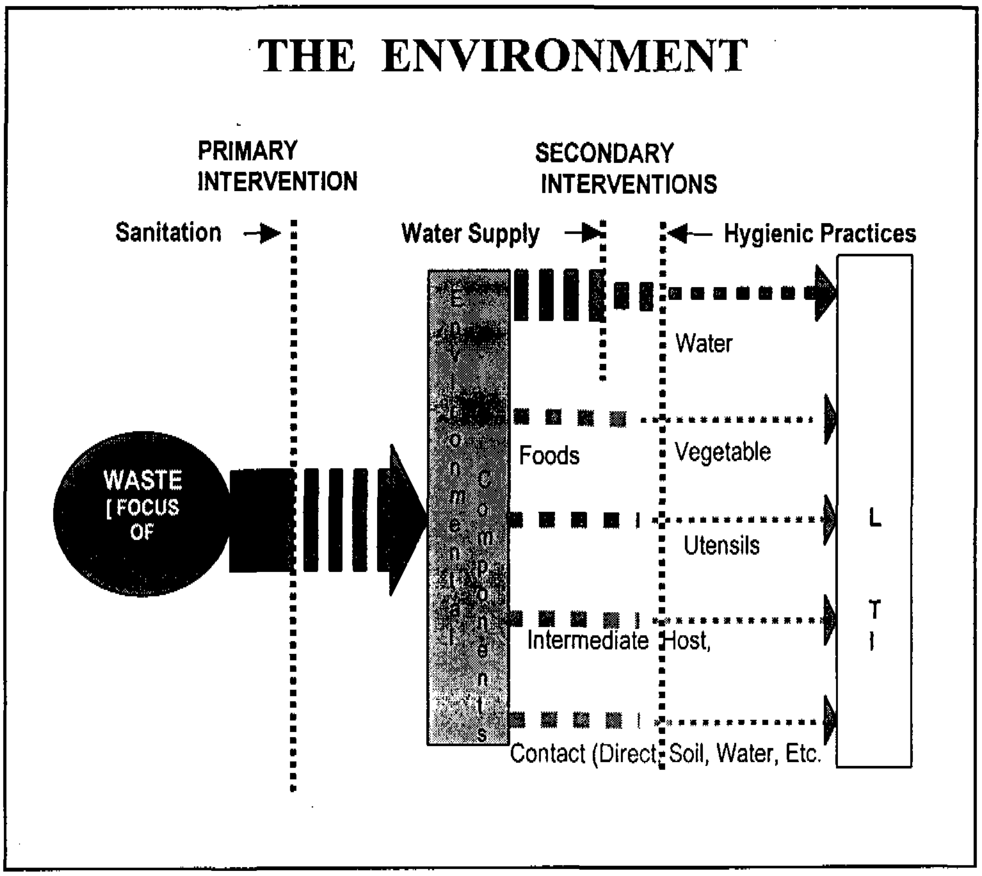


Figure 4 Routes of Transmission of Diseases and interventions

Sanitation is the primary intervention for the protection of quality of the environment and control of all diseases. Proper treatment and disposal of and all forms of wastes both liquid and solid including human excreta are most important for the protection of health. Most on-site sanitary latrines retain excreta for certain time for the stabilisation of organic fraction by aerobic and anaerobic processes and destruction of pathogens. Pathogens have different decay rate depending on the environmental conditions and some may survive quite long. The influence of time and temperature on decay of few common pathogens present in night soil and sludge is shown in **Figure 5**. The safe zone in respect of time and temperature has been marked in the figure. It may be observed that a detention time of about a year is required for the destruction of common pathogens present in excreta.

Since all the developing countries lack in sanitation coverage, the environment is contaminated and much efforts are needed to protect human population from diseases by erecting secondary interventions. Safe water supply is the most important secondary intervention to prevent transmission of water-borne diseases through oral route. A man drink a lot of water every day and bacterial pollution of drinking water allows largest ingestion of pathogen. Safe water supply, therefore is a major barrier against transmission of water-borne diseases. Since there are other routes of transmission of diseases, provision water supplies alone cannot control transmission of all diseases. Hygiene education is another secondary intervention to protect human health. Hygiene education and hygienic practices can erect effective barrier on all routes of transmission of diseases as shown in Figure 4. The effect different interventions on reduction of diarrhoeal diseases is shown in **Figure 6.**

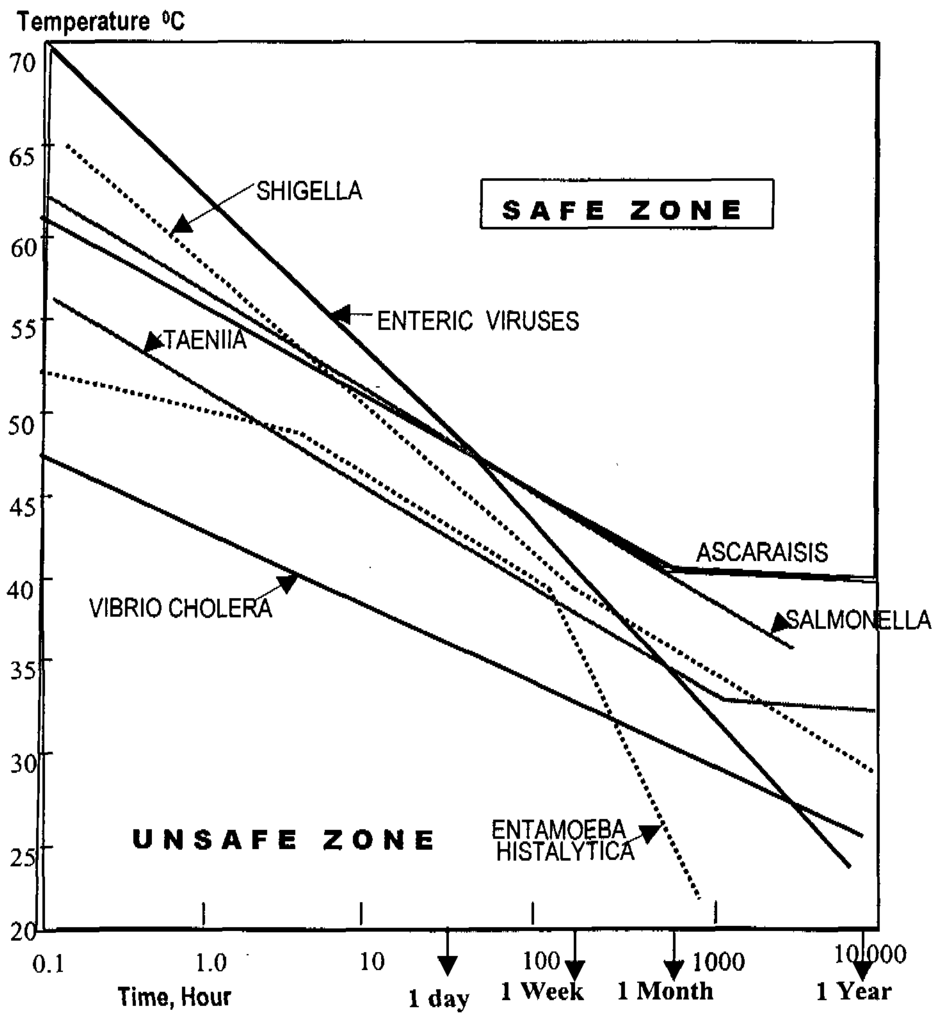


Figure 5 Influence of Time and Temperature on Selected Pathogens

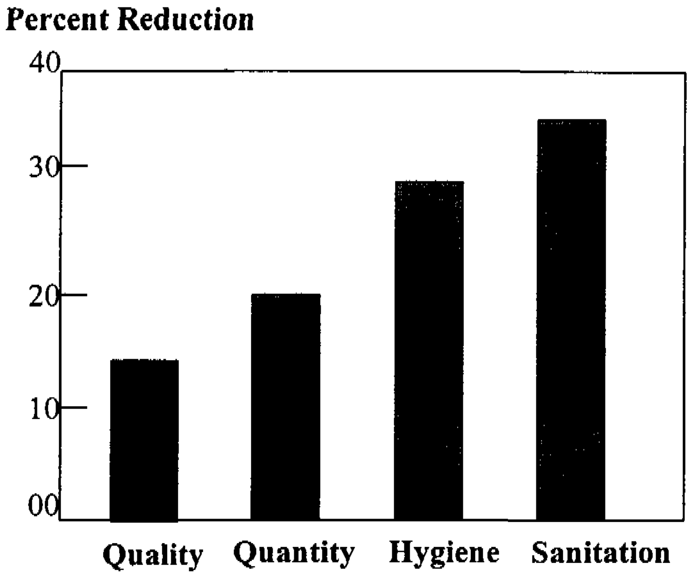


Figure 6 Influence of Different Interventions on Reduction of Diarrhea

A recent study in Bangladesh has shown a reduction of two-third in diarrhoea prevalence by interventions like drinking tube well water, proper sanitation, environmental cleanliness, food hygiene, hand washing and diarrhoea management.

The important measures to prevent transmission of diseases are as follows:

Sanitation

- Use sanitary latrine
- Dispose of all human faeces including that of children and animal excreta hygienically
- Dispose of the garbage properly and hygienically

Water Supply

- Use safe water for drinking, bathing, hand washing, washing of vegetables and fruits and washing of utensils
- Use enough water for washing and cleaning

Hygienic Practices

- Wash hands properly after defecation, cleaning children faeces and contact with any faeces and before preparing and eating food
- Wash raw vegetables and fruits properly with safe water before eating
- Cook food properly, keep covered and protect food from flies
- Destroy feeding and breeding grounds of flies, mosquito and other insects
- Keep the yard and latrines clean.

Socio-economic Aspects of WSS

This is a lecture note prepared for the ITN course on Water Supply and Waste Management. The participant's not thus has been prepared in three parts dealing with A) the general socio-economic profile of Bangladesh, highlighting the WSS sector, B) Necessity of consideration of Socio_economic aspects and it's relation in the PCM and C) Development and Bangladesh perspective. Issues partly, will also be dealt in other sessions of the course (community participation, gender issues etc.

A. General

Introduction

The socio-economic factors of an area, a community or the country as a whole are considered very much essential elements in planning and designing the development projects. Development efforts obviously target a section of people; a particular community or area based masses. It is, therefore, is an urgent issue to know the clientele's socio-economic status, need of the clienteles, demands of them, their absorptive capacity, the gender issues involved and the potential adverse impacts on vulnerable groups. If these factors are known to the planers, decision-makers and project designers, it becomes easier to set the project goal, target and strategic approaches.

Socio-economic aspect ranges a wide area to cover, however, the course materials we will be limiting to some of the specific features of the whole aspects. Remembering the central theme of the course, information and data in this lecture note have been reflected by and large around the WatSan. issues.

Socio-economic Profile of Bangladesh

Economic

With an area of only 144,000 square kilometers and a population of 120 million, Bangladesh is one of the most densely populated countries of the world (WB, 1997). In this semitropical, predominantly rural country about 48% of rural and 44% of the urban population live below the poverty line, a reduction by almost half from 15 years ago (BBS 1993). Per capita Gross National Product in 1993 was US$220 (World Bank 1993). Households spend 59% of their income on food, and 60% of children below 5 years of age are malnourished (World Bank). The country ranked 147 out of 173 countries in the world as per UNDP human development index.

The annual growth of the Gross Domestic Product in the 1980-91 period exceeded the population growth rate and averaged 4.3%, an increase from 2.3% in the previous decade (Word Bank 1993). While agricultural production averaged 2.6% growth annually during that period, its share shrank from 55% to 36% of GDP, while industry grew from nine percent to 16% and services from 37% to 48% (World Bank 1993).

Demographic Trends

The population in 1996 was approximately 111 million, and expected to grow to 131 million by the year 2000. Already an estimate shows that it has further increased to 121.8 million of which 62.4 million male and 59.4 million female (estimated as on January 1996)*. The overall growth rate has dropped from 2.7% in 1970-1980 to 2.2% between 1980-1991 and 1.84%(estimated as on January 1996)*. The urban population has been growing faster than the rural population due to migration, increasing from eight percent of the population in 1970 to 17%, or 21.6 million people, by 1991 (World Bank 1993). About 48% of the urban population live in Dhaka, Chittagong, Khulna and Rajshahi, and 40% live in the 108 Pourashavas.

Education

As per recent BBS publication, 95 literacy rate stands for Bangladesh at 44.3% (male 50.4% and female 28.5%) and the adult literacy rate(15+) is 48.6% (56.3% male and 39.4% female). 80% primary school aged children are enrolled in school but only 40% complete the cycle. Though a higher proportion of children is now being enrolled in primary education, attendance is no more than 50%. After dropping out of school, uneducated children grew into illiterate adults and thus the cycle is repeated.

Emergencies

Bangladesh have a reputation for being disaster prone. Floods, cyclone, tornadoes and draughts strike with depressing regularity and intensity. 1657 lives were lost in the flood of 1987, 2379 in 1988 and 5780 in the cyclone of 1988 and 138, 868 in 1889. The cyclone of 1991 alone caused damage to $2.4 billion.

Water Supply, Sanitation and Health

At present, more than 90% of the rural people have access to a tube-well with 150 meters of their homes compared to only 40% in 1981. About 95% of the people drinks tubewell water. About 44% of the rural population use sanitary latrines compared to less than one percent in 1981. People are now latrine conscious with 61% using some form of latrine. Overall urban water supply coverage has risen from 26% in 1981 to 47%, and sanitation from 20% to 42%.

The health status of this poverty stricken country is appallingly poor. Infant mortality rate persists at a high level with 77 deaths per 1000 live births in 1995 (MOH&FW, 1996). Water related diseases still remain a common occurrence in Bangladesh despite significant improvement in drinking water supply and sanitation over the past decade. Number of deaths due to diarrhoea diseases alone stands at 230,000 annually and in 1992 some 6.9 million cases of diarrhoea diseases have been reported (MOH&FW, 1994).

Although adequate supply of safe drinking water and provision for proper sanitation is extremely important for the reduction of mortality due to waterborne diseases, yet mere access to these facilities may have little impact on health in the absence of other factors influencing their use. Bangladesh have made tremendous strides in improving access to safe drinking water. Sanitation coverage has also increased significantly. Yet the impacts of these interventions in terms of improved health have been very modest.

Experience of the International Drinking Water Supply and Sanitation Decade (1981-90) has indicated that physical provisions of services are not a sufficient pre-condition for improvement of health. Community involvement, hygiene education and social mobilization are identified as indispensable for water and sanitation services to be effective.

W[illegible]

Bangladesh is a [illegible] deltaic region criss-crossed by numerous rivers and subject to periodic and occasionally catastrophic flooding. The hydrology of Bangladesh is characterized by three major international rivers: the Brahmaputra, the Ganges and the tributaries forming the Meghna. Surface water availability varies by region according to rainfall and storage capacity in streams, ponds and lakes. About 37% of the country is permanently or intermittently inundated during the monsoon up to a depth of 30 cms or more.

Sand and clay soils, which predominate in the country, provide a natural filter, which rapidly attenuates bacterial contaminants and creates a vast reservoir of potable groundwater for relatively cheap extraction. Although well water is favoured for drinking, surface water is the traditional and more convenient source of supply for other uses, and much is polluted with human waste (World Bank 1990).

Despite the country's relatively small size, water availability and quality vary and tubewells are not distributed evenly among the regions. In the north, usually spared the severe flooding of the south, groundwater tables are generally shallow but not overly close to the surface. Under these conditions handpumps and latrines are suitable technologies and tubewell coverage is approximately 85% (UNICEF 1993c). Low water tables are becoming more common, from 8% of the country in 1985 to an estimated 50% by the end of the century (UNDP 1991). In the coastal areas, upper aquifers are often saline, usually requiring deep tubewells to reach sweet water, although some potable pockets of shallow aquifers have been tapped with handpumps (GOB-Netherlands 1986). These areas are also underserved. Annual flooding poses a difficult problem for sanitary latrines.

Food

In 1993 food production was at an all-time high, price was low and the country was virtually self-sufficient in rice. But millions still went hungry. Around 30 million Bangladeshies can not afford even 1805 calories per day (20% less than the daily-prescribed intake). Since 1972 the average price of rice fallen by around 30% enabling many families to by enough food. There was a particularly sharp drop between 1991/92 and 92/93 when it fell by 16% and at that time rice consumption increased by 38%.

Poor Bangladeshies have to spend cent percent of their income for daily food consumption (69.7%) of which 41.8% for cereals and 18.5% for protein rich food while vegetables and fruit constitute 16.6%. (BIDS, 1989/90

Women, Water and Sanitation

Women are the prime beneficiaries of water and sanitation projects. It is their productivity and their impact on family health which are most affected by improved access to clean water. Understanding their needs as managers and as water users is important to program success. However, gaining this understanding requires conscious effort to reach women and involve them in projects from the first step, as women operate under constraints not shared by men.

Equal rights guaranteed under the constitution are undermined by civil laws originating from a patriarchal interpretation of socio-cultural norms. Female mobility outside the home is restricted by cultural traditions. Women's status and disadvantages are consistently reflected in statistical data. Cultural practices limiting women's access to sufficient food deprives them of energy needed to meet their various responsibilities (World Bank 1990). More than half of the poor population is female (World Bank 1989). Mortality rates of female infants are higher than that of males, and life expectancy of women is lower than for men (World Bank 1993). Female children have about three times the rate of malnutrition as males (World Bank 1990). Seventy-eight percent of women are illiterate and women are paid lower wages than men (World Bank 1993) are.

It is women who are already investing their time and labour to bring water to the household. Projects which increase their time and labour requirements, such as projects in which fetching tubewell water is more costly in time and labour than scooping up water from a nearby surface water source, will succeed only to the extent that women see a compelling reason, and are able, to make a higher investment in water.

Women's productivity is underestimated, which consequently undervalues the labour-saving benefits of water projects. Their participation in projects and their utilization of water and sanitation facilities must take into account the value of women's time and the opportunity costs of participation. Much of women's labour is non-reflected in national income accounts as it is largely un-priced and uncompensated home-based labour (World Bank 1990). Their tasks include cooking, cleaning, washing, collecting fuel and water, rearing children, caring for the sick, raising fruits, vegetables and livestock, and processing field crop production. In 255 of rural landless families female earnings are responsible for food security. Among male-headed households with female wage earners, female earnings contribute 255 to 50% of family income (World Bank 1990). Non-recognition of their myriad contributions to the economy and household impedes informed decision-making about resource allocation in development planning.

The Fourth Five-Year Plan (4FYP) recognizes the importance of bringing women into the mainstream of development. Many programs administered by NGOs and community based organizations emphasize benefits for women. About 94% of Grameen Bank b3neficiaries are women, many of whom used their credit to purchase tubewells (Khandker et al. 1993). There are many NGOs, such as Banchte Shikhi in Jessore, that are founded and managed by women, These provide models for reaching women in water and sanitation programs.

The statistical demonstration of a direct relationship between water and sanitation projects and positive health impacts remains an elusive goal (Churchill 1987). Despite improvements in water and sanitation in Bangladesh, the expected health impacts have not been realized. It is likely that water, sanitation, and hygiene education are necessary but not sufficient interventions to improve health. Other important factors include rising incomes and increased education (Word Bank 1993). Therefore, while continuing to improve access to and use of water and sanitation facilities, it may be necessary to use non-health measures to assess the impacts of water and sanitation interventions to distinguish their contribution form other actions. Alternative measures may also draw attention to additional, non-health benefits of water and sanitation projects such as increased number of workdays, higher individual productivity, etc.

B. Synopsis of Social issue, it's necessity, context, Analysis and Project Design

Why socio-economic analysis is necessary

Socio - economic analysis is necessary to know information on the following.

- Gender
- Ethnicity
- Social impacts
- Institutional capacity

Social context are considered to do what

- **Identify key stakeholders**
  participation in project selection, design and implementation

- **Ensure that the project objectives and incentives for change**
  acceptable to maximum people
  gender and other social groups are addressed

- **Social impact assessment**
  adverse impact, degree and mitigation possibilities

- **Develop ability**
  enable participation,
  resolve conflict,
  permit service delivery and
  carry out mitigation measures as required

Social Analysis and Project Design

Social Analysis

Clientele Group(s)

- identify population expects to be served by WSS facilities
- identify the key population whose participation is a key in achievement of the project objectives (landholders, workers, business owners' etc.)
- prepare a socio-economic profile of the users
  - population, sub groups
  - gender differentiation
  - households & size
  - single and female headed households
  - location and types of housing in the area
  - peoples occupation
  - level of income and sources
  - level of education and access to education
  - access to health services
  - social organizations
  - water user groups
  - leaders and spokesmen
  - access and utilization of WSS services
  - payments for services if any
  - socio-cultural traditions
  - other special issues seems important

Clientele Needs

- identify the existing sources of WSS
  - spring, stream, deep well, river, pond etc.
  - availability, distribution facilities, distance, seasonally, quality etc.
- assess the level of service desired
  - private house connection, public hydrant, communal bath, connection to the market, school etc.

  assess the needs improvement of the initial services
  - wastewater drainage
  - public latrines
  - health education

Clientele Demand

- assess the demand from the users in terms of
  - expenditures and efforts
  - quantity and quality
  - problems experienced in obtaining access to facilities
  - above all, the comparison between services and cost

- assess the ability and willingness of the users to participate in terms of
  - investing own capital
  - labour
  - undertaking responsibility for O & M

Absorptive capacity

- assess the extent of knowledge & influence of
  - social
  - religious
  - custom and tradition
- acceptance of the recommended hygiene practices
- need for further training and education
- assess the present status of individual/ group initiatives
- capacity of O & M
- assess the appropriateness of technologies in terms of ability of the users in operating and maintenance

Gender issues

- assess the differing roles & activities of men and women
- inside and outside the households activities
- usual work of men and women for water, sanitation and waste management
- assess the relative access to resources
  - public latrine
  - bathing facilities

Project Design

Targeting

- groups and sub- groups
- co-option
- possible method

Participatory development process

- from project design to O&M, the involvement of the users
- users voice in decision making
  - water sources to be developed
  - type and extent of water treatment
  - transmission and distribution
  - level of service
- based on the assessment provision for the WUAs

Delivery mechanism

- capability of the executing agency
- capability and knowledge of the WUAs
- alternative arrangement for execution/ collaboration (NGOs)
- other interested partners (private sector)
- NGOs working in the area and their involvement

Benefit Monitoring & Evaluation

- monitoring indicators
  - outputs
  - purpose
  - goals
- existing MIS
  - follow up mechanism with the community
  - communication from and with the community
- specific indicator to monitor the benefit of the community

C. Development Strategy & Bangladesh

Strategic Issue: A Client-Centred Approach

Improving health is a prerequisite to improving welfare and raising incomes, and safe water and sanitation are necessary for good health. Yet experience has shown the failure of supply-side approaches, particularly in rural areas. Agencies whose targets are solely technical installation may achieve distribution goals without having any impact on increasing the use of those facilities. When users have little voice in obtaining services which have value to them, the result is a mismatch between what users want and what planners provide, and consequently a waste of resources as facilities fail to be accepted and maintained by users.

In rural Bangladesh, tubewell water is in great demand for drinking water and is almost universally available through private as well as public pumpsets, yet only 16% use it for their full range of water needs (Mitra 1992). Sanitary latrines, which are owned, privately rather than publicly, are less widely available, although the recent growth in demand is encouraging. Facilities, which meet, needs appropriately will be valued and are more likely to be used. A client-centered approach promotes greater attention among implementing agencies to providing what clients want rather tan what the agencies decide they need. A strong incentive to adopt this approach is created if clients are given the opportunity, in some cases promoted by access to credit, to pay for the services they desire. When clients choose the services according to what they want and for which they are prepared to pay, they have better incentive to use and maintain the facilities they purchase.

Development Perspective: Bangladesh

Development programs in Bangladesh take place within the general policy framework of the five-year development plans. The policies and strategies for water supply and sanitation sector development are discussed in this situation analysis in terms of the fourth Five-Year Plan (4FYP). Among other things, the 4 FYP emphasizes several shifts:

- a gradual shift of the public service delivery agencies from being "providers" of services to "facilitators" for clients (individuals and agencies),
- particular attention to human resource development within programs,
- bringing women into the main development streams,
- mobilization of local resources,
- encouraging and supporting the growing contribution of the private sector to development efforts, and
- restructuring and reorienting administrative organizations to make these possible.

The above facts and information are just an eye opening to the future planers and decision-makers where they will plan and implement the technical projects where WatSan. issues will be at the core of the project concept. The socio-economic status of the society, cultural behaviour, traditional *thinking and way of cooping with situation, obviously are the factors to be take into consideration towards a successful project planning and implementation. Details of the socio-economic consideration in designing a WatSan project will be discussed in the technical lecture note no.9, 10 16 and 17.*

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Appropriate Technologies in WSS

Introduction

It is very difficult to find out a common definition of appropriate technology, which is accepted all over the world. Different agencies have their own approaches in defining the term. For example International Labor Organisation (ILO), World Bank (WB) and World Health Organisation (WHO) defied appropriate technology compatible to their own perspective. However, definition of WHO is more relevant to water supply and sanitation activities.

Definition by WHO

The appropriate technology elements for water supply and sanitation are characterised by,

- Socio-cultural appropriateness,
- Affordability,
- Ease of maintenance with the skills available in the agency or community,
- Maximum use of locally available materials or spare parts,
- Easily understood attributes, and
- Technical efficiency.

Criteria for Appropriate Technology

From the above definition it may be said that appropriate technology should satisfy the following criteria.

- Employ local skills and material resources.
- Durable, effective and sustainable.
- Employ local financial resources.
- Compatible with local culture and practices.
- Satisfy local needs.
- Acceptable and affordable to users.

Selection of Appropriate Technology

Selection of an appropriate technology for a certain development project for a certain area is literally a very difficult job. It must come from the extensive experience and research. However, a list of principal actions which must complement standard practice to accelerate progress in providing water and sanitation services includes:

- Careful attention to proper balance among water supply, waste disposal and hygiene education.
- Dissemination of research outputs in appropriate technology and analyse the alternatives of meeting the demands of the few at high standards or meeting the basic needs of the many at simple standards.
- Institution-building efforts oriented towards the development of institutions and institutional hierarchies that can reach large numbers of communities and beneficiaries effectively.
- Increased attention to the training of staff in developing countries for improvement of water supply and sanitation - not only technical and commercial personnel, but also promotion, health and extension works.

The process of selecting appropriate technology begins with an examination of all of the alternatives available for improving sanitation. There will usually be some technologies that can be readily excluded for technical or social reasons. For example, septic tanks requiring large drainfields would be technically inappropriate for a site with a high population density. Similarly, a composting latrine would be socially inappropriate for people who have strong cultural objections to the sight or handling of excreta.

Once these exclusions have been made, cost estimates are prepared for the remaining technologies. These estimates should reflect real resource cost, this may involve making adjustments in market prices to counteract economic distortions or to reflect development goals such as employment creation. Since the benefits of environmental factors in the community that act as disease vehicles and recommend improvements that can help prevent disease transmission.

The final step in identifying the most appropriate sanitation technology rests with the intended beneficiaries. Those alternatives that have survived technical, social, economic, and health tests are presented to the community with their attached price tags, and the users themselves decide what they are willing to pay for.

Key Factors for Appropriate Technology

Some of the key factors need to be considered for different WSS facilities are:

Water Supply

Technical

- Source of water
- Hydro-geological conditions
- Quality and quantity of available water
- Design of technology
- Capacity/output
- Availability of skills
- Availability of spare parts

Social

- Ability and willingness to pay
- User friendliness
- Ease of operation
- Ease of repair and maintenance

Financial

- Installation cost
- Operation cost
- Maintenance cost
- Cost of spares

Sanitation

Technical

- Ground condition
- Design of technology
- Users number
- Availability of Skill
- Location / site
- Sources of water

Social

- Hygiene education
- Motivation to use
- Privacy
- Super structure
- Defecation habit
- Religious sanctions

Financial

- Installation cost

Technological Options in Water Supply and Sanitation

Water Supply

Drinking water supply in Bangladesh is based on groundwater sources. Groundwater is free from pathogens and requires no treatment for domestic water supply. But ground water is rich in dissolved salt specially dissolved iron and hardness in groundwater in relatively shallow aquifer is quite high which restricts the other domestic uses of tubewell water. Now presence of Arsenic in groundwater has become a great concern in Banglsdeh.

Depending on the hydrogeological conditions of our country, three types of tubewell technologies are mainly used for abstraction of water in rural areas. These are:

- Shallow Tubewell Technology
- Deepset Intermediate Technology
- Deep Tubewell Technology.

Shallow Tubewell Technology

In shallow tubewell technology, handpumps are operated in suction mode. The suction handpumps can practically extract water from upto a depth of 7.5m of static water level. The following handpumps are within this category:

- No.6 Handpump,
- Rower Pump,
- Treadle Pump,
- Bamboo Handpump,
- Shallow Shrouded Tubewell (SST),
- Very Shallow Shrouded Tubewell (VSST) etc.

The most common technologies used for the abstraction of water in Bangladesh are No.6 pump in high water table areas. About 3 million public and private No. 6 handpumps are operational in rural areas of Bangladesh. In some very high water table areas Rower and Treadle pumps are mainly used for irrigation purpose and occationally used for domestic purpose. Open dug wells and bamboo handpumps are also used for domestic water supplies and homestead gardening.

Shallow Shrouded Tubewell (SST) and Very Shallow Shrouded Tubewell (VSST) are used in coastal areas. SST is installed at a relatively shallow depth in a fine sand aquifer bearing fresh water in the coaster belt. The strainer of this type of tubewell is usually shrouded by coarse sand to obstruct the fine sand to facilitate the pumping of water. This type of tubewells are usually installed upto 15-20 metres in depth. VSST is appropriate to abstract water from fresh water pockets in the saline belt. This type of tubewells is installed between 8 to 10 metres below the ground level.

Deepset Intermediate Technology

Water can be abstracted beyond suction limit using intermediate technology. The following handpumps are within this category:

- Tara Handpump,
- Bangla Handpump,
- Moon Handpump
- Other locally produced improvised deepset pumps, etc.

Deepset handpumps can withdraw water beyond the suction limit. They can abstract water upto 30m of static water level depending on the technological advancement of the handpumps.

Analysis of groundwater level reveals that groundwater table in 35% of the area of Bangladesh will be beyond suction limit within year 2000 as compared to 25% in 1993. This will make one hundred thousand handpumps operating under suction mode in-operational. A technological shift from shallow technology to intermediate technology would be required to maintain the existing water supply coverage in these areas.

Tara handpump is a deep-set pump which is a product of the research by UNICEF and UNDP-World Bank Program. A standard low-lift direct action Tara handpump was designed in 1986. It is suitable for drawing water from the low water table zone upto a depth of 15m of static water level. There are different versions of Tara pump. These are:

- *Tara*
- *Mini Tara:* (conversion of existing 1.5 in dia suction pipe with total head capacity of 50 ft)
- *Super Tara*: (improved version of standard Tara pump with total head capacity of 80 ft)
- *Tara-II*: (improved version of standard Tara pump with total head capacity of 100 ft)
- *Tara-dev.*: (improved version of standard Tara pump with total head capacity of 100-150 ft)

Bangla Pump is a deep-set pump designed for low water table areas. It uses No.-6 pump head for getting leverage advantage. Maximum discharge of a Bangla handpump is about 0.6 lit/sec and suitable for lifting head upto 30 meter.

Moon Pump is a lever action deep-set handpump. It is a hybrid pump and special feature of Moonpump is its head assembly. No.-6 Pump head is used for head assembly of a Moon pump. Maximum discharge of a Moon handpump is 0.6 lit/sec and is suitable for lifting head upto 25 meter.

Local tubewell mechanics , in collaboration with local private workshops / manufacturers, have installed many deepset handpumps in LWT areas. These are functioning to some extent and require further research for technological advancement.

Deep Tubewell Technology

Though deep tubewell operates under suction mode exactly in the same principle as a shallow tubewell, the only difference is that the length of a deep tubewell is more than 75m. In most saline zone (coastal belt) the depth of the tubewell is about 300m. Deep tubewells are usually installed in saline areas to extract water from fresh water aquifer. Mechanical devices are necessary for construction of these tubewells.

Comparison among some conventional water supply technological options is shown in Table-1.

Table 1: Comparison among some conventional water supply technological options

Different Technological Options	Cost	Advantages	Disadvantages	Status in Bangladesh
Open Dugwell	Low	❑ Lowcost ❑ Free from iron and arsenic.	❑ Sanitary protection is difficult. ❑ Water collection is difficult.	❑ Construction has been restricted by large scale installation of tubewells.
No. 6 Handpump	2,000-4,000 Tk.	❑ Suitable for favourable shallow water table area (upto 7.5 m). ❑ Presenly private sector is providing services and spare parts for installation, maintenance and repairing. ❑ The spares are available in open market. ❑ Easy to operate.	❑ Many tubewells producing water with high arsenic content. ❑ Water generally hard, use for bathing and cooking is restricted by different complaints.	❑ Well adopted throughout the country. ❑ No.6 handpump is promoted by UNICEF, DPHE and also private sector.
Tara Handpump	13,000-15,000 Tk.	Suitable for LWT zone upto a depth of 15m of static water level.	❑ More force is required. ❑ Buoyancing force is not always available due to leakage in pump rod. ❑ Provides moderate output upto 7 m lift and very low output upto 12 m lift. ❑ Repairing/ replacement of any part is inconvenient. ❑ Installed mainly through the public sector. ❑ Tara has not yet been proved to be user friendly.	❑ Tried on experimental basis. ❑ Tara handpump is promoted by UNICEF, DPHE, UNDP-WB.
Deep Tubewell	50,000-70,000 Tk.	Deep tubewells are usually installed in saline areas to extract water from deep fresh water aquifer.	Mechanical devices are used for construction of these tubewells. The installation cost of deep tubewell is too high.	Deep tubewells are promoted by UNICEF and DPHE.

Different Technological Options	Cost	Advantages	Disadvantages	Status in Bangladesh
Pond Sand Filter (PSF)	20,000-30,000 Tk..	PSF can utilise surface water and especially suitable for coastal belt and arsenic affected areas.	❑ O&M and construction of PSF are difficult. ❑ Performance of PSF depends on regular cleaning. ❑ Cost of PSF is high.	Tried on experimental basis. PSFis promoted by UNICEF and DPHE.
Shallow Shrouded Tubewell (SST)	10,000-20,000 Tk.	Extract sweet water in saline belt.	❑ Identification of the existence of fresh water pockets is difficult.	❑ Tried on experimental basis. ❑ SST is promoted by UNICEF and DPHE.
Very Shallow Shrouded Tubewell (VSST)	8,000-12,000 Tk.	Extract sweet water in saline belt.	❑ Identification of the existence of fresh water pockets is difficult. ❑ Drilling failure is common. ❑ Lifespan is short.	❑ Tried on experimental basis. ❑ VSST is promoted by UNICEF and DPHE.
Rain water harvesting	Medium	Suitable for arsenic affected areas. Free from impurities.	❑ Uneven distribution of rainfall throughout the year.	❑ Tried in experimental basis, but not accepted.

Water Treatment Technology

Surface water in Bangladesh is highly polluted and needs extensive treatment for use as drinking water. The installation of treatment plants for water supply for the scattered population in the rural area is not feasible. In water quality problem areas especially in saline areas small scale experimental treatment facilities are being used for the purification of low saline surface waters for community water supply. These treatment facilities are:

- Pond Sand Filter (PSF)
- Infiltration Gallery (IG)

Pond Sand Filters are slow sand filters installed to purify pond water. Infiltration galleries are also constructed very close to low saline surface water sources to collect treated (infiltrated) water for domestic purpose. These are low cost technologies but the main problems encountered include lack of maintenance and management by the users.

The small-scale community type Iron Removal Units (IRUs) are now being used in Bangladesh for the treatment of ground water. A few experimental units of different models have been tried and some are being used successfully. Also maintenance is the problem in the operation of these plants. their performance is under observation.

Arsenic in groundwater has been found in presence of iron. Iron Removal Units also remove arsenic to a certain extent. A few iron-arsenic removal units attached with hand tubewells have been constructed in some iron-arsenic problem areas of Bangladesh. These units operate under aeration-sedimentation-filtration principles. The performance of these plants is under observation.

An Iron-Arsenic Removal Unit attached with Handpump is shown in Figure 1.

Figure 1 Iron-Arsenic Removal Unit attached with Handpump

Sanitation

There are many technological options available for on-site and off-site treatment and disposal of human wastes. Some of these options have been shown in **Figure 2**.

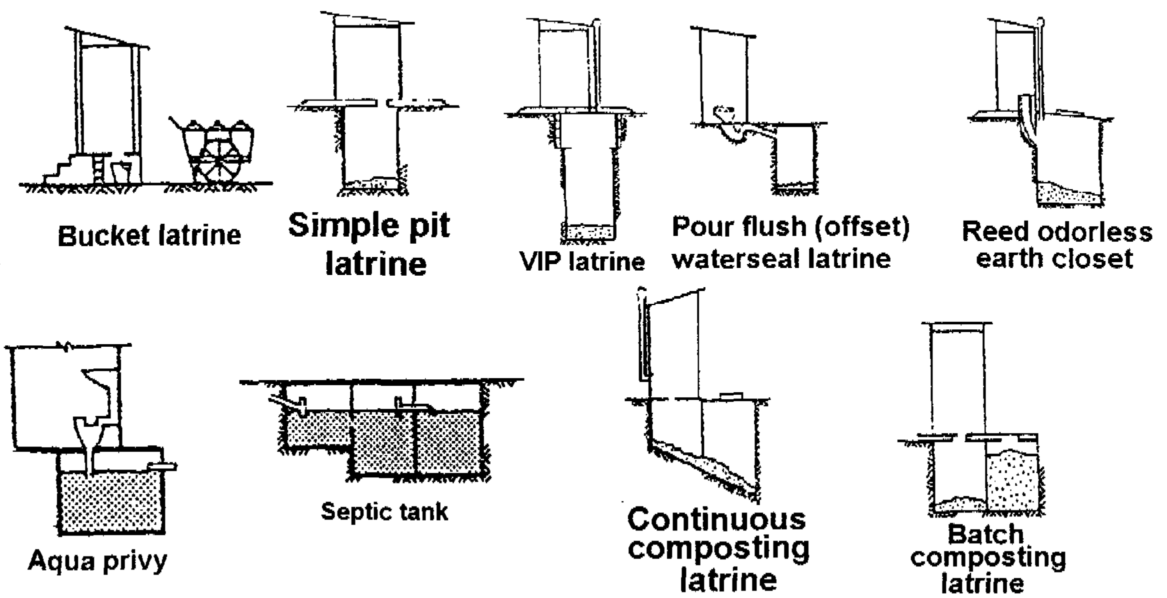


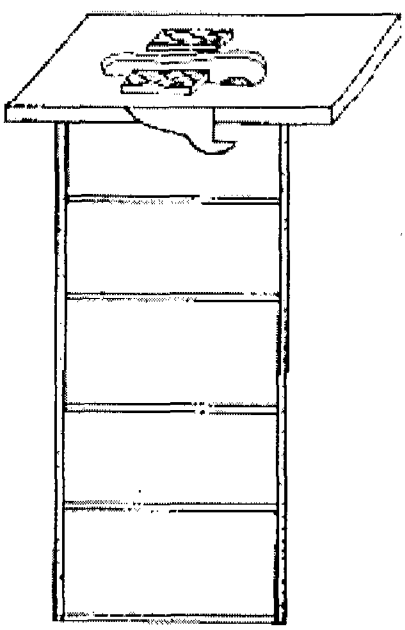
Figure 2 Alternative Technological Options for Sanitation

The common sanitation technologies in Bangladesh are sewerage system, septic tank, sanitary pit latrines and others including home made latrines and defecation in open areas. The population coverage by different technological options is shown in Table 2.

Table 2: Population coverage by different sanitation technology

Sanitation Technology	Population Coverage %				
	Dhaka	**Chittagong**	**Zilla Towns**	**Thana Towns**	**Rural Area**
Sewerage System	**18**	-	-	-	-
Septic Tanks	40	31	22	6	-
Sanitary Pit Latrines	15	7	16	16	18
Others	27	62	62	78	**82**

In Bangladesh water-seal direct pit latrine shown in **Figure 3** has been found suitable for rural areas and twin pit water seal latrine as shown in **Figure 4** has been recommended for use in the small urban centres. Septic tank is the preferred option for large urban areas.



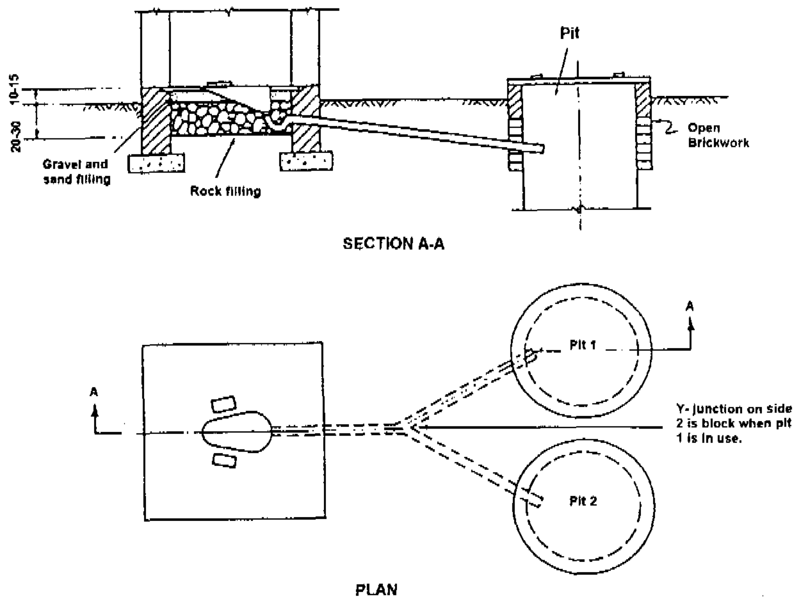


Figure 3 Water-seal Direct Pit Latrine

Figure 4 Twin Pit Water-seal Latrine

The comparison of different alternative sanitation technological options in respect of cost, health benefit, water requirement and status in Bangladesh has been shown in Table 4.

Table 4 : Alternative Sanitation Technological Options

Type	Cost	Health Benefit	Water Requirement	Status in Bangladesh
Bucket Latrine	Medium	Low	None	Available, being gradually phased out.
Direct Pit Latrine	Low	Low	None	Acceptable as low-cost method.
Offset Pit Latrine	Low	Moderate	Water near toilet	Acceptable as low-cost method.
Ventilated Improved Pit (VIP) Latrine	Low	Moderate	None	Tried on experimental basis.
Reed Odourless Earth Closet (ROEC)	Low	Moderate	Water near toilet	Modified version adopted in limited scale.
Pour-Flash, Water-Sealed Direct Pit Latrines	Low	Good	Water near toilet	Accepted in rural sanitation programme
Pour-Flash, Water-Sealed Offset Pit Latrines	Medium	Very Good	Water near toilet	Accepted in municipal sanitation programme.
Double Vault Composting Latrine	Medium	Low / Moderate	None	Tried on experimental basis, but not accepted.
Continuous Composting Latrine	Medium	Low / Moderate	None	Not available.
Aqua Privy	High	Good	Water near toilet	Not available.
Septic Tank and Soak Pit	High	Very Good	Piped or enough water	Widely accepted in municipal sanitation.
Small Bore Sewer (SBS) System	Very High	Very Good	Piped water supply	Designed but not yet implemented.
Conventional Sewer System	Very High	Very Good	Piped water supply	Available in Dhaka only.

Sanitation Practices and Problems in Bangladesh

Introduction

In our country about 38% of the rural population uses sanitary latrines including homemade latrines. People are now conscious of using latrine and 61% of the total population are using some form of latrine. Overall urban sanitation coverage is 42%.

The commonly used options for sanitation in Bangladesh are the 'home-made', single pit water seal and twin pit water seal latrines. Of the sanitary latrines in the rural areas, 60% are home made. In urban areas water borne sewerage system and a range of on-site options such as septic tanks, single and double pit latrines are used. Only Dhaka city has a limited sewerage system that covers only 18% of the population.

Sanitation Practices

People in general have very poor understanding about the relationship between health and sanitation. Rural sanitation suffers much from poor understanding of the health benefits of sanitary latrines. Latrines are used for reasons of convenience and privacy rather than health reasons.

In slum areas, situation is deplorable. The sanitary condition of slums is miserable and inhuman. Most of the slum dwellers have literally no latrines, only a few have pit or surface latrines. They often defecate in open fields, in the bushes, near the roads, in the drains or on the riversides. The problem is acute with female residents who have to wait till sunset for defecation or use a neighbour's latrine, if available.

Difference in Defecation Practice

There is difference in defecation practices between males, females and children. There are some significant gender variations in defecation habits as well as there are variation between adult and children.

A Survey: 'Socio-economic Survey on Low Cost Sanitation'

A survey was carried out by Local Govt. Engineering Bureau (LGEB) on 'Socio-economic Survey on Low Cost Sanitation' in 9 pourashavas during 1989. An analysis was done on the basis of survey on sanitation practices, arrangements for excreta disposal, defecation practices, low cost sanitation system, willingness to acquire and ability to pay for sanitary latrines etc.

Some findings of the survey is given below:

Latrine Type and Income

There is a relationship between latrine types and income. It was found in the survey that, household with an annual income of Tk. 10,000 do not have any sanitary latrines, while household having high income often acquire sanitary latrines, although little above than 50% still have unsanitary latrines for use. Among the households of the lowest income group, 42.6% have unsanitary latrines and 57.4 % have no latrines. It was observed from the survey that a high percent of households with annual income upto Tk. 30,000 have either no latrine or only unsanitary latrine.

Latrine Type and Education

There is a linear relationship between the level of education of the respondents and the type of latrines they use. It was observed that, there is an increase of the use of sanitary latrines by respondents as they progress on the educational ladder.

Defecation Practices of the Households having no Latrine

The household survey found that defecation practices of adults and children vary according to social groups. This finding confirms actual observations made during the study.

Out of 715 households, 195 reported not possessing any latrine. It is therefore interesting to know the places where the members of these households defecate. The data in the Table-1 have been generated asking the household respondents about places of defecation for family members.

Table 1 : Distribution of Respondents having No Latrine.

Places	Male (%)	Female (%)	Children (%)
Landlord's Latrine	2.6	2.6	1.5
Neighbour's Latrine	14.4	27.2	2.6
Roadside Drain	1.5	0.5	6.1
Open Field	46.2	29.7	75.4
River, Water Bodies	12.3	12.8	8.7
Jungle	12.8	27.7	8.7
Public toilet	10.2	0	1

Table 1 shows that 14.4% males and 27.2% females use a neighbour's latrine for defecation, while 46.2% males, 29 females and 75.4% children defecate in the open fields. The percentage of children defecting in the open fields is found very high because children defecate more frequently than the adults and some parents instruct them not to use a latrine since the pit will fill up too fast. Females more frequently use a neighbour's latrine (27.2%) and are much more accustomed to defecate in the jungle (27.7%) than their male counterparts (14.4% use neighbours' latrine, and 10.25% defecate in the jungle). For children's defecation, public toilets are seldom used. There is a gender variation among the adults in using public toilets. Women folks do not use public toilets at all, which males do (10.25%). The group discussions revealed that the public toilets are not safe for women because of the lack of privacy.

Children's Defecation Practices

During group discussions it was confirmed that most of the children below 5 years in households either having a latrine or no latrine defecate in the open homestead compound. This is due either to the high altitude of the latrine door, or the squatting plate is so designed that it is difficult for children to squat comfortably. It is unrealistic to expect that children should use a fixed place for defecation, while their parents defecate indiscriminately. Many mothers do not feel the necessity to enforce strict rules on children's defecation practices, because they opine that children's faeces do not produce offensive smell, and that children's faeces are less harmful than those of adults. There is hardly any difference between households with a latrine and those without latrine in this respect.

Children's faeces are generally disposed of by washing in the water bodies (34.7%) and throwing in the jungle (52.1%). Table 2 further illustrates this fact.

Table 2: Household wise Distribution of Methods for Children's Faeces Disposal.

Ways	%
Washing in Water body	34.6
Washing under Tubewell	3.2
Throwing in the Jungle	52.1
Throwing in the Yard	10.1

Hand Washing after Defecation

Group discussion reveals that women folks do not properly wash their hands after defecation and before preparation of food. The prevalent Pourashava picture shows most of the women prepare and serve food for the family members without proper cleaning of their hands.

Major Finding

Women's participation in sanitation program is indispensable to promote use of safe latrines.

Sanitation Problems in Bangladesh

Housing Density

Single-pit latrines are suitable for use in rural areas and low-density urban areas up to about 300 people per ha. It is difficult to be more precise in general terms, as local factors, such as average household size, housing design, plot layout and area, have such a large influence. At higher densities alternating twin-pit latrines may be feasible, but other options- such as small bore sewers, community latrine cum biogas plant etc. may be more appropriate solution.

Water Supply Service Level

In areas where water use is low (say, less than 30 l/c/d) and where water has to be hand-carried from public standpipes, tubewells or communal wells, pit latrines (of whatever type) are technically feasible sanitation options.

Operation and Maintenance

- In all latrines cleanliness is of the utmost importance. Squatting slabs easily become fouled and pour-flush bowls may block up. Fouled and unhygienic pit latrines are found all over the country, often because they have been constructed in communities previously accustomed to defecation on the open ground who have also had inadequate health education. Fouled pit latrines become a focus of disease transmission and may create health hazard.
- Water seal, the essential part of the sanitary latrine often breaks down. Sometimes, other garbage thrown into the pan blocks the latrine.
- Often it is observed that necessary action has not taken by individual households when the pit fills up. Sometimes, the pits are very shallow and fill up too soon for households to get into the habit of using latrines. As a result, they prefer to go back to open defecation to avoid the inconvenience of frequent cleaning or change of pits.
- Most of the time, Y junction of the double pit latrines does not work properly.

Pathogen Survival in the Pit

For twin pit sanitary latrines when a pit is dug out a year or two after closing to use the contents as fertiliser, it is expected that it is safe against pathogens. But there is chances of Ascaris eggs being present especially even to a greater extent if the pit is wet and partly below the water table. There is a risk of health hazard for reusing material to use on the fields immediately.

Insect Breeding

Pit latrines usually become breeding sites for flies. Flies that visit a pit latrine to reed or feed carry pathogens and promote disease transmission. If the pits are wet, these may also become breeding sites of mosquitoes *(culex pipiens)*.

Soil Permeability

Soils with permeability below 2.5 mm per hour (for example, expansive clays) are unsuitable for pit latrines, as the liquid fraction of the excreta is unable to infiltrate into the soil.

Groundwater Pollution

The deposition of excreta in pits may pollute water sources: particularly wells, tubewells, pond etc. located nearby. The danger of pollution increases if the pit is dug down to the water table or to fissured or weathered rock. Bacteria will not penetrate more than 1-2 m in most unsaturated soils, but they have been known to travel over 100 m in gravel below the water table and in rock fissures. In general, the bacterial contamination may spread as far as the distance travelled by the ground water itself in ten days. Where it is necessary to avoid any risk of faecal contamination of ground water, there should be at least 2 m of soil depth between bottom of the pit and the water table surface.

Wet pits have the advantage over dry pits that they last longer, as the rate of solid accumulation is lower. But they can pose problems of mosquito breeding in the high water levels within the pit and subsequently cause groundwater pollution. The extensive literature on groundwater pollution from on-site sanitation systems has recently been critically reviewed. This review highlights the need for a thorough understanding of the local soil and hydrogeological conditions may have the potential of groundwater pollution from on-site sanitation systems can be made.

Users are advised to locate pits at least 10m from water sources to avoid potential pollution. The 1992 national study showed that in rural areas over 30% of the latrines were located within 10m of a pond, over 24% were within that range of another water source, and 18% were within 10m of a handpump. In urban slums and fringe areas, 49% of latrines were located within 10m of a handpump.

Construction of Pit Latrines

- Pits dug in loose and unconsolidated soils (e.g., sand or fine-grained alluvium) is difficult and the lining must not prevent the seepage of faecal liquors out of the pit into the surrounding soil.
- Pit latrines are vulnerable in areas which are annually flooded or where water tables rise during the monsoon. Flooding undermines the durability of latrines and contributes to the contamination of the surrounding ground water. The usual practice is to elevate the soil excavated from the pit. But often it is seen that the latrines are not placed above flood level. In such circumstances an elevated pit of about 1 m high with an impermeable lining extended down at least 0.6 m below ground level is appropriate.

- Construction of pit latrine becomes both difficult and expensive in rocky ground. Householders wishing to build pits in rocky areas might need assistance from the local public works department for digging with mechanical devices. In these areas, there is a common tendency to dig shallow pits which fills up rapidly and do not serve the purpose.
- Tilted placement of waterseal pan may cause losing of criteria for watersealing.

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Sanitation Technology Options

Introduction

Healthy life can be achieved by adopting simple hygiene habits like using safe water for all purposes, using sanitary latrines and taking care of personal hygiene and keeping the surrounding environment clean. Infectious diseases are transmitted by pathogens present in human excreta. Therefore, proper sanitation system is necessary to carry human excreta back to nature, providing comfort and convenience to users, minimising risk to excreta related diseases, and creating less pollution to the environment.

In urban areas water borne sewerage system and a range of on-site options are used. Only Dhaka city has a limited sewerage system that covers only 18% of the population. In rural areas and urban fringes, low cost sanitary latrines are preferred. Sanitary latrines prevent spreading of excreta related diseases, reduce bad smell and cause minimum pollution to soil, underground water and environment.

A brief overview of various sanitation technology options is given in this note. The commonly used sanitation technology options in rural areas and urban fringes are:

- Pit Latrine Technologies
- Pour Flush Technologies

Pit Latrine Technologies

Pit latrines are the simplest of all on-site disposal systems. Pit latrine consists of a pit with a platform having a defection hole. Excreta fall into the pit through squat hole. In rural areas of our country traditionally people defecate into a squat hole on a bamboo/wooden platform placed over a pit. This type of latrine is called homemede latrine as shown in **Figure 1**.

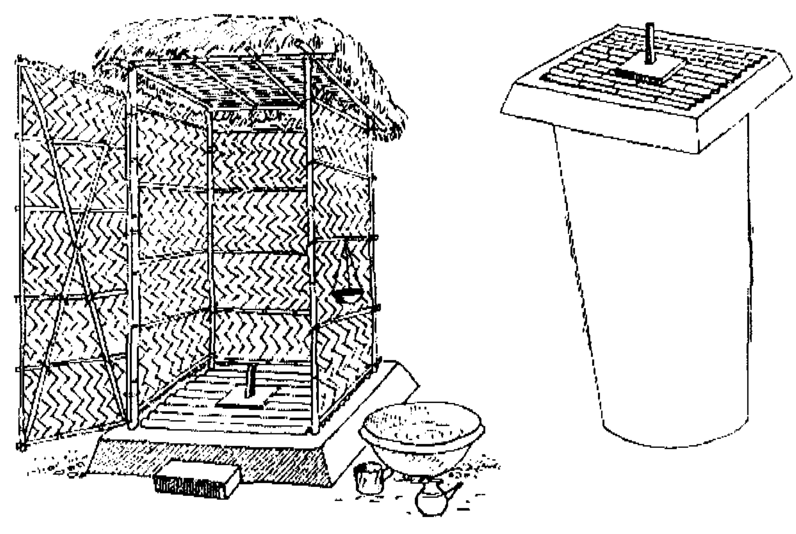

Figure 1 Homemade Latrine

Basically this is not a recommended practice, however, it is much better than open defecation. Since home-made latrine is low-cost and can be easily constructed even by the family members, promotion of this type of latrines is sometimes encouraged though it is not fully sanitary. With little intervention, this type of latrines can be altered to be a hygienic one.

General Design Considerations for Pit Latrine

- The pit should be as large as possible, however, it should not be more than 1.5 m wide, otherwise construction of cover slab will be more expensive.
- Soils with permeability below 2.5 mm/hour are unsuitable for pit latrines as the liquid fraction of excreta is unable to infiltrate into soil.
- Pits in unstable soils must be fully lined, otherwise there is risk that the pit will collapse and the superstructure may fall into it. A wide variety of materials can be used to line the pit; for example, concrete blocks, bricks, cement-stabilised soil blocks, masonry, perforated oil drums, etc. The pit can also be strengthened against collapse by putting a ring beam around the upper part.
- Safe distance between pit and tubewells or any other waterbodies should be at least 10.0m.

Pit Latrine Design

Effective Pit Volume: The effective pit volume depends on the solids accumulation rate, the number of users and desired life of pit. The effective volume can be calculated as,

$$\mathbf{V = C \times P \times N}$$

Where,

V= Effective Volume of the pit,
C= Solids accumulation rate,
P= Number of person will be using the latrine, and
N= Design life in years.

Solid Accumulation

Excreta deposited into the pit have two essential components;

a) liquid fraction of excreta (mainly urine), together with small amount of water that enters the pit due to anal cleansing, slab washing which ultimately infiltrates into the surrounding soil;
b) faecal solids in excreta that are digested anaerobically to produce (i) gases such as methane, carbon dioxide and hydrogen sulphide which are exhausted from the pit via the vent pipe; and (ii) soluble compounds which are either further oxidised in the pit or are carried into the surrounding soil by infiltrating liquid fraction.

In dry pits (not extend below groundwater table), solids accumulation rate varies between 0.03 and 0.06 m^3/person/year, and in wet pits between 0.02 and 0.04 m^3/person/year. Accumulation rates are lower in wet pits because biodegradation is faster under wet conditions than under the only just moist conditions in dry pits. For design purpose, solids accumulation rate may be taken as 0.04 and 0.06 m^3/person/year in wet and dry pits respectively.

The effective pit depth is calculated from effective pit volume.

Effective Pit Volume, $V = (\Pi d^2/4)h$

$$\text{or,} \quad V = \Pi d^2 h/4$$

Where,

d = diameter of pit and
h = effective depth of pit.

Assuming a suitable diameter (maximum permissible diameter is 1.5m) of pit, the effective pit depth, h can be obtained. Then total depth will be effective depth plus the desired free space above inlet of the pit. Usually a free space of 0.5 m is kept at top of the pit.

Total Depth of Pit, H = Effective Depth of Pit, h + 0.5m

Simple Pit Latrine

The simplest and cheapest improvement of a homemade pit latrine by providing with a prefabricated slab with a squatting pan is called a simple pit latrine. It is a very cheap sanitation option. For structural stability reinforcement is placed in the slab as shown in **Figure 2**.

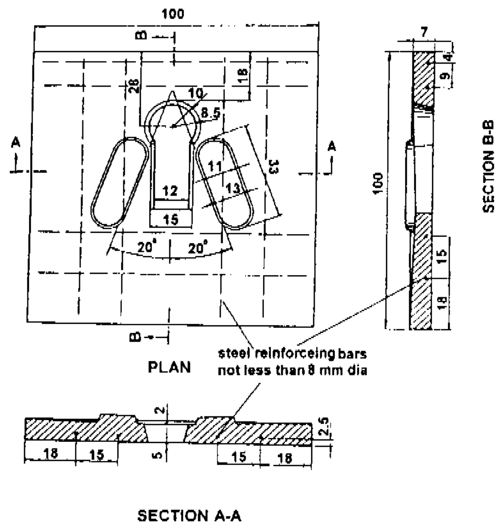

Figure 2 Square, reinforced, concrete squatting slab of a simple pit latrine

The need for steel reinforcement can be reduced or even avoided by making the slab slightly domed or conical in shape as shown in **Figure 3**. Prefabricated cement slab of a simple pit latrine prevents transmission of hookworm. Pit lining is required in loose soils.

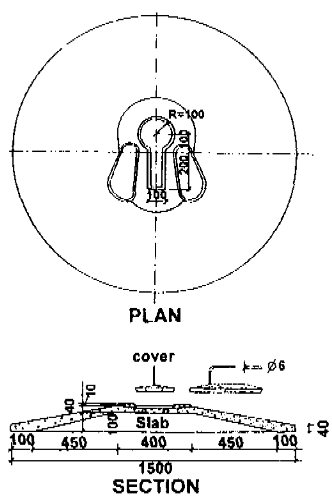

Figure 3 Round, conical, unreinforeced concrete sqatting slab of a simple pit latrine

Advantages

- Least costly.
- Structurally safer.
- Easy construction and maintenance.
- Free from the risk of falling a child into it, and therefore safer and less frightening for children.
- Prevents hookworm transmission.

Disadvantage

- Flies lay their eggs in faeces within poorly built latrines. Increase in the population of flies helps in spreading of diseases caused from faecal pathogens carried by flies.

VIP Latrine

A VIP latrine has a tall vertical vent pipe with a flyscreen fitted at its top as shown in **Figure 4**.

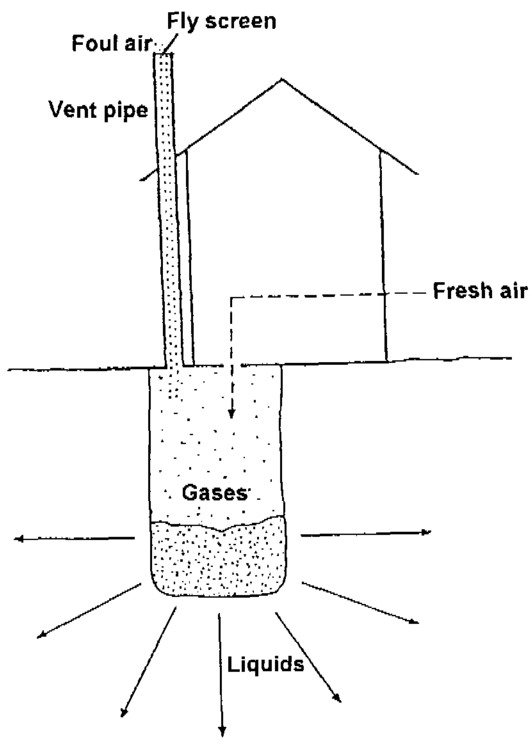

Figure 4 Sketch of a Ventilated Improved Pit (VIP) Latrine

Types of VIP Latrines

There are two types of VIP latrine,

- Single-pit VIP Latrine and
- Alternating Twin pit VIP latrine.

Single-pit VIP Latrine

Single pit VIP latrine has only one pit with own vent pipe and a superstructure over it. It is designed with a long life (at least ten years) and acts as a permanent structure (**Figure 5**).

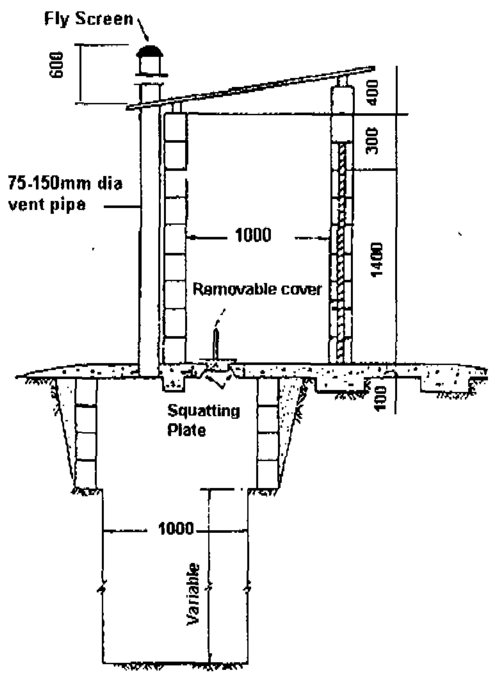

Figure 5 Single Pit VIP Latrine

Alternating Twin pit VIP latrine

Alternating twin-pit VIP latrines have two separate pits, each with their own vent pipe under only one superstructure. The slab within the superstructure has two squat-holes, one over each pit (**Figure 6**).

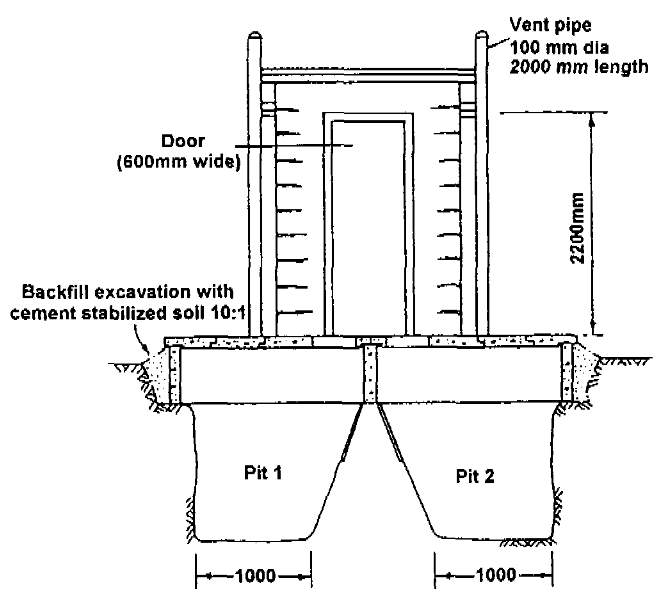

Figure 6 Alternating Twin Pit VIP latrine

Only one squat-hole and pit are used at a time. When this pit is full, after 1-3 years, its squat-hole is covered up and the second pit is put into service. After a further period of 1-3 years, when the second pit is full, the contents of first pit are removed to enable it to be used again. This alternating cycle goes on. This type of VIP latrine is thus a permanent sanitation facility suitable for using in urban areas where there is insufficient space.

Special Features of VIP Latrine

Odor control: The principle mechanism of ventilation in VIP latrines is action of wind blowing across top of the vent pipe. The wind effectively sucks air out of the vent pipe and this air is replaced from atmosphere via latrine superstructure and squat-hole. Moreover, gases generated in the pit are warmer and lighter. Therefore, the gases flow through the ventpipe. A constant circulation of air from outside the latrine, through superstructure and squat-hole, and up and out of the vent pipe keeps the latrine odor-free.

Insect control: Female flies, searching for an egg-laying site, are attracted by faecal odors coming from the vent pipe but they are prevented from entering by the flyscreen at outlet of vent pipe. Some flies may enter into the pit via squat-hole and lay their eggs there. When new adult flies emerge they instinctively fly towards light, however, if the latrine is dark inside the only light they can see is that at top of the vent pipe. If the ventpipe is provided with a flyscreen at its top, new flies will not be able to escape and they will eventually fall down and die in the pit.

Design Considerations for VIP Latrine

Design Life: For Single Pit VIP latrine, design life should be as long as possible; at least 10 years is desirable. Longer the design life, longer the interval between relocating or emptying latrine. For Alternating Twin Pit VIP latrine the design life should be 1-2 years.

Dimensions: Usually the pit cross-sectional area should not be more than 2 m^2 in order to avoid cover slabs with large spans. In practice, VIP latrines serving one household commonly have a diameter of 1-1.5 m or, in case of square or rectangular pits, a width of 1-1.5 m.

Vent Pipe Design: Vent pipes of a wide variety of different materials are used, for example, polyvinyl chloride (PVC), unplasticized PVC (uPVC), bricks etc. Whatever material is used, its durability (including corrosion resistance), availability, cost and ease of construction are important factors.

Length: The vent pipe should be sufficiently long so that the roof does not interfere with the action of wind across top of the vent pipe. For flat roof, top of the vent pipe should be at least 500 mm higher than the roof, and in case of sloping roof the vent pipe should be 500 mm above the highest point of roof.

Diameter: Internal diameter of the vent pipe depends on required venting velocity necessary to achieve recommended ventilation rate of 20 m^3/hr, and this in turn depends on the factors like internal surface roughness of the pipe, its length (which determine the friction losses), the head loss through flyscreen and wind direction. Current recommendations for minimum internal size of vent pipes are as follows:

PVC	150 mm diameter
Brick	230 mm square
Others	230 mm diameter

Flyscreen Specification: The purpose of flyscreen is to prevent passage of flies and mosquitoes; therefore, the mesh aperture must not be larger than 1.2 mm × 1.5 mm. The flyscreen must be made of corrosion-resistant material that is able to withstand intense rainfall, high temperatures and strong sunlight. It is preferable to use stainless steel screens.

Relocation and Emptying of Pits: When single-pit VIP latrines become full, there are two options: i) construction of a new latrine on adjacent site, ii) emptying the existing pit. In rural areas, construction of a new latrine, reusing slab and vent pipe from the old one is preferred if space is available for a new latrine. Otherwise manual emptying is required which might pose health risks due to pathogens present in the fresh faecal material at top of the pit. A better solution might be to use single-pit VIP latrines with soakaway or alternating twin-pit VIP latrines.

No health risk is expected from manual removal of humus-like material from pit of an alternating twin pit VIP latrine, which is at least two years old, as all the excreted pathogens are non-viable, except a few Ascaries ova.

Soakaway Design: VIP latrine with adjacent soakaway increases the pit life. The latrine pit is completely sealed with cement mortar or mortared brickwork and a PVC pipe of 75mm dia is attached at a height of about 2.25m above the pit base which leads to the adjacent soakaway (**Figure 7**).

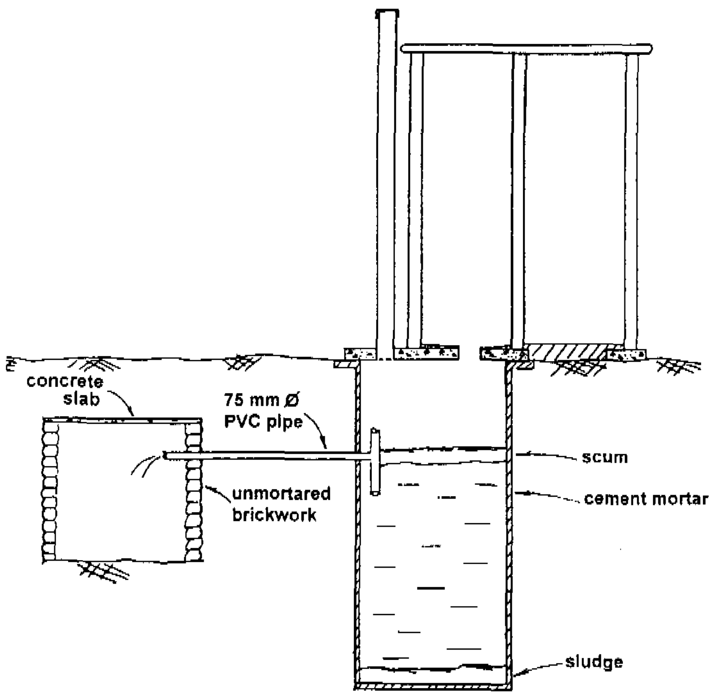

Figure 7 VIP latrine with adjacent soakaway

The soakaway has a diameter of 1.5 m and a depth of 2m; it is lined with unmortared bricks to a depth of 1.4 m. At this depth a reinforced concrete cover slab is placed on the bricks and the remaining space above it backfilled.

Advantages

- Low cost.
- Easy construction and maintenance.
- Minimum water requirement.
- Minimum health risk.
- Controls odor and insect.

Disadvantages

- Lack of space for relocating the pit in densely populated areas.
- Potential for groundwater pollution.
- Difficulty of construction in rocky and high water table area.

Reed Odourless Earth Closet (ROEC)

In Reed Odourless Earth Closet (ROEC) excreta are deposited into the pit via a chute located at the base of squat hole (**Figure 8**).

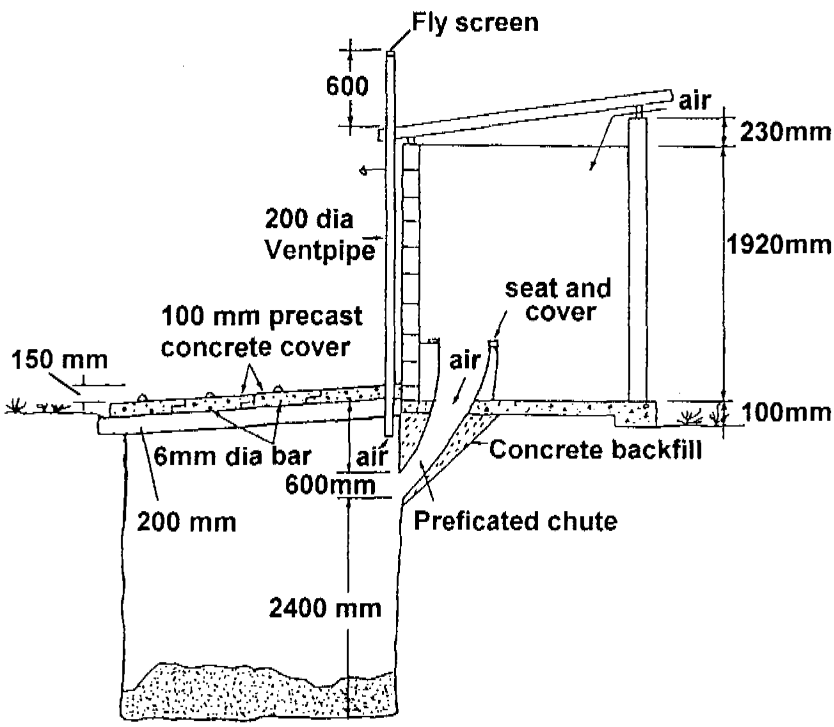

Figure 8 Reed Odourless Earth Closet (ROEC)

The ROEC is fitted with a vent pipe to control odor and insect nuisance. This latrine is common in southern Africa. The design considerations and design principles of ROEC is similar to those of a single pit VIP latrine.

Advantages

- Pit of ROEC is larger and thus has a longer life than VIP latrine.
- Pit can be easily emptied without disturbing the superstructure and it can be a permanent facility.
- It is not possible to see the excreta in the pit, which encourage use of the latrine.

Disadvantages

- The chute of ROEC can be easily fouled with excreta providing a site for insect and odor nuisance.
- The chute has to be regularly cleaned with a long handled brush.

Pour-flush Technologies

A further improvement to the pit latrine can be obtained with a water seal. Waterseal is a U-pipe filled with water, attached below the squatting pan that completely prevents passage of flies and odours. The water seal is only 15-25 mm deep and the latrine can be flushed by hand using 1.5 to 2.0 litres of water. The latrine can also be located, if desired inside the house with off-set pit. Smaller quantity of water used in a pour flush toilet is sufficient to carry the excreta to a soakage pit up to 8 m away.

General Design Considerations for Pour Flush Latrine

- The shape of pits can be circular, square, rectangular or even triangular depending on shape and size of the site.
- Minimum water requirement is 1.5 to 2.0 litres for flushing the toilet by hand.
- For ease in emptying and avoiding the possibility of ground water pollution it is desirable that the pits will be shallow in depth. In most areas in Bangladesh, pits should not exceed 1.8 meters.
- Pits may be lined with burnt clay, concrete, brick masonry, or even bamboo. About 0.60 meter below the top of pit, honeycomb brick with horizontal open brick joints should be provided.
- The inlet into the pit should be at least 0.5 meter above the highest ground water level.
- A free space should be kept over inlet of the pit. In practice, 0.5 m of free space at top of the pit usually kept above the inlet.
- In low lying or flood prone areas, the pits should be constructed on elevated earthen mounds with at least 1.50 m earth covering all around the pits.
- Bottom of pit should remain undisturbed and unsealed.
- Safe distance between pits and tubewells or any other waterbodies should be at least 10.0m.
- Permeability of surrounding soil is important for function of the pit latrines. Sandy or silty soil with/without clay is considered ideal. For pits in compacted clayey soil of low permeability, such as in the Barind Tract, a sand envelope of at least 0.3 meter should be provided around the pits.
- Distance between two pits should be, at least, equal to the effective depth of pits which is measured from the inlet pipe to bottom of the pit.

Design of Pour Flush Latrine

Pit Volume: The volume of the pit may be calculated from the following equation (Kalbermatten, et al, 1980):

$$\mathbf{V = 1.33 \times C \times P \times N}$$

Where,

V= Effective Volume of the pit (m^3),
C= Sludge accumulation rate, which is $0.04m^3$ /person/year for Pour Flush Latrine,
P= Number of person using the latrine, and
N= Number of years the pit is to be used before emptying.

Total Depth of Pit = Effective Depth of Pit + 0.5m

Types of Pour Flush Latrine are,

- Single pit pour flush latrine and
- Twin pit pour flush latrine.

Single Pit Pour Flush Latrine

The single pit pour flush latrine comprises of a squatting slab with a water seal and a pit. When the pit fills up, a new pit has to be dug and superstructure has to be relocated over the new one or the pit has to be emptied.

Types of Single Pit Pour Flush Latrine are,

- Direct Single Pit Pour Flush Latrine and
- Off-set Single Pit Pour Flush Latrine.

Direct Single Pit Pour Flush Latrine

Latrines having in-built water seal trap with its slab and directly placed over a pit is called direct single pit pour flush latrine as shown in **Figure 9**.

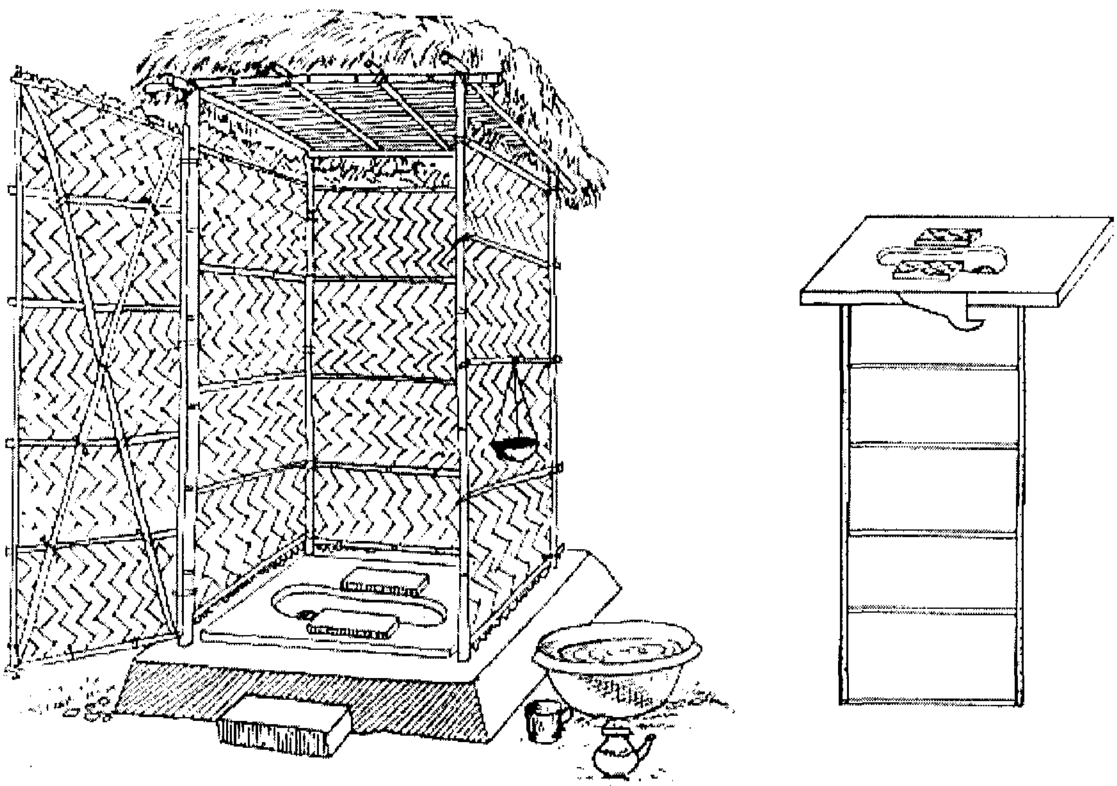

Figure 9 Direct Single Pit Pour Flush Latrine

Off-set Single Pit Pour Flush Latrine

Latrines having siphon as connector between the waterseal and the pit situated at a distant place is known as off-set single pit pour flush latrine (**Figure 10**).

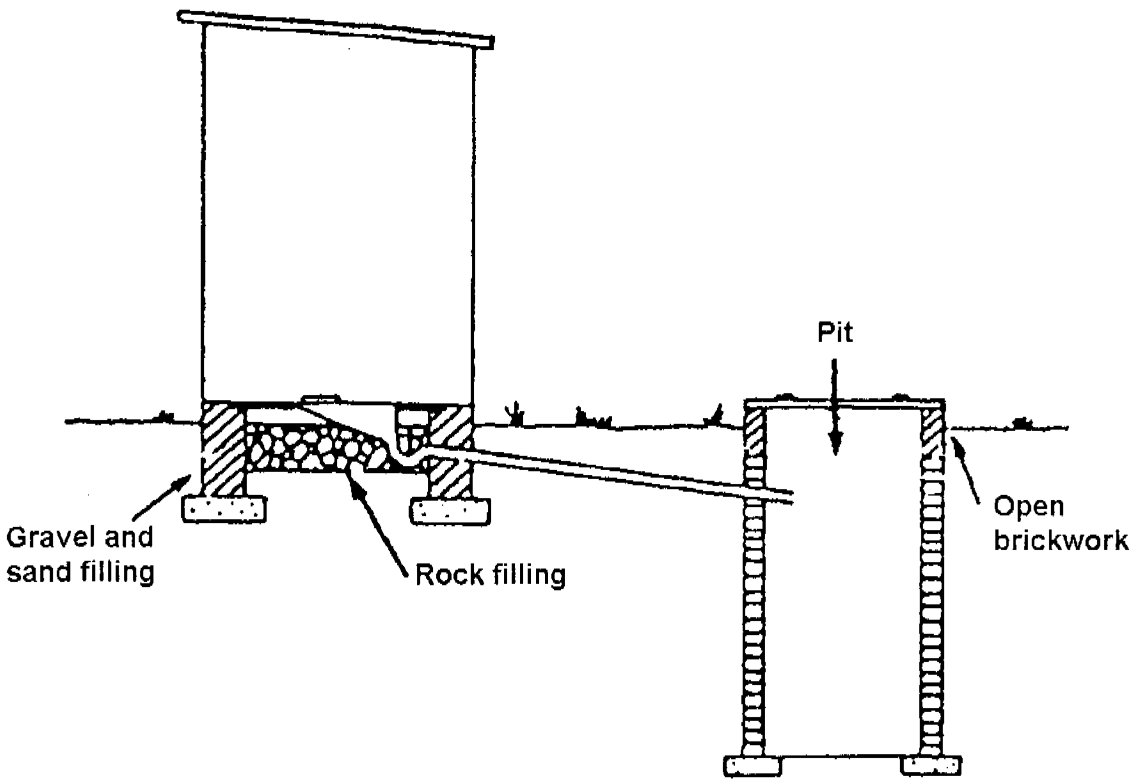

Figure 10 Off-set Single Pit Pour Flush Latrine

Advantages

- Less expensive compared to conventional latrines (with sewerage systems).
- Offers appropriate and hygienic solution for excreta disposal.
- Requires low volumes of water for flushing, (1-3 lit/flush only).
- Can be upgraded to connect to a sewer system or septic tank system.
- Eliminates odours, insect and fly breeding.
- Safe for children.
- Can be located, if desired, inside the house.
- Potential for resource recovery using the sludge as soil conditioner.
- Easy construction and maintenance of single pit pour flush latrine.

Disadvantages

- Requires separate sullage disposal facilities.
- Water (at least 4 litres / person / day) must be available throughout the year.
- Waterseal may be clogged easily if garbage is thrown into it.
- Construction is difficult and expensive in areas with high groundwater and shallow soil overlying hard rock.
- Risk of polluting nearly water sources.

Twin Pit Pour Flush Latrine

Twin Pit Sanitary System comprises of

i) a squatting pan,
ii) two leach pits and
iii) a Y-junction for directing excreta from squatting pan to either of the two leach pits.

The pits are used alternately and at any time only one pit is in use. When the first pit is full, the flow of excreta is directed to the second pit through a y-junction and contents of the first pit is left to decompose. The contents of first pit decompose to safe, pathogen free humus within 18 to 24 months. The contents of first pit may then be dug out and the pit is kept ready for reuse. The pit emptying should be done during dry seasons and humus may be used as manure.

Types of Twin Pit Pour Flush Latrine are,

- Twin Pit Waterseal Pour Flush Latrine
- Twin Pit Non-waterseal Pour Flush Latrine

Twin Pit Waterseal Pour Flush Latrine

A twin pit waterseal pour flush latrine consists of a siphon fitted to pan which maintains at least a 20mm water seal to prevent passage of gas and insects from pits into the latrine (**Figure 11**).

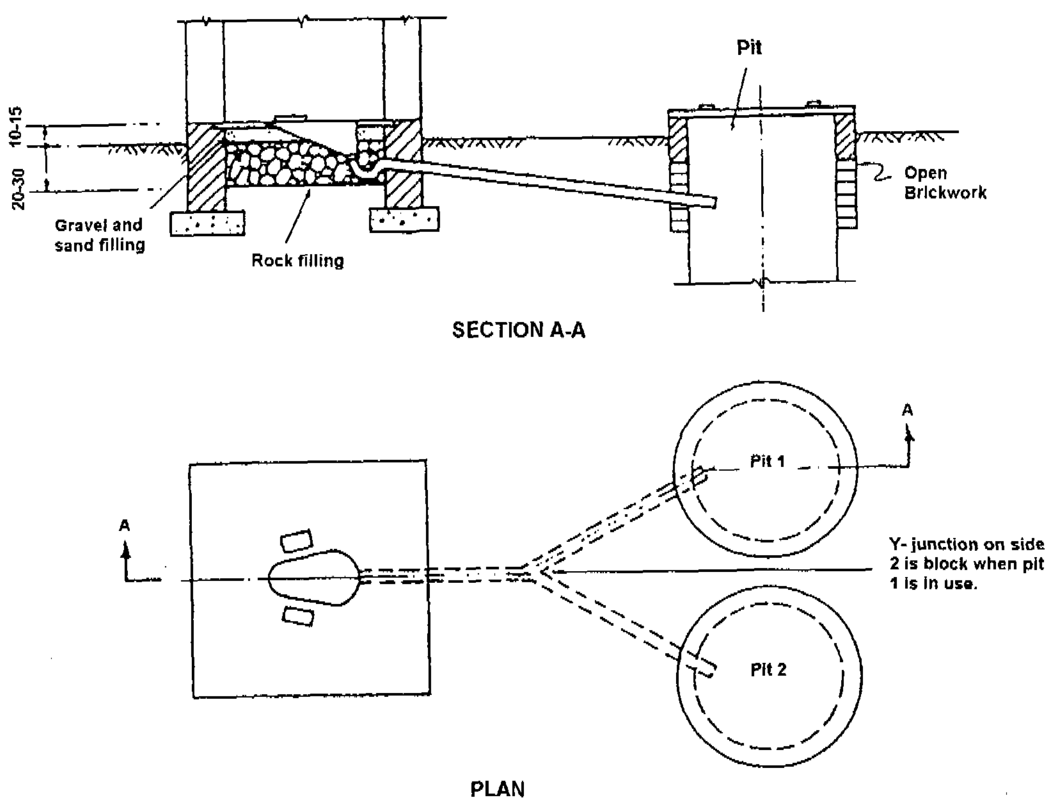

Figure 11 Twin Pit Waterseal Pour Flush Latrine

The gases generated in the pit are normally absorbed by the soil. However, a vent pipe may be provided on the siphon ahead of Y-junction for ease passout of excreta through siphon with less amount of flushing water.

Twin Pit Non-waterseal Pour Flush Latrine

A twin pit non-waterseal latrine consists of a bend fitted to the pan and connected to the pit (**Figure 12**). A vent pipe, exposed to the sun and/or wind which may be installed as stated earlier to induce a current through the pan and up the vent. This will prevent bad smell from pits getting into the toilet. The end of vent should be covered with a mesh to prevent flies/insects getting into or out of pits.

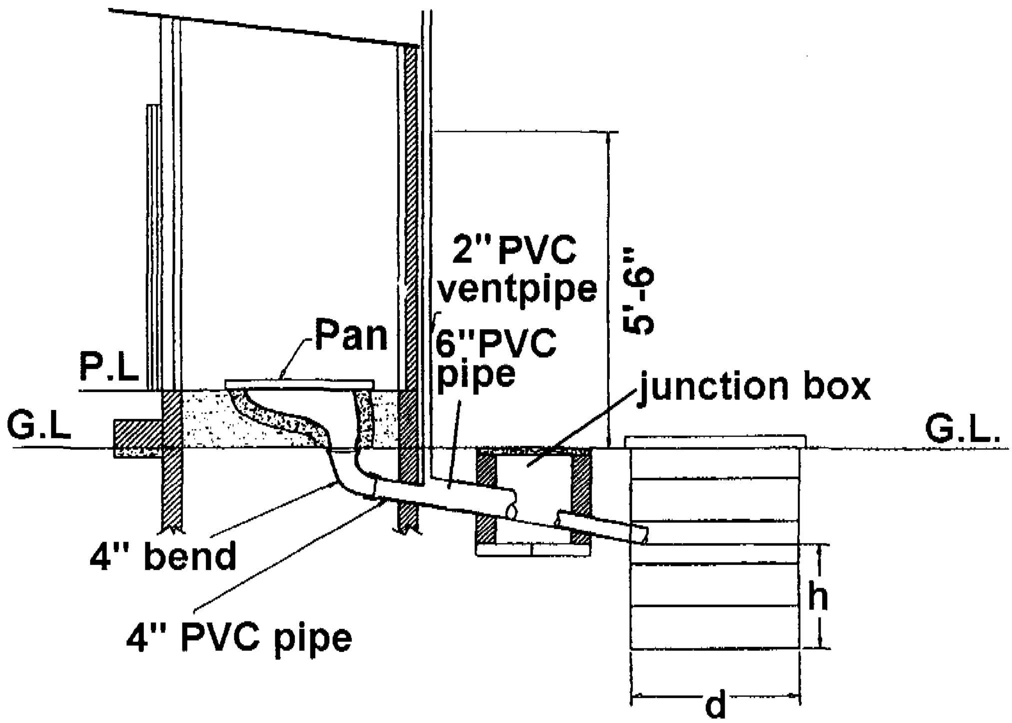

Figure 12 Twin Pit Non-waterseal Pour Flush Latrine

Advantages

- Less expensive compared to conventional latrines (with sewerage systems).
- Offers long term, appropriate, and hygienic solution for excreta disposal.
- Requires low volumes of water for flushing, (1-3 lit/flush only).
- Can be upgraded to connect to a sewer system or septic tank system.
- Eliminates odours, insect and fly breeding.
- Safe for children.
- Can be located, if desired, inside the house.
- Potential for resource recovery using the sludge as soil conditioner.
- Twin pit latrine can serve as a permanent structure because of its pits are used alternately.

Disadvantages

- Requires separate sullage disposal facilities.
- Water (at least 4 litres / person / day) must be available throughout the year.
- Waterseal may be clogged easily if garbage is thrown into it.
- Construction is difficult and expensive in areas with high groundwater and shallow soil overlying hard rock.
- Risk of polluting nearly water sources.
- Difficulty in construction and maintenance of twin pit pour flush latrine.

Some Other Technological Options for Sanitation

Small Bore Sewerage (SBS) System

On-site sanitation systems such as septic tank systems are largely used in many unsewered urban communities as well as in rural townships. These on-site systems often create acute problems of effluent disposal because of unfavourable soil conditions, high groundwater tables, and increased use of water by the modern household appliances. In densely populated areas (like urban slums) on-site sanitation options are sometimes not appropriate in terms of ground conditions, risk of pollution and availability of vacant areas. On the other hand the traditional sewerage system requires high initial investment cost. However, Small bore sewerage system is a recent sanitation technology that offers the modification of the traditional sewerage system with the cost which is far less than the conventional one.

Major Elements of SBS System

There are three basic elements to a small bore sewerage system. These are:
- Septic tanks,
- Small bore sewer reticulation, and
- Treatment plant.

The SBS system (**Figure 13**) collects wastewater discharges from all the fixtures in households (or other premises) in a similar fashion to the conventional sewerage system. Basic difference between the two systems is the incorporation of septic tanks within the individual premises as part of the SBS system. The wastewater collected in the septic tank is then transported under gravity through a network of reticulation sewers to a treatment plant comprising a series of stabilisation lagoons.

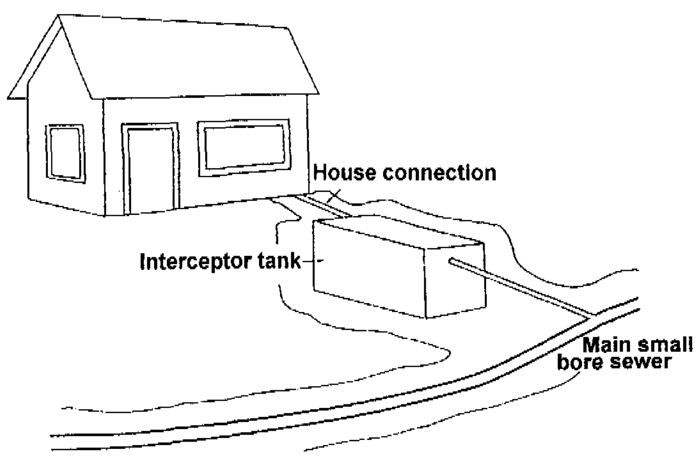

Figure 13 Small Bore Sewerage

Septic Tanks

Septic tanks are required to be installed within individual premises to receive wastewater from toilets baths, laundry and kitchens. The septic tank has the following fundamental functions:

- Sedimentation of undissolved, settleable solids.
- Storage of sludge and scum for at least three to five years or more.
- Reduction of the biochemical oxygen demand (BOD) of wastewater through anaerobic decomposition of organic matters in the wastewater.
- Substantial attenuation of peak flows within the tank.

Small Bore Sewer Reticulation

The important parameters that bring significant changes in the design criteria of the SBS collection system, due to the presence of septic tanks are design flow, sewer sizes, minimum velocity, sewer grades and manholes.

Design Flows: Estimation of the wastewater flow is an important factor in the overall design of a sewerage system. Over-estimation of the flow usually results in the sewerage system being over-designed, whereas under-estimation may result in system failure. Considerable care has therefore to be exercised in estimating the design flow.

Sewer Diameter: In the SBS system sewer sizes are smaller because of low average flow due to attenuation of peak flow in the septic tank. Since most of the settleable solids are retained in the septic tank, possibility of solids deposition and blockage in the sewer is minimised. The minimum size of small bore sewer is 50 mm. In developing countries however, where the specialised equipment for cleaning smaller diameter sewers are not generally available, a minimum diameter of 100 mm may be recommended.

Sewer Gradients: The grades of conventional sewers are established to produce self-cleansing velocities in order to avoid solids deposition in the sewer. The usual practice for hydraulic design of circular sewers is to maintain a minimum velocity for achieving the self cleaning action. In the SBS system, it is not necessary to maintain a self-cleansing velocity in the sewer reticulation system. As a result the grades can be substantially reduced thereby reducing the volume of excavation to a great extent.

Manholes and Flushing Points: A fewer number of manholes are installed in the SBS system on the basis that less maintenance is required in the system due to minimal solids content of the wastewater. Flushing points are used in the system at locations where the manholes would exist. These points consist of a 100 mm PVC riser with a removable screw-cap under a concrete cover at the surface to provide access for flushing.

Treatment Plant

In the SBS system, treatment of wastewater is performed in two stages, firstly, on-site treatment in septic tanks and secondly, off-site secondary treatment in a series of stabilisation lagoons. In the septic tanks the larger particles and settleable solids are retained and also BOD and suspended solids are significantly reduced. To attain a certain effluent quality, the primary effluent from the septic tanks is treated in a series of stabilisation lagoons. Treatment in stabilisation lagoons is simple, effective and the cheapest of all treatment processes.

Technical Advantages

The small bore sewerage system has specific technical advantages over the conventional sewerage system as listed below.

- Smaller sewer sizes.
- Reduced sewer grades.
- Minimal sewer blockages.
- Reduced volume of excavation because of smaller sewers and lower sewer grades;
- Rapid construction is possible because of lesser volume of excavation and fewer numbers of manholes to be constructed.

Economic Considerations

Although the basic principles of both SBS system and conventional sewerage system are similar, there will be differences in the initial capital costs and the annual maintenance costs between the two systems resulting from the following factors.

Reduction in capital cost of SBS system due to:

- reduction in the sewer sizes;
- reduction in grades and thereby reduction in the volume of excavations;
- reduction in the number of manholes;
- reduction in hydraulic and organic loading of wastewater due to existence of septic tank and thereby reduction in treatment plant area; and

Increase in capital cost of SBS system due to:

- installation of septic tanks (if septic tanks do not exist) and
- installation of flushing points.

Differences in annual maintenance costs between the two systems result from the following factors:

Reduction in maintenance cost of SBS system due to:

- lesser number of manholes;
- less frequent cleaning of sewers because the possibility of blockage due to solids deposition is minimum, and
- no sludge handling is required at the treatment site.

Increase in maintenance cost of SBS system due to:

- 3 to 5 yearly desludging of septic tanks, and
- regular flushing of sewers.

Cost comparison between conventional sewerage system and SBS system indicates that SBS system is cheaper. The SBS system can be considered as a viable alternative to conventional sewerage system. This is particularly suitable in areas of old development where septic tanks are already in existence and where the future growth potential is minimal. For areas of new development with high growth potential the SBS system may be marginally cheaper because of the high cost of septic tank installations. It is important however, that emphasis be given to assess relative costs on a case by case basis as both SBS and conventional sewerage systems costs are sensitive to local conditions.

DWASA is currently installing a small bore sewer system in Mirpur, under the ADB funded Environmental Improvement Project.

Community Latrine

Community latrine consists of a number of squatting facilities with common disposal system. It is very common in different institutions. Community latrines can be built for poor communities where individual household cannot afford their own latrine. Community latrine is shown in **Figure14**.

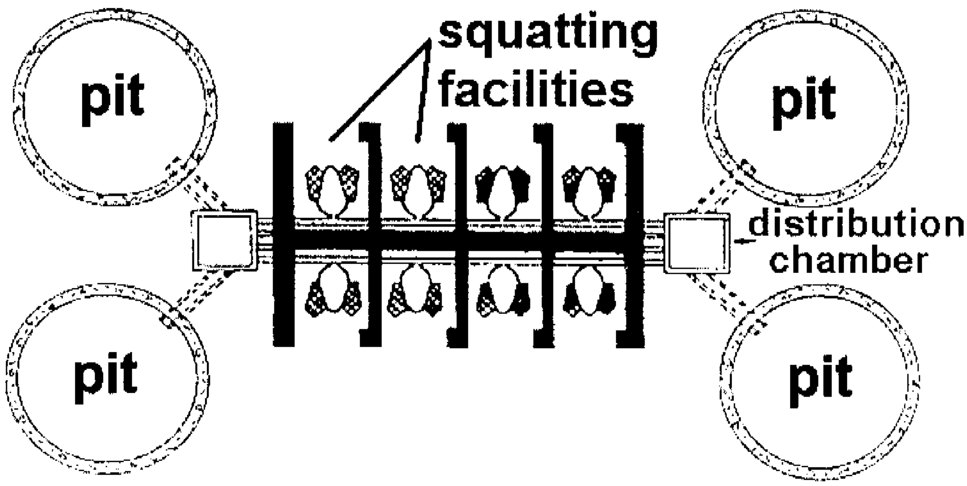

Figure 14 Community latrine

Community latrines can be connected with pits, conventional sewerage system or small bore sewer system depending upon fund availability and existing sanitation system in adjacent area.

Recently Local Government Engineering Department (LGED) is promoting community latrines with biogas facility at various districts. Biogas plant offers use of gas produced from human excreta for cooking, lighting or other purpose with an additional advantage of safe sanitation. For accumulating sufficient amount of human excreta to produce reasonable amount of biogas, community latrines are preferred to be used as the source of input materials for the biogas plant. This type of sanitation system is suitable for densely populated areas like slums and squatters. It is also possible to introduce a shallow sewer network connecting the latrines to a biogas plant in a densely populated planned area. Such an attempt had been made at Bauniabadh slum, Mirpur on experimental basis and the performance is satisfactory.

Advantages

- Suitable for densely populated slum areas.
- Total cost of community latrines can be shared by the users.
- Community latrine attached with a biogas plant provides gas for the users.

Disadvantages

- Users' acceptance of the facility.
- Payment arrangement.
- Maintenance & management.

Waste Composting

Introduction

Composting is the process of bacterial conversion of organic solid and semisolid wastes into compost which can be handled, stored and transported without any adverse effect and used as organic manure for improvement of soil quality and fertility. About 90% of the world's solid wastes are disposed of in landfills (Ambrose, 1983) - while sanitary landfilling is the widely used method in the developed world, crude dumping is very common in the developing countries. With urbanization and industrial development on the increase in the developing world, it is natural to expect an increase in the generation of solid wastes which must be disposed of in proper manner. Although the awareness for environmental degradation is not so prevalent in developing countries, the potential problem very much exists and is envisaged to escalate with increased urbanization and increasing population densities. The problem is more critical since these countries have limited treatment facilities and a major portion of the wastes go unnoticed or uncared for, into the environment. On the other hand, with the growing world population and the limited extent of world's resources, efforts are being taken to utilise the wastes' by-products and thus give a bit of relief to our natural untapped resources which are being depleted so fast.

Recycling, or reuse or resources or waste by-products is practised in many developing countries, not so much for reasons of environmental control as in the developed countries. Faced with the situation of limited resources and population explosion, however, it is expected that resource recovery from wastes and their reuse will gain tremendous importance in the waste management programs in developing countries with the increasing consciousness for environmental pollution control as well as with the realization of the immense benefits associated with waste recycling.

This paper attempts to review the important aspects of composting - an ancient resource recovery system practised, though less frequently, in both parts of the world. While composting his taken a beating in some western countries with collapse of markets associated with high costs of sophisticated processing techniques, yet the system appears to present a potential solution in high population cities of the developing world where waste characteristics are suitable for such method of resource recovery. The paper also considers the characteristics of solid wastes in Bangladesh, and examines their suitability for composting.

Characteristics of Compost

Compost is a very good soil conditioner. It also supplements nutrients to soils. The important chemical characteristics of compost are shown in Table I.

Table 1 : Important Chemical Characteristics of Compost

Substances	Percent by Weight
Organic matter	25 - 50
Carbon	8 - 50
Nitrogen (as N)	0.4 - 3.5
Phosphorus (as P_2O_5)	0.3 - 3.5
Potassium,(as K_2O)	0.5 - 1.8
Ash	20 - 65
Calcium (as CaO)	1.5 - 7.0

The product is stable humus like in content and is an excellent soil conditioner. The application of compost to agricultural lands

- increases humus (organic) content,
- increases moisture retention capacity,
- improves aeration at root zone,
- improve texture of soils,
- increases fertility of lands, and
- replenishes micro-nutrients in soils,

Basic Composting Process

Composting is a biological process, dependent on several important factors, which include -

- the substrate subject to composting must be biodegradable;
- suitable number and type of microorganism must be present;
- the rate and efficiency of composting are dependent on activity of microorganisms:
- environmental factors like pH, temperature and presence of oxygen control the process;
- the waste must be nutritionally balanced; and
- the presence of toxic substances affecting the process.

The aerobic and anaerobic processes of composting have been represented by the following equations:

Aerobic Process

$$C_aH_bO_cN_d + mO_2 \dashrightarrow nC_wH_xO_yN_z + qCO_2 + rH_2O + sNH_3$$

(Organics) (Compost)

Anaerobic Process

$$C_aH_bO_cN_d \dashrightarrow mC_wH_xO_yN_z + nCH_4 + sCO_2 + rH_20 + sNH_3$$

(Organics) (Compost)

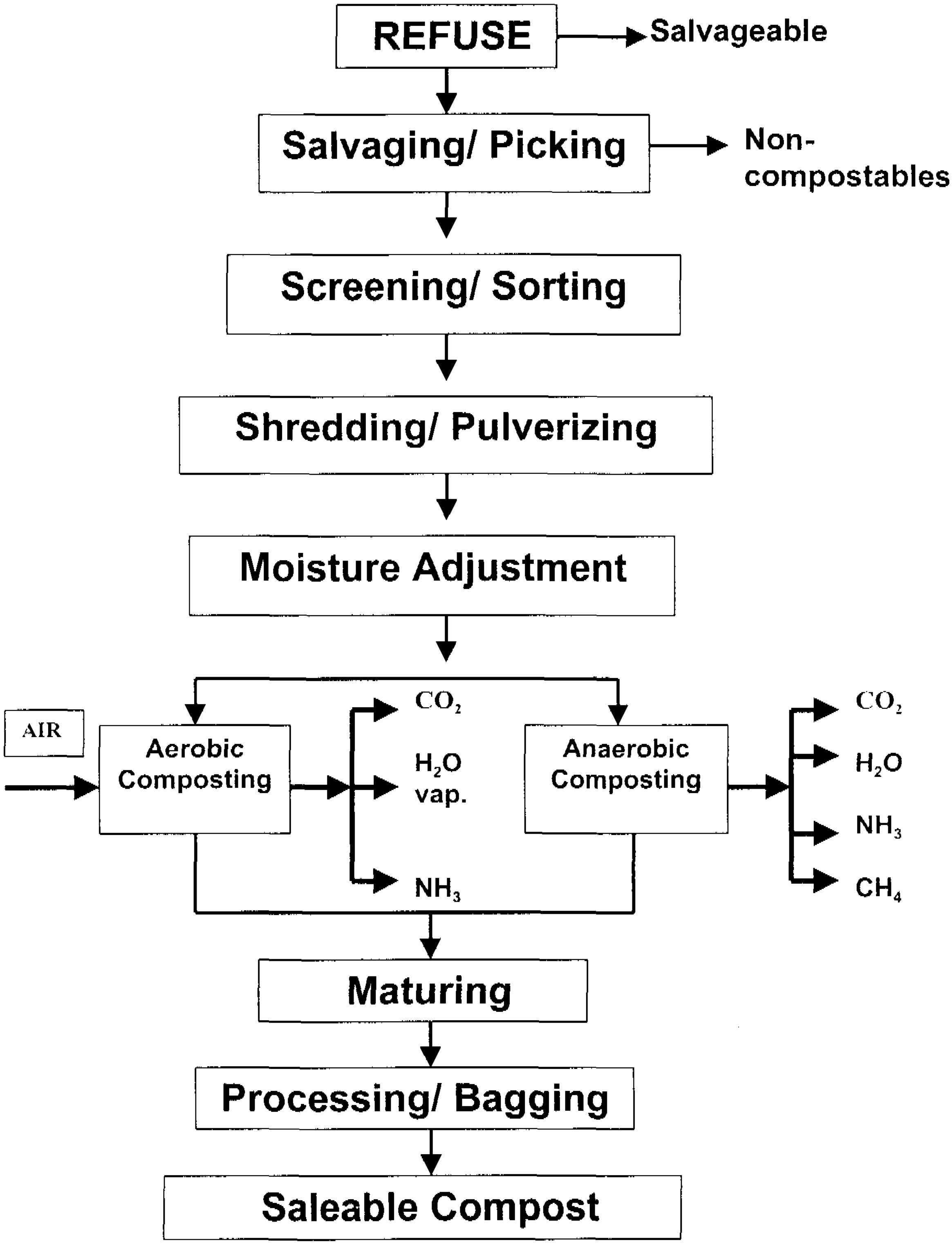

Figure 1 Flow Diagram for Composting Process

The relative advantages and disadvantages of aerobic and anaerobic processes of composting are shown in Table 2.

Table 2 : Relative Advantages and Disadvantages of Aerobic and Anaerobic composting

Aerobic Composting	Anaerobic Composting
No objectionable odours.	Malodourous, hence composting is done in closed environment.
The process is rapid and suitable for large-scale operation.	The process is slow.
Fist destruction of pathogens at relatively high temperature of operation.	Slow destruction of pathogens at relatively lower temperature of operation.
Highly mechanized rapid processes available requires controlled operation and skilled attention.	Minimum attention is needed.
Mechanized processes are energy intensive.	CH4 can be recovered for use as fuel.

Controlling Factors

There are certain important factors which have to be in desirable conditions for efficient aerobic composting to occur at high temperatures.

Moisture Content

Moisture content is a critical factor in aerobic composting. Moisture content should be in the range between 50 and 60 percent during the composting process. The optimum value appears to be about 55 percent (Tchobanoglous et al 1977). At moisture levels above 65%, water begins to fill the interstices between the particles of waste, reducing tile interstitial oxygen and causing anaerobic conditions resulting in a rapid fall in temperature and tile production of offensive odours (World Bank, 1986). When the moisture content drops much below 50% the compost process will be slow.

Carbon-Nitrogen Ratio

An optimum balance in the carbon (C) to nitrogen (N) content is necessary because the bacteria need a minimum supply of nutrients to survive. Bacteria use carbon as an energy source and nitrogen for cell building. The initial CIN ratio, is a deciding factor in the speed -it which decomposition takes place. Tile ideal initial ratio is between 30:1 and 35:1 (Holmes, 1981), if it exceeds 50 tile time required increases considerably. At lower ratios ammonia is given off. Biological activity is also impeded at lower ratios. In solid wastes tile main source of nitrogen is tile vegetable/putrescible matter which has a C/N ratio of about 24:1 (Holmes, 1981), and paper is the main source of carbon. Thus the higher the ratio of paper to vegetable/putrescible matter tile higher the C/N ratio.

Temperature

Temperature is also a key factor affecting biological activity. The range of optimum temperature for the composting process, 45^0C to 65^0C, is quite broad because of the many groups of organisms taking part in the process. The temperature generated by the thermophilic bacterial activity result the destruction of disease causing organisms. Higher temperatures e.g., 60 to 700C for about 24 hours should be maintained for pathogen destruction.

Oxygen Requirement

In the aerobic process, the availability of air is a key factor to its success. However it is very difficult to determine the true oxygen requirements because it depends on so many variables as temperature, moisture content, availability of nutrient etc. The theoretical quantity of oxygen required can however, be estimated (Peavy et al 1986). An effective and in expensive means of monitoring oxygen is to check the compost for foul odours (World Bank 1986). If these are present it indicates an insufficient oxygen supply.

pH Control

A final parameter which is important in evaluating the microbial environment is the pH of waste. The pH varies with time during the composting process and is a good indicator of the extent of decomposition within the compost mass. The optimum pH range for most bacteria is between 6 and 7.5. During the initial period (first 2 or 3 days) pH drops to 5.0 or less and then begins to rise to about 8.5 for the remainder of the aerobic process. If the digestion is allowed to become anaerobic, the pH will drop to about 4.5 (Ambrose, 1983). To minimize the loss of nitrogen in the form of ammonia gas, pH should not rise above 8.5.

The values for major controlling parameters for composting are listed in Table 3.

Table 3 : Values for Major Composting Parameters (ENSIC, 1994).

Parameters	Important Values
C/N Ratio of Feed	**30:1-50:1**. At lower ratios biological activity is impeded and nitrogen is given off as ammonia. At higher ratios nutritional deficiency occurs.
C/P Ratio of Feed	**75:1-150:1**
Particle Size	**0.5-1.5 inch** for agitated print and forced aeration **1.5 - 3.0 inch** for windrows, unagitated plants and natural aeration.
Moisture Content	50-60%
Air Flow (Oxygen)	**10 - 30 cu.ft**. air/day/lb during active composting, progressively lowered during cooling and maturing. No air flow for anaerobic composting.
Temperature	**15^0-45^0 (38^0 optimum)** for mesophilic composting **45^0-65^0 (55^0 optimum)** for thermophilic composting
pH	No control is required. 5.0-5.5 at initial stage of mesophilic composting 8.0-9.0 - at thermophilic composting 7.0-8.0 -during maturing

In view of the above factors, the character of the constituents of solid wastes have to be analysed to determine the suitability for composting. Although similar constituents occur in solid wastes throughout the world, there are wide variations in relative proportions, which have significant bearing on tile controlling factors for composting. For instance, the organic component of urban solid waste only is treated by composting process. Human and animal wastes can also be composted but they tend to have high nitrogen and moisture contents. They are therefore, mixed with carbonaceous wastes such as garbage and crop wastes to achieve an optimum C/N ratio.

Global Practice of Composting

Although composting has been carried out for centuries by farmers and gardeners, the first systematised development of composting as a process took place in India in 1925 (Howard, 1935 in GEC 1975). Howard (1935) developed a process called 'Indore Process' which involved anaerobic degradation of leaves, garbage, animal manure and night soil for six months in pits or piles. Later, this process was modified to include laying down successive layers of refuse and night soil and turning the pile frequently to hasten aerobic condition. This system, known as the 'Bangalore process' is now in use in over 2500 small installations in India.

Composting has since developed into a multitude of processes and are identified by the names of their inventors or by proprietary names. In Europe, composting usage ranges from about 1% of municipal waste in Germany to 17% in the Netherlands (GEC, 1975). The figure quoted for the Netherlands has lowered later on with installation, of incineration plants. Israel makes extensive use of composting - about 43% of the total refuse, tile largest windrow plant being located in Tel Aviv (GEC, 1975). Since about 1950, a number of mechanised composting plants have been built and operated in tile United States. Of these, some are intermittently operating, some are closed and some are operating continuously, e.g., the Fairfield Hardy process in Altoona, Pennsylvania. Other countries such as Argentina, Egypt, frail, Italy, Greece, England, Spain, Austria, Russia, Japan, Thailand and China are reported (GEC, 1975) to be using a variety of low to high cost composting processes.

Composting in Bangladesh

Though composting has not been considered on a large scale basis in Bangladesh, small scale practice is common in some parts of the country, e.g., in Rajshahi where night soil mixed with garbage are processed and the product sold to local farmers. The major considerations for composting of solid wastes in Bangladesh are as follows.

- Availability and Suitability of the Wastes.
- Socio-economic Conditions.
- Technological Access.
- Market for the Compost.
- Price Affordable to Farmers.
- Environmental Legislation and Enforcement.
- Present Disposal Costs.
- Support from the Local Authority.

The municipal solid waste in Dhaka city is mostly generated from domestic, commercial and industrial sources. The total quantity of solid wastes collected by the Dhaka city corporation for final disposal varies from 1400 tons per day in dry season to 1800 tons per day in wet season. The estimated per capita per day collection of solid wastes in Dhaka city ranges from 0.23 kg to 0.30 kg is fir lower than the waste generation rate of 0.51 kg in Calcutta, 1.8 kg in New York and 2.42 kg US National average. The lower rate of waste generation may be due to the fact that some of the wastes escape municipal collection and are dumped in local low-lying areas. More over extensive recycling of wastes in Dhaka City may be the cause of reduction of quantity of wastes for collection and disposal by city corporation. The total waste generated in the city is estimated to be at least 1.5 times the waste collected by the city corporation.

The characteristics of the wastes computed from the chemical composition determined to evaluate the quality of domestic refuse and market wastes by Ahmed (1985) and mixed refuse by Islam (1992) have been presented in Table 4. The results of the analysis show that tile moisture contents just right for composting. The high ash and inorganic contents are due to the presence of dust and grits dumped by the sweepers in the bins after street sweeping. The presence of inorganic matters is also responsible for comparatively high C/N and C/P values the mixed refuse of Dhaka City. The N.P.K. contents represent the fertilizer value for the waste and potential for conversion of the waste into good compost. It appears that to improve N,P,K values food wastes suitable for composting need separate collection/ shorting from non-compostables.

There exists a good demand for compost for vegetable growing around urban centres. Continuous depletion of human content in agricultural lands due to intensive agriculture in Bangladesh needs a good soil conditioner to sustain productivity. Selected wastes can be converted into organic manure by composting to meet these demands. A carbon-nitrogen ratio between 30 and 50 is considered optimum for aerobic composting but the carbon-nitrogen ratio of Dhaka City waste as shown in Table 4 is comparatively higher.

Table 4: Chemical Composting of Refuse Generated in Dhaka City

Constituents	Domestic Refuse (Ahmed, 1985)	Market Wastes (Ahmed, 1985)	Fixed Refuse (Islam, 1992)
Moisture Content (%)	45.3	53.6	95.31
Fixed Residue (%)	57.2	55.6	83.31
Organic Carbon (C,%)	22.6	25.7	21.84
C/N Ratio	55	71	56
C/P Ratio	45.2	-	44.6
Potassium (K,%)	Trace	Trace	Trace

The aerobic process of garbage composting by mechanized plants has not been found cost-effective in the developing countries like Bangladesh. However, selected garbage collected separately or obtained by shorting mixed refuse can be converted into good compost by anaerobic composting developed in India (Pickford, 1978) and in China. In this process excreta and sludges may also be mixed to enrich organic wastes of low fertilising value. Less mechanized small labour intensive aerobic composting can also be a suitable process in Bangladesh.

Composting can also help prevention of environmental pollution in Bangladesh. The organic decomposeable fraction of the solid wastes left after unorganised reclamation of items of immediate market value is disposed of by open dumping in low-laying areas in and around urban centres. Rapid decomposition of mixed refuse in temperature humid climate causes odour nuisance, obnoxious conditions and hazards in surrounding area. The leachate produced by infiltration of rainwater or floodwater into a garbage dump has extremely high pollution potentials. Characteristics of leachate produced in landfill sites in Dhaka are shown in Table- 5.

Table 5: Characteristic Quality of Leachate (Rahman, 1991; Islam, 1992)

Parameters	Unit	Range of Values	Average Value
pH	-	4.5-6.0	4.75
Suspended Solids	mg/l	3,000-14,000	10,000
Chlorides	mg/l	1,300-5,000	1,400
Nitrate	mg/l	0-200	50
Phosphate	mg/l	0-15	5
COD	mg/l	5,000-17,000	14,000
BOD_5	mg/l	5,000-15,000	9,000

Bangladesh Environment Policy, EPC Ordinance, 1977 and Environmental Quality Standards provide stingent control and do not permit discharge of such, liquors in surface and ground waters. Control of leachate is extremely difficult even in sanitary landfills because of flood and high rainfall intensity in Bangladesh. Composting of organic fraction of solid waste and disposal of noncompostable fraction by landfilling is an alternative option for control of quality of leachate at landfill site. Some household and industrial wastes will give rise to highly toxic leachate detrimental for natural degradation of solid wastes in landfills.

The proposed method of recycling organic fraction of the municipal waste has been illustrated in **Figure 2**. The non-decomposable fraction -of solid wastes may be used for reclamation of low land in the conventional method, which eliminates tile possibility of environmental pollution.

It may be mentioned that organic manure and soil conditioners produced by composting are environmentally friendly and widely used in the both developed and developing Countries. Small scale composting has already been initiated in Dhaka. The scope, need and importance of conversion of municipal wastes into organic manure from both agricultural and environmental considerations demonstrate the need for undertaking relatively large scale composting as well as marketing of product.

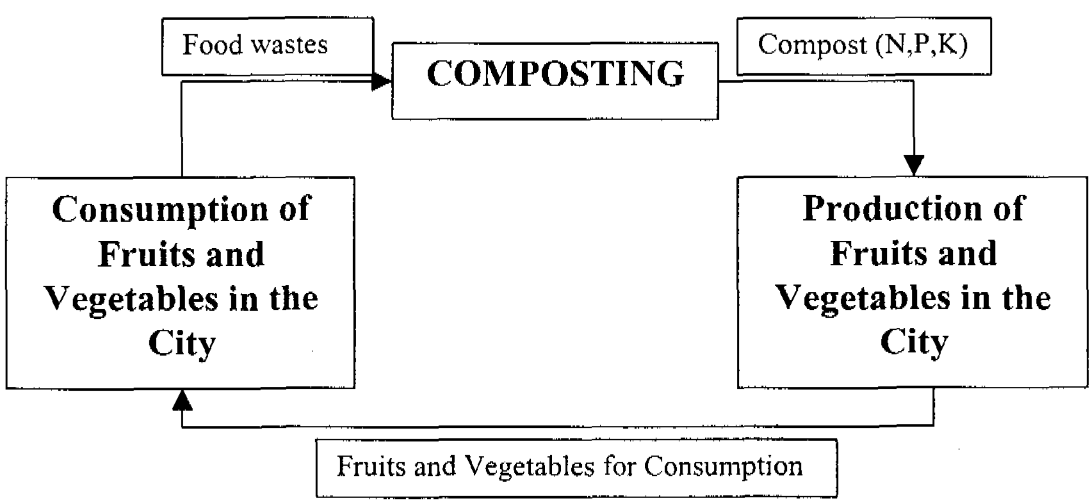

Figure 2 Proposed Recycling of Resources in Organic Fraction of Solid Wastes

Conclusions

The present practice of disposal of municipal by open dumping is a potential threat to surface and ground water pollution. The decomposition of organic matter present in the wastes in rain and floodwater produces obnoxious odours and highly polluting leachate. As a practice, organic fraction of municipal wastes may be separated before land filling and converted into compost for environmental protection and to promote recycling of nutrients present in tile wastes. The process of composing, thus, can prevent environmental pollution and help recovery of resources from decomposing wastes.

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Biogas Technology

Introduction

The ANEROBIC DIGESTIVE method has the advantage of low or no energy consumption in operation, less Sludge left and small land occupancy. The use of anaerobic digestive method for the treatment of various organic wastes from domestic, commercial, industrial and agricultural sources generates biogas (which is being used as energy) and preserves the nutrients which are recycled back to agricultural land and fish pond in the form of slurry for agriculture and aquaculture application - soil fertilizer, crop irrigation, farming of fish, duck, algae, water plants, etc. Biogas is a mixture of methane (usually 55% to 79%) and carbon-dioxide (30% to 45%). Traces of moisture, hydrogen sulphide, ammonia, etc. may also present is the biogas.

The relevance of biogas technology in Bangladesh lies in the fact that it makes the best possible utilisation of various organic wastes (which have no or little economic value at the present moment) as a renewable source of clean energy in the rural and semi-urban areas. The implementation of biogas technology has a great potential of mitigating several problems related to ecological imbalance, minimise crucial fuel demand, improve hygiene and health and therefore, there is an overall improvement in quality of life in rural and semi-urban areas.

Biogas Technology

The biogas production technology has been available since the early 1900's when it was used for the stabilisation of organic sludge produced during the treatment of domestic sewage (Stuckey, 1983). It has also been used in India since 1923 (Prased et al.,1974) and in China for a period of nearly sixty five years (APH, 1989). During the last 50/60 years this technology has not realised its full potential due to a number of factors (Stuckey, 1983). Recently, there has been increasing interest in this technology, especially in the developing world. The Government of same Asian countries such as China, India, Nepal, Thailand have paid varying degree of attention to biogas technology. More than 90 per cent of presently existing biogas plants are of family size and the rest are at the farm and industrial scale. The potential of biogas technology for the replacement of traditional energy sources is highest in china (about 80 per cent) and that of India, Nepal and Thailand is about 10 per cent (Tentscher, 1986). The estimated potential for generation of biogas in Bangladesh shown in Table -1 indicates that the best possible utilisation of organic wastes through biogas generation can supply clean energy to cook three meals for a population of about 76 million, which is about 66 percent of the total population of Bangladesh. The daily fertiliser contribution would be equivalent to 2,785 tons of urea, 7,030 tonnes of super phosphate and 1,280 tonnes of muriate of potash (Rahman, 1996).

Table 1: Potential of Biogas Generation in Bangladesh (Rahman, 1996)

Feed material	Total Population (X 10'nos)	Waste Disposal Rate (kg/head/day)	Gas Production Rate (m3/kg)	Amount of Gas (X10'm3/day)
Cattle dung	2.42	11.50	0.03	8.35
Sheep and goat dropping	3.33	1.50	0.04	2.00
Poultry manure	13.79	0.18	0.06	1.49
Human excreta	11.50	0.40	0.07	3.22
Municipal solid wastes	2.25	0.22	0.06	0.30
Rural solid waste	9.25	0.07	0.06	0.39
Total volume				15.75

Mechanism of Biogas Fermentation

The anaerobic fermentation process converts organic matters to methane and carbon dioxide in the absence of molecular oxygen. The mechanism of this anaerobic process is much more complex than the aerobic ones. This is a result of many pathways available for anaerobic community. All the pathways and micro-organisms responsible for the reactions are a not well-known, but a broad outline of the process has been established by different investigators are presented here.

These are three stages in the conversion of organic substances into methane by biogas microbes as follows:

- **Fermentative bacteria:** mixed group of bacteria involved in the first stage of biogas fermentation process. Their function is to hydrolyse various complex organic substance and then to ferment them to yield various volatile acids, hydrogen and carbon dioxide, etc. according to the typical reactions :

  $C_6H_{12}O_6 + H_2O \rightarrow 2CH_3COOH$ (acetic acid) $+ 2CO_2 + 4H_2$

  $C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2COOH$ (butyric acid) $+ 2CO_2 + 2H_2O$

  $C_6H_{12}O_6 + 2H_2 \rightarrow 2CH_3CH_2COOH$ (propionic acid) $+ 2H_2O$

- **Hydrogen- producing acetogenic bacteria :** their function is to decompose substances produced in the first stage (such as propionic acid, aromatic acid, alcohol, etc., which can not be utilised directly by the methane producing bacteria) into acetic acid, hydrogen, carbon dioxide, etc, according to the reactions :

  $CH_3CH_2COOH + 2H_2O \rightarrow CH_3COOH + CO_2 + 3H_2$

  $CH_3CH_2CH_2COOH_3 + 2H_2O \rightarrow 2CH_3COOH + 2H_2$

- **Methane- producing bacteria :** This group of bacteria are active in the third stage of biogas fermentation. Their function is to convert the substances produced into the first and second stages (acetic acid, hydrogen, carbon dioxide, formic acid, etc.) into methane and carbon dioxide by acetoclastic methane bacteria (acetophilic) and hydrogen-utilizing methane bacteria according to the reactions :

  $$CH_3COOH \xrightarrow[\text{methane bacteria}]{\text{acetoclastic}} CH_4 + CO_2$$

  $$CO_2 + 4H_2 \xrightarrow[\text{methane bacteria}]{\text{hydrogen-utilizing}} CH_4 + 2H_2O$$

  The better the different fermentation processes merge together, the shorter the digestion process.

Factors Affecting Fermentation Process

- **pH of Fermentative Fluid :** Biogas fermentation process requires an environment with neutral pH i.e. usually 7.0 to 8.0. When a biogas plant is newly started, the acid former become active first, reducing the pH to below 7 by increasing acid content. The methanogense then start using these acids increasing the pH back to neutral. A working plant is therefore, buffered, that is, the acid levels is controlled by the process itself.

  The generation of biogas will be hampered if the pH of the fermentative fluid is either too high or to low. An experiment carried out at Chengdu Research Institute varying the pH of input materials, has shown a maximum output of biogas at pH 7.5 - 8.0. (Table 2).

Table 2 Effect of pH on Yield of Biogas

Starting pH	5	5	7	8	9	10
Final pH	6	7	7	7.5	7	7
Total Output of Biogas (cum)	12.70	14.80	22.50	24.69	19.89	10.25

- **Fermentation Temperature :** The gas production efficiency increases with the increase of temperature. According to the temperature of the digester content, the following types of digestion are distinguished:
  - psychrophilic digestion (10^0C - 20^0C)
  - mesophilic digestion (20^0C - 35^0C)
  - thermophilic digestion (50^0C - 60^0C).

  The retention time for psychrophilic, mesophilic and thermophilic digestion may be more than 100 days, 20 days and 8 days respectively. The higher the temperature the faster the bacteria use the food in the slurry and sooner replacement of the slurry is needed. A stable fermenting temperature is required to maintain the normal state of biogas fermentation. Biogas microbes, especially methane producing bacteria are sensitive to sudden change of temperature. The generation of biogas will be slowed down noticeably if there is an abrupt change of temperature of 5^0C or more.

- **Solid Concentration :** Generally 6% to 12% solid concentration of the feed material is considered to be optimal for the production of biogas. This also depends on fermentation temperature and type of materials used. However, biogas can be produced with the feed materials of solid concentration of as low as about 1% to higher tan 30%. Although biogas can be produced from any organic materials but some materials may require pre-treatment for biogas fermentation to minimise retention time of biogas digester. In Chinese rural areas, the most practical method of pre-treatment is to compost the feed materials. Solids content of some of the common fermentation materials are shown in Table 3.

Table-3 : Properties of Some Common Feed Materials

Animal species/ feed material	Proportions in fresh feed material		
	%DM	%ODM	C/N
Cattle dung	16	13	25
Buffalo dung	14	12	20
Pig manure	17	14	13
Sheep droppings	30	20	30
Horse manure	25	15	25
Poultry manure	25	16	5
Human excrement	20	15	8
Straw/husks			70
Leaves/grass	approx. 80		35
Water hyacinths	7	5	25

- **Carbon-Nitrogen Ratio (C/N) :** Materials with different Carbon-Nitrogen ratios differ widely in their yields of biogas. Table 3 shows the Carbon-Nitrogen ratio (C/N) of some commonly used fermentation materials.

  It is very important to mix the raw materials in accordance with the C/N ratio to ensure normal biogas production. The carbon to nitrogen ratio represents the production of the elements of carbon in the form of carbohydrate to that of nitrogen in the form of protein nitrates, ammonia etc. They are the main nutrients of anaerobic bacteria. Anaerobic bacteria use carbon for energy and nitrogen for building the cell structure. The rate of use of carbon by anaerobic bacteria is 20 to 30 times faster than the use of nitrogen. Experiments show that the result of fermentation will be quit good if nitrogen ratio ranges from 20:1 to 30:1. If the carbon content is high enough the excess carbon will slow down the digestion.

- **Effect of Toxins on Biogas Fermentation :** Industrial effluent can contain toxic materials which may kill methane-producing bacteria. Metals, antibiotics, disinfectants, detergent, pesticides, chlorinated hydrocarbons, such as chloroform and other organic solvents also kill bacteria and thereby stop the functioning of a digester. Therefore, care must be taken so that the fermentation materials or the water used are not polluted by such materials.

- **Particle Size :** Particle size of the substrate is another considerable parameter. Smaller sized particle is better for fermentation and give fewer problems then bulky materials. Smaller sized particles have greater exposed surface area for bacterial action and therefore, reduce the retention time of the digestion process.

- **Intensity of pressure :** The intensity of pressure within the biogas digester increase the solubility of methane in the fermentation fluid if it exceed the 40 m head of water (APH, 1989). But in the common hydraulic digester, an increase in the intensity of pressure to such an extent never occurs and thus the generation of methane is not affected by this factor. The efficiency of the fermentation processes influenced by the intensity of pressure in the gas holder of the biogas plant.

Fermentation Process and Different Types of Biogas Plants

The various techniques available to carry out anaerobic digestion are discussed into this section. These are:

1. Dry-Fermentation
2. Fixed Dome (Chines)
3. Floating cover (Indian or KVIC design)
4. Flexible Bag (Taiwan)
5. Plug Flow
6. Anaerobic Baffler Reactor.

Batch and "Dry" Fermentation

This is the simplest option available, and operation involves charging an airtight reactor with the substrate, a seed in column, and in some cases a chemical to maintain a satisfactory pH. The reactor is then sealed, and the fermentation is allowed to proceed for 30 - 180 days. During this period the daily gas production builds up to a maximum and then declines. This fermentation can be run at "normal" solids contents (i.e. 6% - 10%), or at high concentrations (i.e. > 20%) which is known as a "dry" fermentation. This design is shown in **Figure-1**.

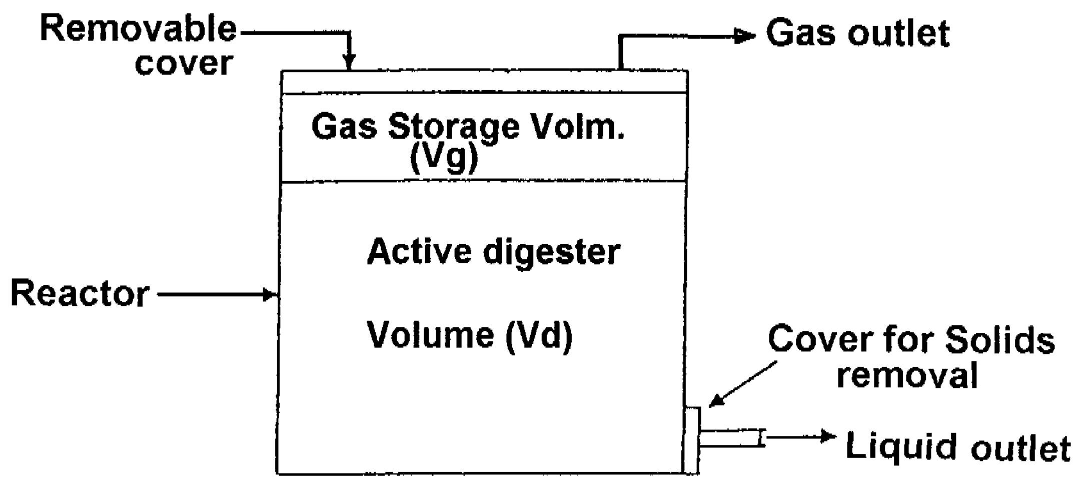

Figure 1 Batch Digester

Fixed Dome (Chinese Model)

This is the most common digester type in developing countries, and the basic design originated in China. The reactor consists of a gas tight chamber constructed of either bricks, stone, or poured concrete. Both the top and bottom of the reactor are hemispherical, and are joined together by straight sides. The inside surface is sealed by many thin layers of mortar to make it gas tight, although gas leakage through the dome is often a major problem in this type of design. The digester is fed semi-continuously (i.e., once a day) and the inlet pipe is straight and ends at mid level in the digester. The outlet is also at mid level, and consists of a fairly large storage tank. There is a manhole plug at the top of the digester to facilitate entrance for cleaning, and the gas outlet pipe exists from the manhole cover (**Figure-2**).

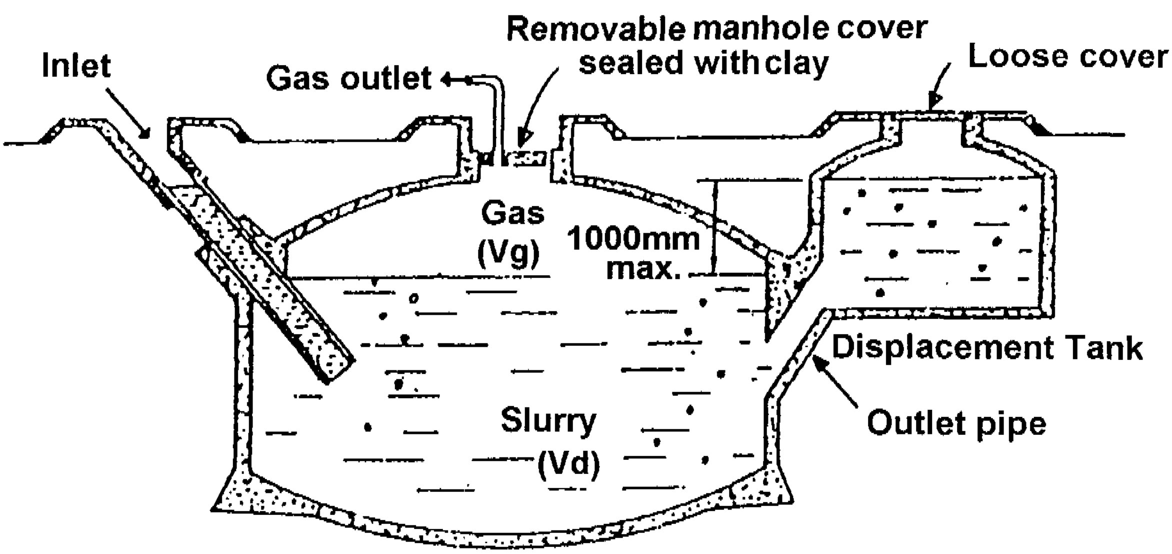

Figure 2 Fixed Dome (Chinese model) Digester

Floating Cover (Indian or KVIC design)

This design is the most popular in India, and is used extensively throughout the world being the most common type of digester used for treating sewage sludge in developed countries. The Khadi Village Industries Commission (KVIC) design consists of a cylindrical reactor with an H/D ratio of between 2.5 and 4.1 (**Figure 3**).

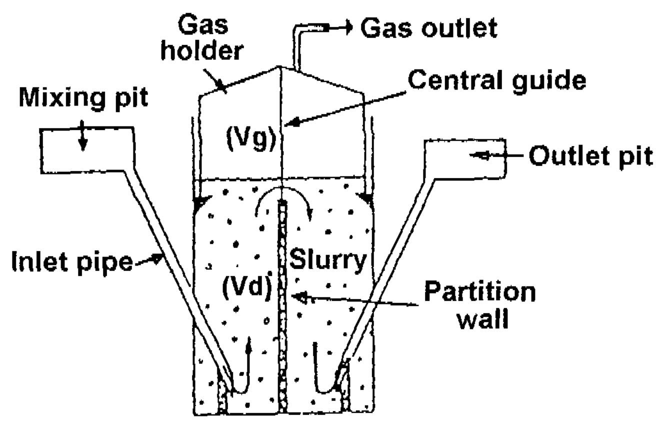

Figure 3 Floating Cover (Indian) Digester

The reactor is usually constructed of brick, although chicken wire reinforced concrete has been used. The construction does not have to be as strong as the fixed dome type since the only pressure on the walls is the hydrostatic pressure from the liquid contents. The gas produced in the digester is trapped under a floating cover on the surface of the digester that rises and falls on a central guide. The volume of the gas cover on the surface of the digester which rises and falls on a central guide. The volume of the gas cover is approximately 50% of the total daily gas production, and the cover is usually constructed of mild steel, although due to corrosion problems other materials such as ferro-cement and fibreglass have been used. The pressure of the gas available depends on the weight of the gas holder per unit area, and usually varies between 4-8 cm of water pressure.

Bag Design (Taiwan)

The bag digester is essentially a long cylinder (L/D = 3 - 14) made of either PVC, a Neoprene coated fabric (Nylon), or red mud plastic (RMP) (**Figure-4**) integral with the bag are feed inlet and outlet pipes, and a gas pipe.

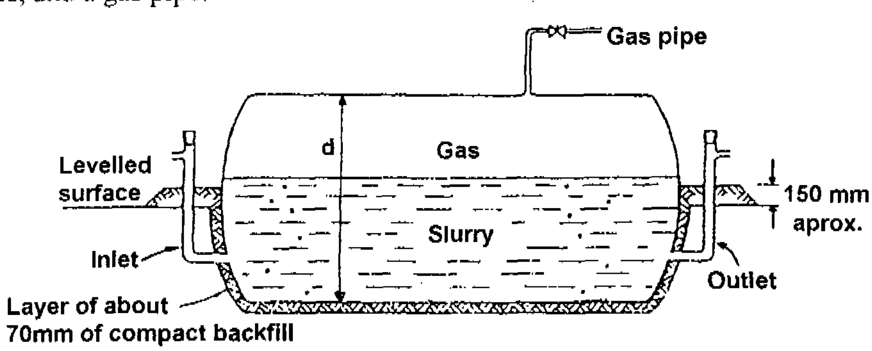

Figure 4 Bag (Taiwan) Digester

The feed pipe is arranged such that a maximum water pressure of approximately 40cm is maintained in the bag. The digester acts essentially as a plug flow reactor, and the gas produced is usually stored in the reactor under the flexible membrane, although it can be stored in a separate gas bag (Park et al, 1981).

Plug Flow Digester

The plug flow reactor, while similar to the bag reactor, is constructed of different materials, and hence for the sake of classification it is considered as a separate entity. A typical plug flow reactor consists of a trench cut into the ground and lined with either concrete, or an impermeable membrane (**Figure-5**).

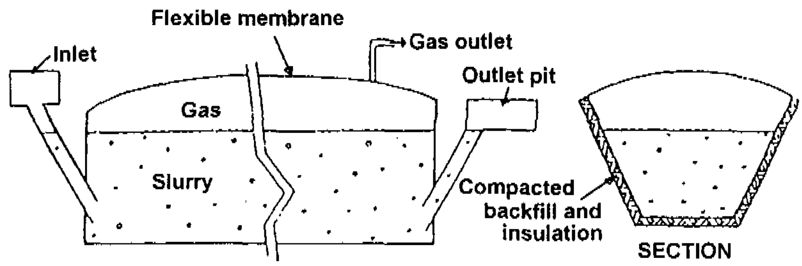

Figure 5 Plug Flow Digester

To ensure true plug flow conditions, the length has to be considerably greater than the width and depth. The reactor is covered with either a flexible cover anchored to the ground, which acts as a gas holder, or with a concrete or galvanised iron top. In the latter type a gas storage vessel is required. The inlet and outlet to the reactor are at opposite ends, and feeding is carried out semi-continuously with the feed displacing an equal amount of effluent at the other end.

Anaerobic Baffler Reactor (ABR)

The design, which is very recent, was evolved by Bachmann and McCarty at Stanford University. The reactor is a simple rectangular tank, with physical dimensions similar to a septic tank, and is divided into 5 or 6 equal volume compartments by means of walls from the roof and the bottom of the tank (**Figure 6**). The liquid flow is alternative upwards and downwards between the walls, and on its upward passage the waste flows through an anaerobic sludge blanket. Hence the waste is in intimate contact with the active biomass, but dew to the desugn most of the biomass is retained in the reactor.

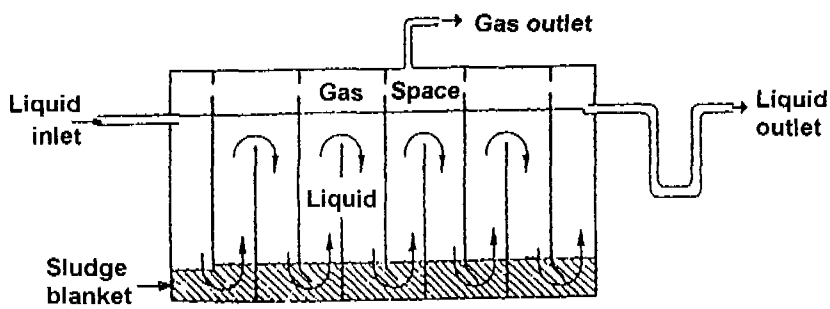

Figure 6 Anaerobic Baffled Reactor (ABR)

Sizing of Biogas Plant

To calculate the size of a simple biogas plant, the following characteristic parameters are used:

- Quantity of fermentation slurry
- Retention time
- Specific gas production rate

Quantity of Fermentation Slurry

This depends on biogas digester loading rate. The digester-loading rate is the amount of dry organic matter has to be supplied to the digester or has to be digested per day per unit volume of digester. In a simple biogas plant, 1.5 kg/m^3/day is quite a high loading rate. But temperature controlled and mechanically stirred large-scale plants can be loaded at about 5kg/m^3/day.

Retention Time (t)

Indicates the period spent by the feed materials in the biogas digester. It is chosen by the economic criteria. In general this time is chosen so as to achieve about 70-80 digestion.

Specific Gas Production Rate

It is the amount of gas that will be obtained per day per unit weight of specific feed material(s) at a given retention time at a specific temperature. The Figure-7 shows a typical example of gas production rate for cow dung with retention time and temperature of the digester content.

Scaling of Biogas Digester

The principal parameter which dictates the cost of biogas plant is its volume (v), which comprises of the active digester volume (V_d) and the gas storage volume (V_g) (See Figs 1, 2, 3).

The active digester volume (V_d) is calculated by the formula,

$$\mathbf{V_d\ (m3) = daily\ slurry\ feed\ (m^3/day) \times retention\ time\ (day)}$$

The daily gas storage volume (V_g) depends on gas production and the volume of gas drawn off. Gas production depends on the nature of fermentation slurry, digester temperature and retention time as shown in **Figure** 7.

The biogas production rate of some common fermentation material relative to cattle dung is shown in Table-4. Again, the ratio of the gas storage volume to the daily gas production rate is called gasholder capacity (c). For design purpose, a gas holder capacity of 50-60% is normally correct for peasant households in developing countries. However, a capacity of 70% or even more may be considered only where not more than one meal a day is cooked regularly or where eating habits is highly irregular.

$$\therefore\ \mathbf{V_g\ (m3) = Gd\ (m^3/kg/d) \times dry\ organic\ mater\ per\ day\ (kg) \times 1\ day \times C}$$

$$\therefore\ \mathbf{V = Vs + Vg}$$

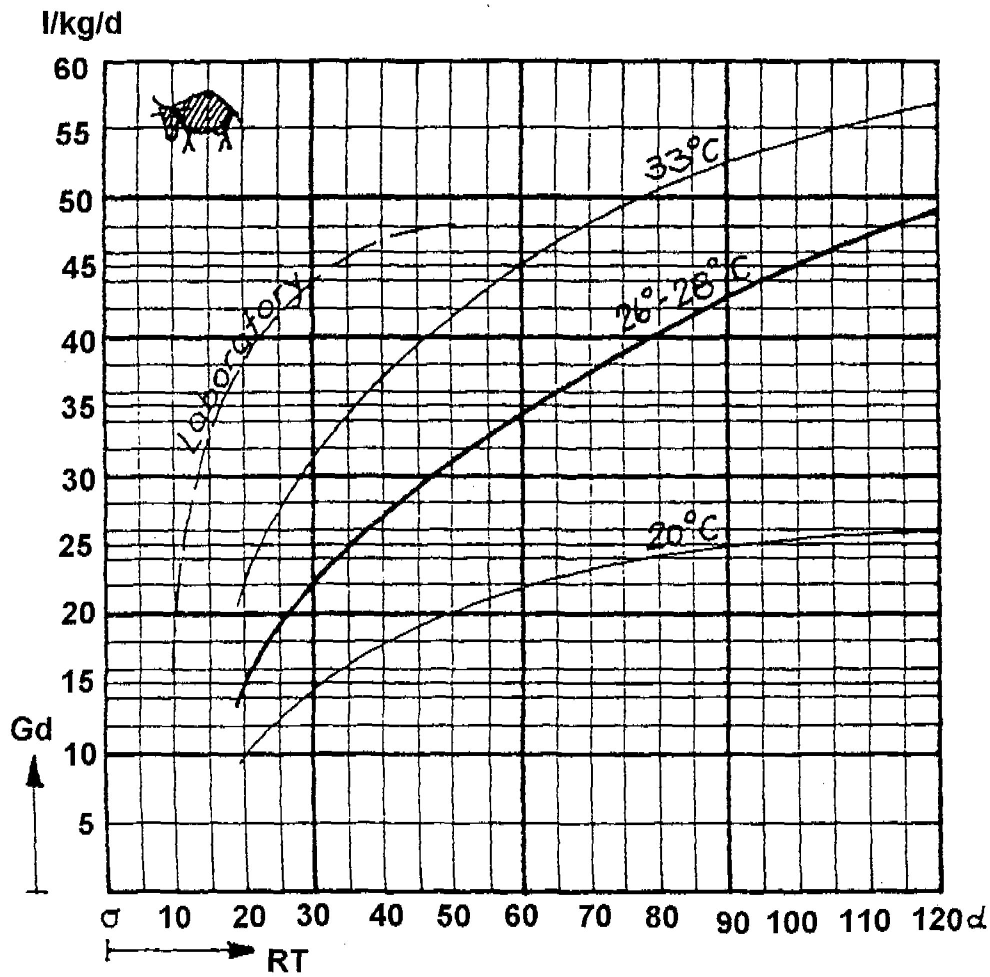

Figure 7 Gas Production from Cattle Manure Depending on Retention Time and Digester Temperature.

(The curves represent averages of laboratory and empirical values. The values vary a wide range owing to differences in the solids content of the dung, animal feeds and types of biogas plant. Regular stirring increases gas production. The 26-280 C line is a secure basis for scaling in the majority of cases.)

Table 4 : Gas production of different feed materials relative to cattle dung

Feed material	% of cattle dung
Cattle dung	100%
90% cattle 10% pig	125%
80% cattle 20% rice husks	120%
Pig manure	200%
Horse manure	150%
Goat droppings	70%
Poultry manure	60%

Biogas Fertiliser

In anaerobic digestion, various kinds of nutrient contents basically remain as residue left except that such elements as carbon, hydrogen and oxygen decompose stepwise and finally transformed into methane and carbon dioxide. Some water-soluble remain in digested slurry insoluble organic and inorganic solids in digested residue, whose surface adsorb a great amount of effective nutrient content. As a result the nutrient of biogas fertilisers are higher than those of the compost and the manure in open dump/farm yards (Table-5, APH,1989).

Table 5 : Nutrient Contents of Biogas Fertilizer and Compost

	Feed stock	Biogas Fertilizer	Compost
Total N (%)	1.54	1.52	1.26
Hydraulic N (%)	0.28	0.66	0.43
Portein N (%)	1.26	0.86	0.83
Total P (%)	0.717	0.703	0.482
Organic P (%)	0.612	0.572	0.371
Rapid available P (%)	0.105	0.131	0.111
Mineralization rate (%)	-	6.56	39.28
Loss rate (%)	-	1.97	32.61

Environmental Aspects

The main component of urban solid wastes in Bangladesh is organic food wastes (Rahman, 1993). Most of the solid wastes generated in the rural and slum areas of Bangladesh are also organic wastes and are as fuel. The combustion of these organic wastes, such as dung and agricultural residue, in the rural and slum areas of developing countries causes severe ecological imbalance due to loss of nutrients and serious indoor air pollution. The most important effects of air pollution are eye infections and respiratory diseases, ranging from predisposition to acute infection in children to chronic obstructive pulmonary disease in adults. About 700 million women in developing countries may be at risk of developing such serious diseases (WHO, 1992). The traditional use of these organic wastes as fuel is not only hazardous to health but is also a most inefficient way of using them as energy. The use of biogas technology will mitigate the adverse effects on health and ecological imbalance and will also improve fuel efficiency.

According to UNICEF and DPHE (1994), 33% of rural households in Bangladesh have hygienic latrines. Therefore, 67% of rural households do not have access to a sanitation system. The situation is also very poor in urban areas. The status of urban sanitation as shown in Table-6 (Task Force, 1990) indicates that only 15% of Dhaka city's population is served by a conventional waterborne sewerage system. All other cities mainly have septic tank system, with some coverage by poor flush pit latrines or bucket latrines.

Table 6 : Urban Sanitation Coverage in 1990 (in % population coverage)

Area	Sewerage	Septic tanks	Pour flush latrine	Bucket latrine	Unsanitary system
Dhaka	15	40	15	-	30
Chittagong	-	31	5	15	49
District towns	-	22	16	26	36

The implementation of biogas technology would be one of the best methods of sanitary practice with the reduction of problem of groundwater pollution from pit latrines or such other types of latrines. During the digestion process, a significant reduction of BOD occurs. The percentage reduction of BOD in the digestion process is shown in Table-7, from which it is evident that about 70% of BOD_5 removal occur with in five days of the retention period. Thus, the digestion process improves the quality of digester effluent and minimises water pollution.

Table 7 : BOD Reduction in the Digestion Process

Retention Time (days)	% Reduction of BOD
1	40-50
3	55-60
5	65-70

The Application of biogas technology will also minimise the spread of diseases because of the digestion of human excreta and other organic wastes. The more fully the wastes are digested, the more pathogens are destroyed. The reduction of pathogens in this anaerobic digestion process is influenced by retention time and the temperature of the digester contents. The higher the temperature, the shorter the time required for complete digestion. It has been reported that the principal organisms killed in biogas plants are typhoid, paratyphoid, cholera and dysentery (in one or two weeks), hookworm and bilharzia (in three weeks) (Sasse, 1988). Feachem (1979) reported that average virus removal was about 90% at a digester temperature of 35^0 C at twenty days' retention time. Therefore, it can be concluded that a great reduction if pathogens occurs in the biogas generation process but in the case of high concentrations of pathogens in the excreta of infected persons or animals, this reduction does not lead to a pathogen-free effluent.

However, complete removal of pathogens is possible with further treatment of digester slurry. The most common treatment methods are (i) drying, (ii) composting and (iii) composting with additional chemicals. Tapeworm and roundworm die completely if the fermented slurry is dried in the sun. Composting is an exothermic reaction (releases heat) and a temperature of 60^0C to 70^0C can be obtained. At higher temperatures, most of the pathogens are reduced as all of them are biological entities and rapidly denature at temperatures higher than 55^0C, even at a retention time of one day. The addition of liquid urea 9as done by the Chinese to a compost heap results in a high concentration of ammonia, Which disinfects the sludge. The use of these organic fertilizers minimises the use of chemical fertilizers and thereby reduces the most adverse impact of chemicals on the environment.

Bangladesh Experience

Experiences on biogas technology in Bangladesh are still at research level. At present more than 120 fixed dome Chines type and about 80 fixed dome biogas plants are operating in Bangladesh.

A few experimental plants based on human excreta have been installed, but documented data about their performance are lacking (Sinha, 1984). In this Section , an attempt has been made to evaluate the performance of a biogas plant constructed at Sreepur Shishu Palli, Gazipur. The biogas plant at Sreepur Shishu Palli is under ground fixed dome (Chinese model) type construction. This was constructed with brick walls and reinforced concrete top dome. The volume of the plant is $41m^3$. This plant servas for a population of about 550 with sanitary waste disposal system. The feed raw material is human excreta. The plant has been operating well with the biogas production rate of about 6 m^3/d since November 15, 1994. The construction cost of this plant was TK. 1,05,000 (US$ 2,625). The biogas generated in this plant has been used for cooking purpose. This replaces 51,000 kg of firewood per year which cost of about TK. I,02,000 (US$ 2,550). The use of this technology minimises indoor air pollution caused by the during of fire wood in the kitchen of Sreepur Shishu Palli, provides environmental sanitation for excreta disposal, treats huge amount of polluted water in excreta disposal system and will provide soil nutrients during the time of disposal of sludge from the biogas plant. It is also evident from the cost-benefit analysis of about 25 properly maintained biogas plants that the payback period of these biogas plants ranges between 1 to 5 years.

Problems Associated with Biogas Technology

At present different implementing authorities (Table-8) in Bangladesh are mainly active in promoting this technology without proper attention to research and development to renovate and optimise the design by suiting them to the local condition.

Table 8 : Biogas Plants Constructed by Different Organisations in Bangladesh

Organisation	Number of Biogas Digester				Present Condition
	Fixed dome	Floating dome	Bag type	Total	
BAU	-	5	-	5	Not working
BARD	-	1	-	1	Not working
BSSIR	22	35	-	57	50% not working
EPCD	110	109	-	219	85% not working
BSCIC	-	92	-	92	80% not working
BADC	-	5	-	5	Not working
LGED	89	8	-	97	10% not working
DANIDA	2	4	4	10	60% not working
Other	6	73	1	80	90% not working

It is evident from an internal report of the Local Government Engineering Department in 1992 (Table-6) that about 75 percent of the constructed biogas plants did not operate properly mainly because of design, construction and maintenance problems. The different implementing authorities in Bangladesh have limited research and development capabilities and there is limited co-ordination among the researchers and implementing authorities.

There is also a very limited follow-up action program. At present the administrative and technical infrastructure are not developed well enough to cope with this technology in Bangladesh. Therefore, the success of application and extension of biogas technology depends on:

- Prediction of realistic benefit of this technology.
- Opportunities for users' over-sighted feedback (meaningful public involvement is essential).
- Social mobilisation (construction of demonstration plant and popularisation of the technology in the rural and semi-urban community).
- Public awareness (this should have objectives to pass the relevant information of this technology to each person of the community, to increase awareness to minimise the non-acceptability of biogas from human excreta and from other organic wastes).
- Experience of biogas plant management and service reliability (Successful operation, repair and maintenance services, and user benefit-gas distribution and fertilizer application scheme).
- Availability of standard specification for design, construction and maintenance of biogas plants for the specific area.
- Institutional measures (there should be comprehensive sanitation and energy development policies for the rural semi-urban communities. This should include, among others, provision of soft term loans and/or subsidisation of this technology as a integral part of the sanitation program which currently exists in Bangladesh.

Conclusion

The relevance of biogas technology in Bangladesh lies in the fact that it makes the best possible utilisation of various organic wastes as a renewable and perpetual source of clean energy in the rural and semi-urban communities; can be improved by providing comprehensive sanitation and energy development policies. However, present experience of implementing this technology in Bangladesh indicates that there is an urgent need to develop an indigenous technical expertise, together with strong national co-ordination among different implementing authorities and research institutions to diffuse the technology in a meaningful way.

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Water Supply Technologies in Bangladesh

Drinking water supply in Bangladesh is based on ground water sources. Ground water is free from pathogens and requires no treatment for domestic water supply. For reasons of cost, quality, and availability, ground water is the preferred source of domestic water supply.

In most of the urban areas, power driven production wells to extract ground water, are widely used for piped water supply system. In some limited areas water is being treated for iron removal. Use of surface water after treatment is very limited. About 99% of urban people have access to safe drinking water supply. However, coverage by public water supply is only is 47%.

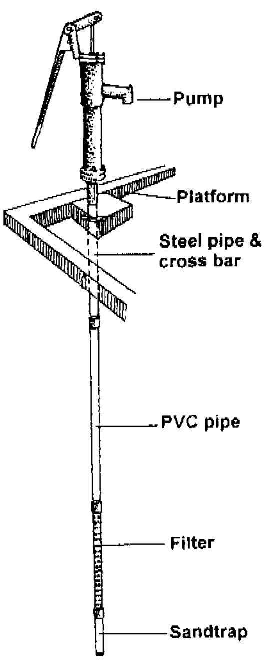
In rural areas and urban fringes, use of different types of handpumps is pre-dominating. At present, more than 90% of the rural people have access to a tubewell within 150 metres of their homes and about 95% of the people drinks tubewell water.

The handpumps can be mainly divided into two: i) suction pump and ii) deepset pump. The suction handpumps are operated in suction mode and can practically extract water upto a depth of 7.5m of static water level. Shallow tubewell, known as no.6 handpump is the most common in Bangladesh. Rower pump and Treadle pump are also operated in the same principle. Deepset pumps can withdraw water beyond the suction limit. Different versions of Tara handpump, Moon handpump and Cylinder handpump are within the category of deepset. These pumps can abstract water upto 30m of static water level depending on the technological advancement of the handpump.

No.6 handpumps are used in high water table areas. Rower and Treadle pumps are used in some very high water table areas, but mainly for irrigation and occasionally for domestic purpose. Deepset handpumps are used in low water table areas. Shallow Shrouded Tubewell (SST), Very Shallow Shrouded Tubewell (VSST), Pond Sand Filter (PSF) and Deep Tubewell are used in coastal areas. Open dug wells are also used in some areas for domestic purpose.

Brief description of different types of handpumps is given below:

Shallow Tubewell/ No.-6 handpump



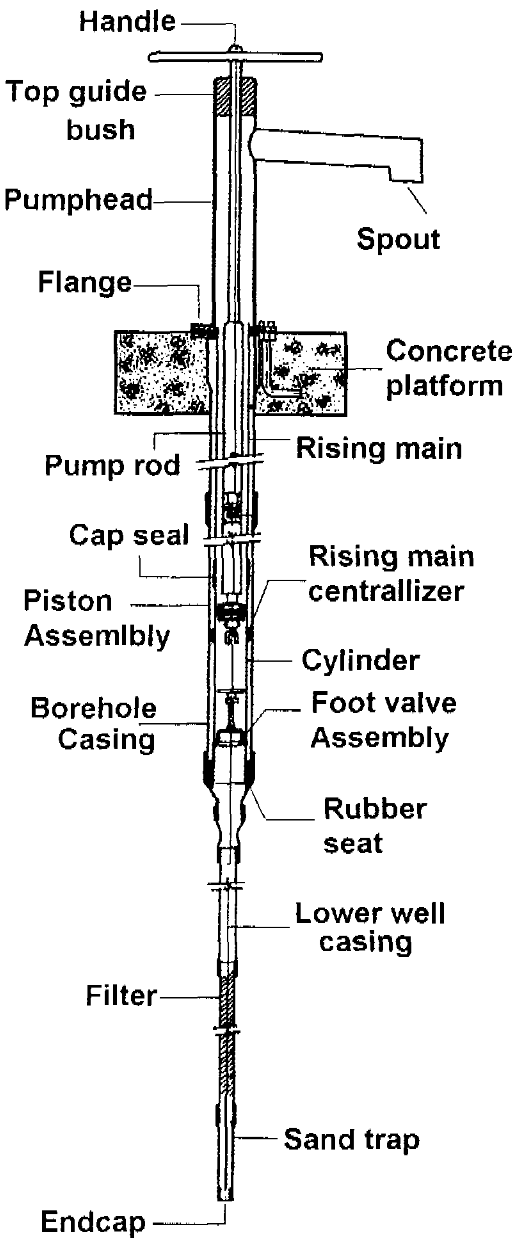
Shallow Tubewell (ST)/No.6 handpump performs well where the water table is within its suction limit. In Bangladesh the No.-6 handpump is predominant. Approximately 2.5 million pumps are already in use throughout the country and a very high percentage of these pumps are in operational condition. No.6 handpump is well known to all. Presently the private sector is mainly providing services and spare parts for installation, maintenance and repair of No.6 pump. The spares are available in open market.

The main components of the pump are head, handle, barrel, piston assembly etc.

No.6 handpump is promoted by UNICEF, DPHE and also private sector.

It is suitable for favourable hydrogeological conditions where water table normally remains within suction limit.

Tara Handpump



Tara handpump is a deep-set pump which is a product of the research by UNICEF and UNDP-World Bank Program initiated to develop an alternative technology to the suction handpump (No.-6) for using in areas where suction pumps can not withdraw water throughout out the year because of lowering the water table. A standard low-lift direct action Tara handpump was designed in 1986. The piston assembly is set below the ground at a depth where it can suck water easily.

The problems of Tara pump:

- Because of direct action, more force required even at low head.
- Buoyancing force, is not always available due to leakage in the pump rod.
- Tara provides moderate output (max. $4m^3$/day) for 7 meter lift and very low output (max. $1.5m^3$/day) for 12 meter lift. Failure of key components is likely at moderately high daily output.
- Repairing upon any breakdown or replacement of any part below the ground needs to open a major portion of the assembled pump which is often inconvenient.
- Installed mainly through the public sector.

Maximum discharge from a Tara handpump is 0.7 lit/sec.

Tara handpump is promoted by UNICEF, DPHE, UNDP-WB.

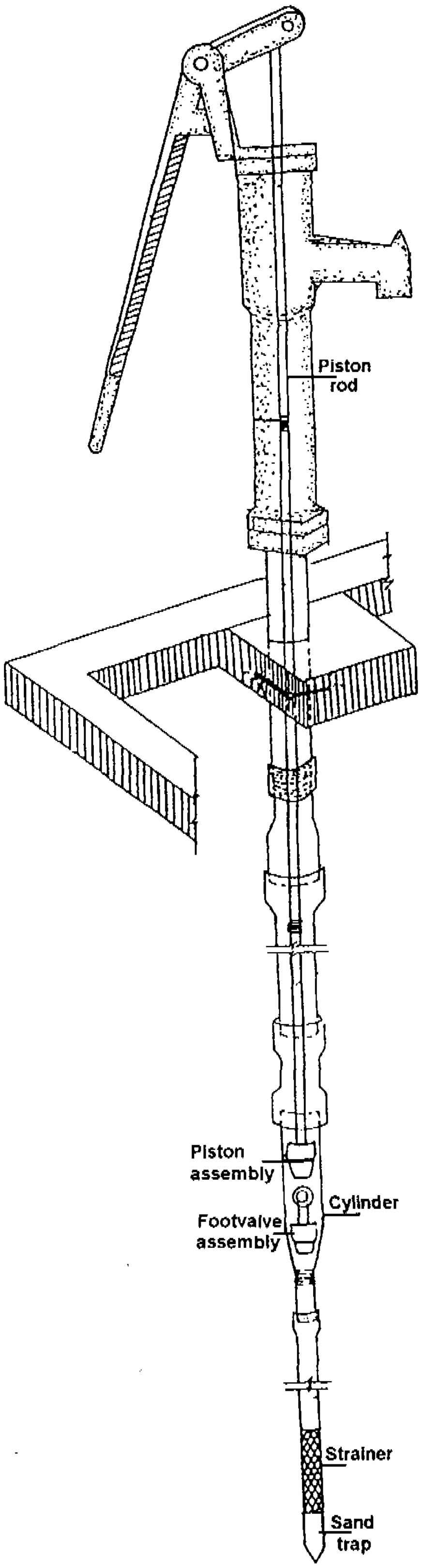
It is suitable for drawing water from the low water table zone upto a depth of 15m of static water level.

Tara has not yet been proved to be user friendly and needs more research on technical and social issues.

Tara-II handpump

Tara-II Hand Pump is a deep-set pump designed for low water table areas where static water level is beyond the capacity of Tara pump. Tara-II handpump has No.-6 head with modified bottom flange is used as head assembly. Maximum discharge from Tara-II handpump is 0.5 lit/sec. It is suitable for lifting head upto 25 meter. Tara-II handpump is promoted by UNICEF and PROSHIKA (MUK).

Moon Handpump



Moon Pump is a lever action deep-set handpump. It is a hybrid pump and developed on the experience of other pumps like Tara Pump, cylinder pump.

The special feature of Moonpump is its head assembly. No.-6 Pump head is used for head assembly of a Moon pump.

With the increase of lift head, the cost of the pump would increase which might limit the competitiveness of Moon Pump. Corrosion will cause problem to steel parts of the handpump. Problems in operation, maintenance and repairing of Moonpump is yet to be identified.

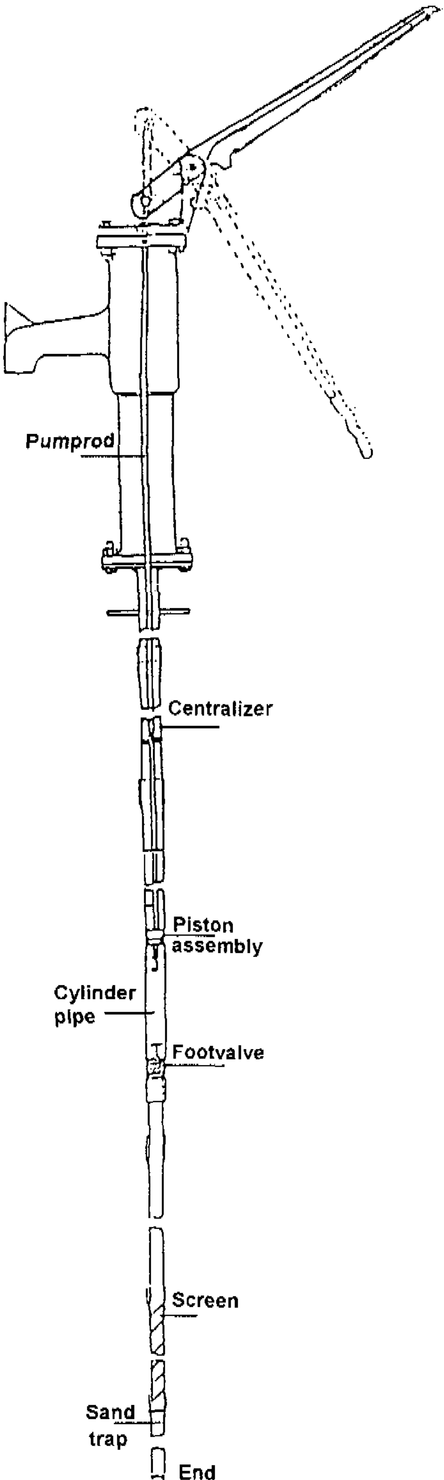
Maximum discharge of a Moon handpump is 0.6 lit/sec.

A good number of Moon Pump has been installed in Naogaon, Chapai Nawabganj and Manikganj under the Dutch Govt. assisted 18 District Towns Project very recently. No evaluation has yet been made for the Moon pump.

Moonpump is suitable for lifting head upto 25 meter.

This type of pump is newly introduced and needs research on its performance, users' acceptability, O&M etc.

Bangla Pump



The Bangla Pump is a deep-set pump designed for low water table areas. It uses No.-6 pump head for getting leverage advantage. The Bangla Pump was developed in 1991. Up-till 5 (five) Bangla pumps have been installed in Savar/Gazipur area and are functioning satisfactorily. A performance evaluation of Bangla pump was done by its developer on these pumps installed in 5 different public places for 2 years from May 1993 to April 1995.

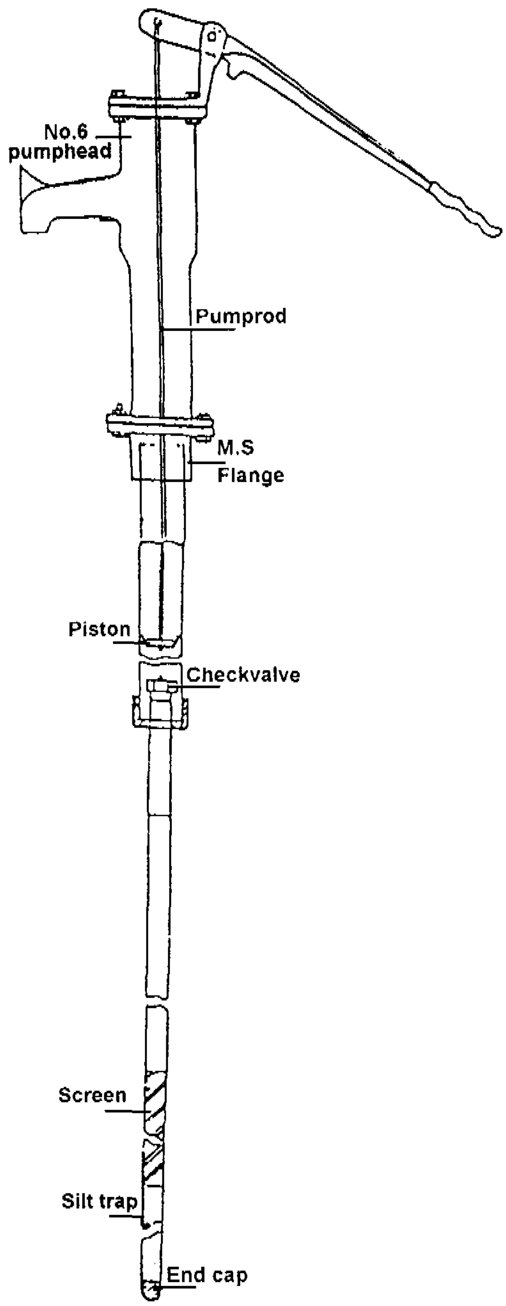
Maximum discharge of a Bangla handpump is about 0.6 lit/sec.

Bangla pump is introduced in a very limited extent by private sector.

This type of pump is newly introduced and needs research on its performance, users' acceptability and O&M.

Suitable for lifting head upto 30 meter.

Disco Pump



The Disco Pump is a suction type of pump having the lever type head of No.6 handpump. The plunger rod has been extended to keep the pump working within suction limit.

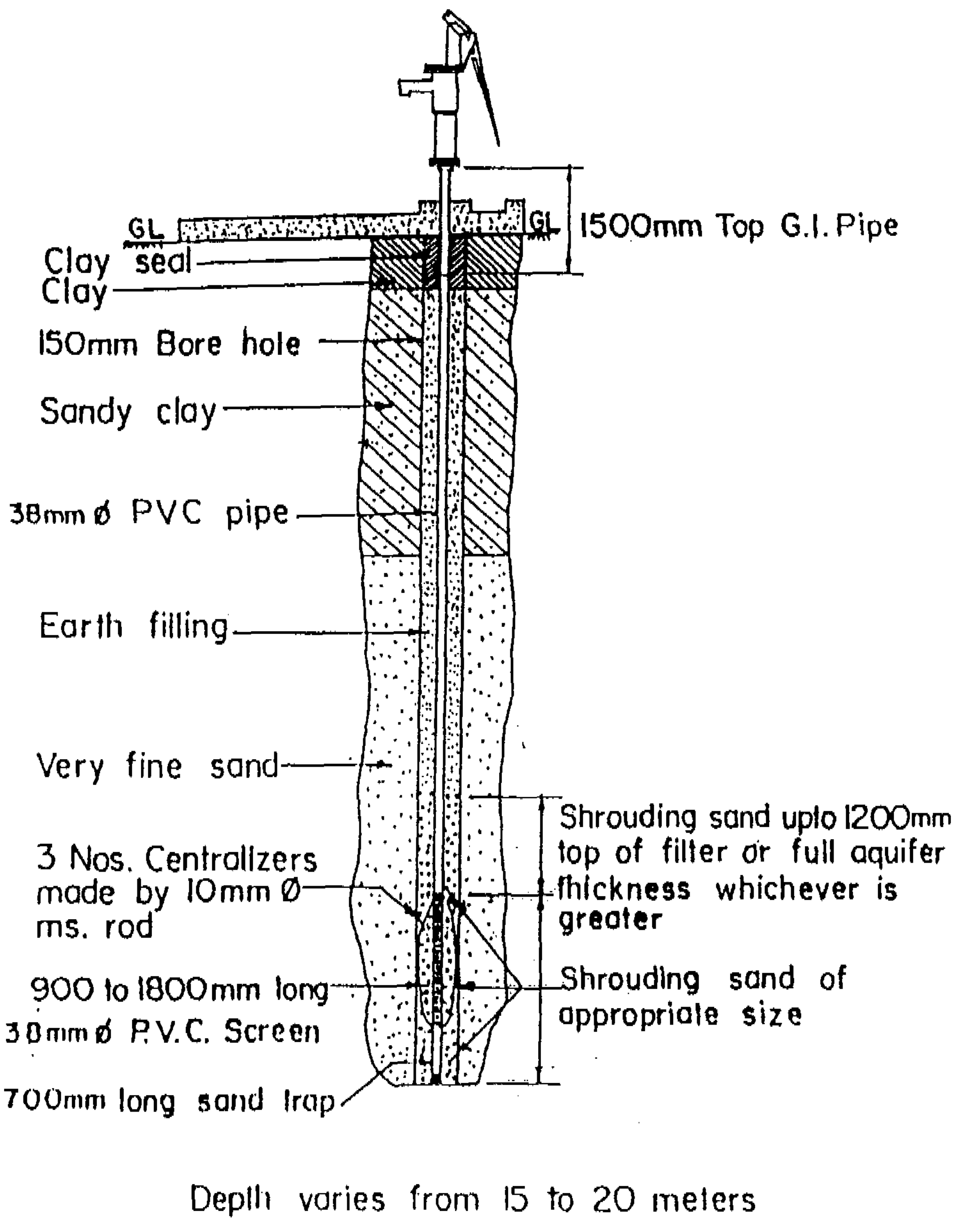
Disco pump is initiated in a very limited extent by private sector.

This type of pump is newly introduced and needs research.

Shallow Shrouded Tube well (SST)

Shallow Shrouded Tube well is a special type of technology followed in installation of hand tubewell at a relatively shallow depth in a fine sand aquifer bearing fresh water in the coaster belt. The strainer of this type of tubewell is usually shrouded by coarse sand to obstruct the fine sand to facilitate the pumping of water. This type of tubewells are usually installed upto 15-20 metres.

Shallow Shrouded Tube well (SST)

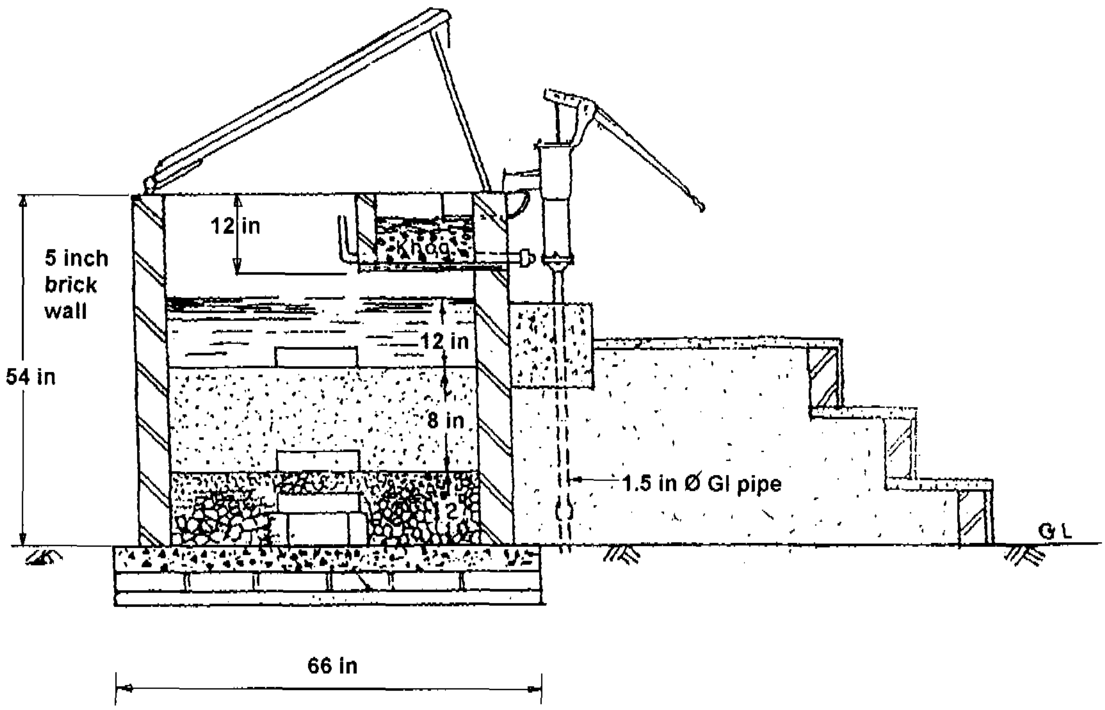


SST is suitable for saline zone. Identification of the existence of fresh water pockets is difficult.

Very Shallow Shrouded Tube well (VSST)

Very Shallow Shrouded Tube wells (VSST) are appropriate to fresh water pockets in the saline belt and are very inexpensive. However, drilling failure in common as they rely on to very specific conditions for success: they can operate only where a pocket of fresh water exists, and where an aquifer (a sand layer) exists within this fresh water zone. This special type of tubewell are installed between 8 to 10 metres below the ground level. Identification of the existence of fresh water pockets is difficult. The life span of VSST is short.

Pond Sand Filter



There are certain areas in the coastal belt, where tube wells are not successful, because suitable freshwater aquifers at reasonable depth are not available and ground water is grossly saline. Such areas are located in the southern fringes of Khulna, Barisal and Patuakhali districts.

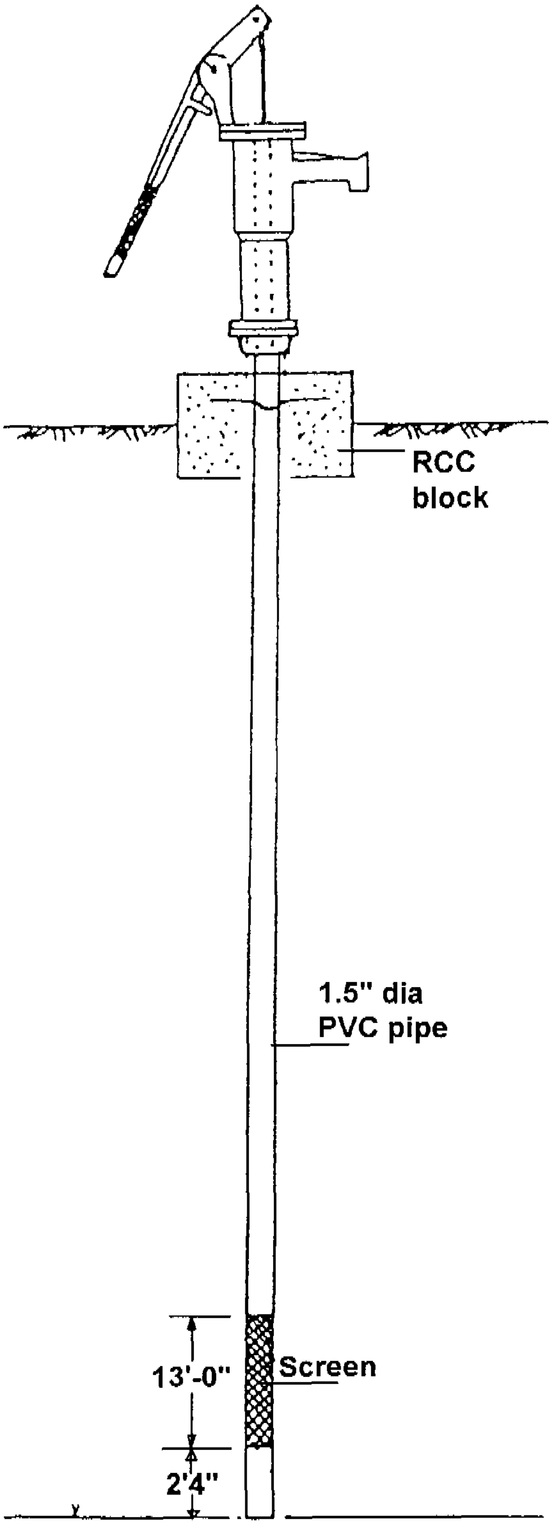
The people of those areas mainly depend on water from artificially dug ponds, so called "sweet water ponds" which are replenished by rain water during the monsoon. But their number is not adequate. The people generally use pond water for drinking and cooking purposes. But the water is dangerously contaminated and is not suitable for human consumption without treatment. Sophisticated treatment is neither economically feasible not practicable for small community water supply in those areas. PSF can utilise these ponds as water sources.

A PSF comprises of a handpump and a small sand filter. Pond water is delivered into the sand filter through the handpump. As the water passes through the filter it is purified upon the principle of slow sand filter and the water is stored in the storage tank. This process takes time. So, it is expected that the person who is taking water from the storage tank must replenish the same amount of water into the filter by pumping the handpump.

The performance of PSF depends on regular cleaning. Problems of PSF include poor O&M, leakage and PSF is promoted by UNICEF, DPHE.

The cost of PSF is high. Construction, operation and maintenance of PSF is difficult. PSF has not yet established as successful and low cost technology option. Therefore, further research is needed on its performance, O&M and users' reaction.

Deep Tubewell



Deep tubewell operates exactly in the same principle (suction mode) as a shallow tubewell. The only difference is that the length of a deep tubewell is more than 75m. These deep tubewells are usually installed in saline areas to extract water from fresh water aquifer. Mechanical devices are used for construction of these tubewells.

The installation cost of deep tubewell is too high.

Iron Removal

Iron Problem in Groundwater of Bangladesh

Introduction

Water is a basic necessity of man along with food and air, the importance of supplying hygienic potable/fresh water can hardly be over stressed. The impact of many diseases afflicting mankind can be drastically reduced if fresh hygienic water is provided for drinking.

Bangladesh is many dependent on groundwater for drinking water supplies. Ground water quality of any area is of great important for human being. The ground waters irrespective of their source of origin contain mineral salts and other chemical compounds such as iron, manganese, nitrate, fluoride, chloride, calcium, sodium etc. The kind and concentration of constituents depend upon various geological, geo-hydrological and physical factors of the aquifers. The quality and composition of the dissolved mineral in natural water depend upon the type of rock or soil with which it has been in contact or through which it has percolated, and the duration it has been in contact with these rocks. The quality of ground water may very from place to place and stratum to stratum. It also varies from season to season.

Iron occurs in underground water as a soluble (ferrous) from and it becomes as an insoluble (ferric) from when it comes in contact with air. Presence of iron in water changes the characteristics of fresh water, alters colour of water as well as taste of water. Iron contained water makes the teeth & nail black and weak, stickiness of hair and roughness of skin. Soaps also do not response well if iron is present in water. Iron problem is acute in various places in groundwater of Bangladesh, but there has been no through investigation on the iron content in groundwater of Bangladesh. The present investigation was therefore carried out to study the iron content in groundwater of Bangladesh, suitability of groundwater for drinking.

Analysis of the Iron Content in Groundwater of Bangladesh

Data collection

The data considered here were collected from the various agencies involved in the work of underground water. Mainly these data were collected from Environmental Engineering laboratory, BUET, Dhaka and Bangladesh water Development Board (Groundwater circle), Dhaka.

These data were compiled according to the administrative distracts of Bangladesh. Maximum 50 numbers of water quality data have been found in Chittagong districts and minimum 4 numbers of water quality data have been found in Saiatpur, Habigang, & Chandpur Districts. Locations of those collected samples have been shown in **Figure-1**.

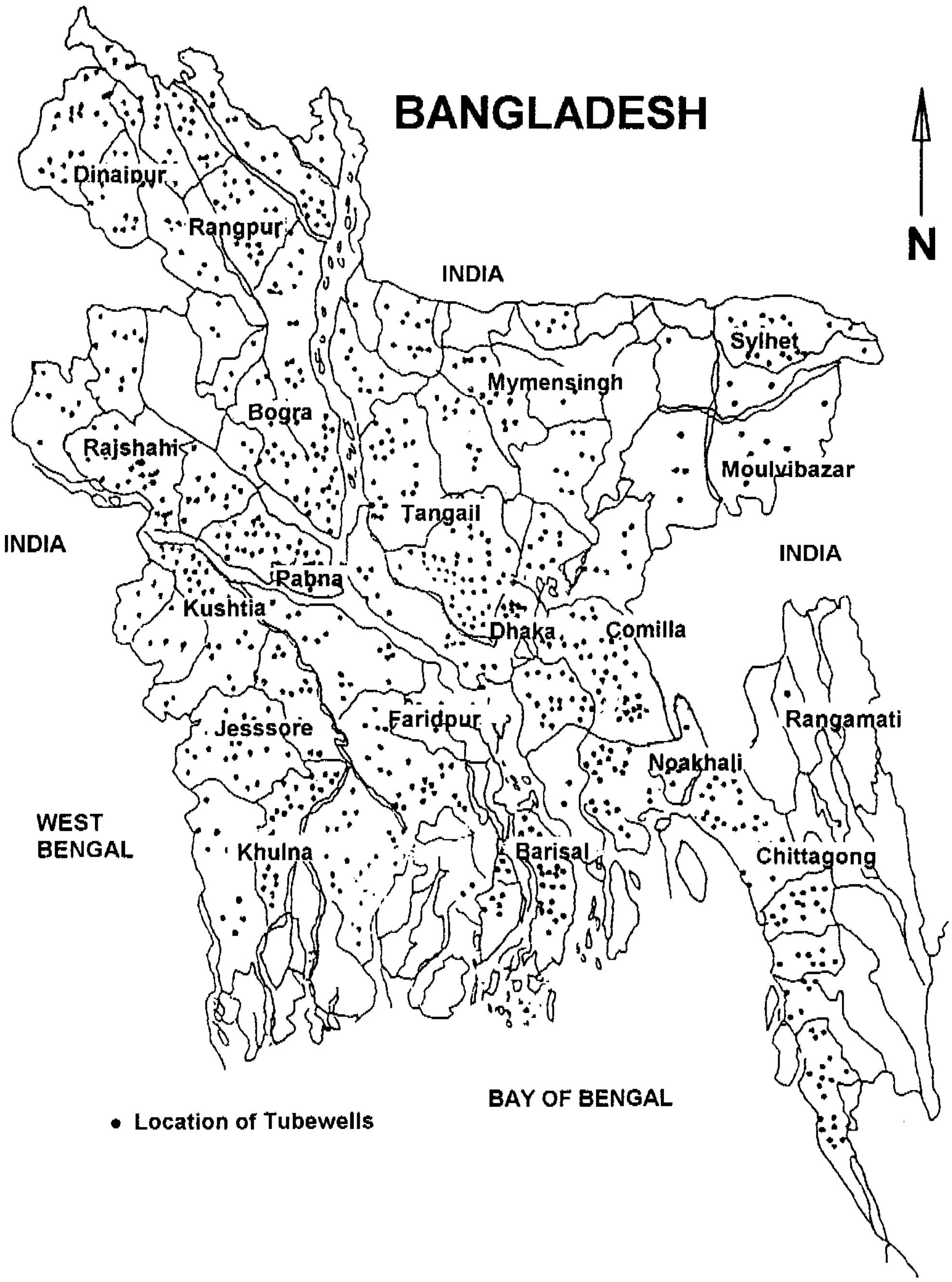


Figure 1 Locations of the Observed Deep Tubewells of Bangladesh

Groundwater Quality Data Analysis

In this analysis, iron content in ground water has been compared with the Bangladesh water quality standard for drinking. Ground water quality data of about 1000 deep tubewell samples from about 124000 Sq. km. area which covers 56 administrative districts of Bangladesh out of 1444000 Sq. km. area of 64 administrative districts were analysed for drinking. Inadequate information is available of about 20000 Sq. km. area (rest 8 districts) of Bangladesh. Allowable limit of iron in water for drinking in Bangladesh is 0.3 - 1. 0 mg/1. The limit may be considered upto 5. 0 mg/1 having no alternative suitable drinking water sources. Two analysis have been performed with the help of GIS, having iron concentration exceeding 1.0 mg/1 and exceeding 5, 0 mg/1 are shown in **Figure- 2 & Figure - 3** respectively.

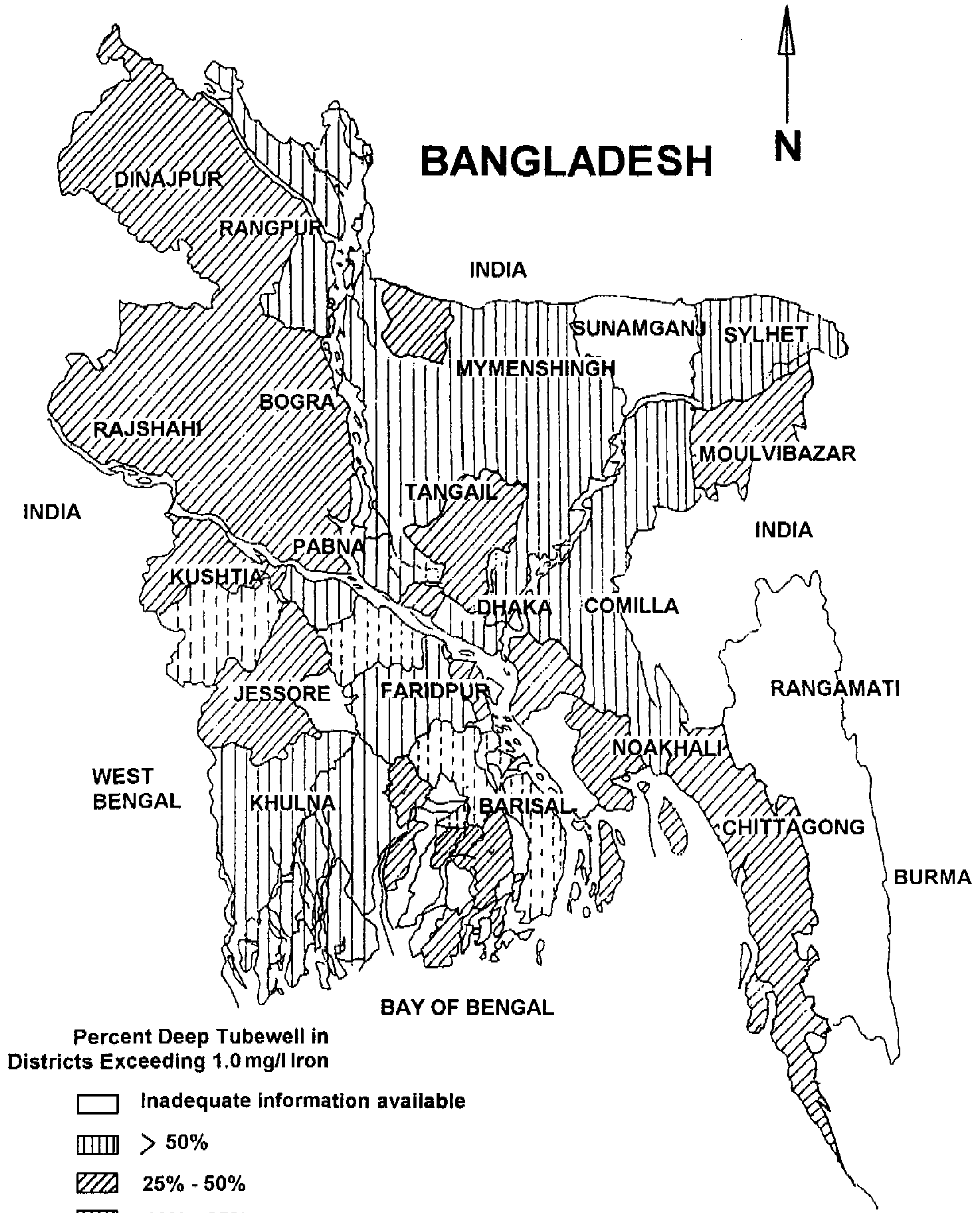


Figure 2 Iron Content in Deep Tubewell water of Bangladesh (Iron > 1.0 mg/l)

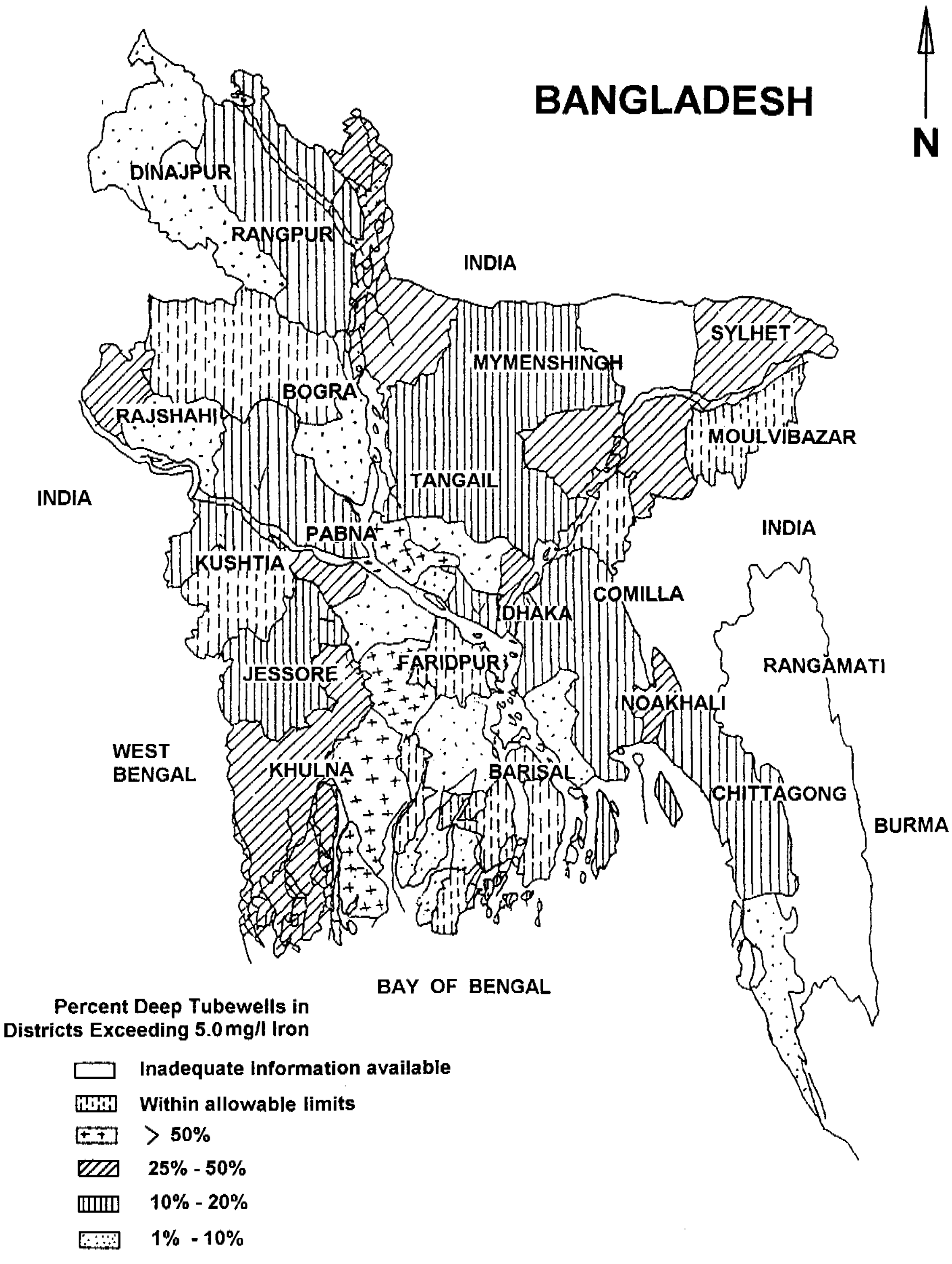


Figure 3 Iron Content in Deep Tubewell water of Bangladesh (Iron > 5.0 mg/l)

From Figure-1, it is observed that there is iron problem almost all areas of Bangladesh. Groundwater of about 51,000 sq. km. (41%) of the studied area contain more than 1.0 mg/l of iron. Whereas about 28,000 sq.km. (22.5%) of the studied area contain iron more than 5.0 mg/l. Iron problem is acute in groundwater in the districts of Manikgonj, Gopalgonj, Norshingdi, Narayangonj, Rajshahi, Bagerhat, Sylhet, Sonamgonj, Noakhali, Khulna and Kurigram. The people in the problem areas use tubewell water having 4.0 mg/l of iron without much hesitation but water of such quality are not acceptable in other region of the country. The major causes of the non-usage of water with excessive iron are bad taste and odour, stickiness of hair and roughness of skin and also it makes the teeth and nail black and weak. Iron removal plant is essential for the above mentioned excessive iron areas of Bangladesh. Aeration, coagulation/flocculation, sedimentation and filtration are required for a large-scale treatment process.

Iron Removal

Sources of Iron

Iron exists in soil and minerals mainly as insoluble ferric oxide and iron sulphide (pyrite). It occurs in some areas as ferrous carbonate (siderite) which is very slightly soluble. Some ground waters usually contain significant amount of CO_2, appreciable amounts of ferrous carbonate may be dissolved by the reaction shown in the equation:

$$FeCO_3 + CO_2 + H_2O \rightarrow Fe^{2+} + 2HCO_3^-$$

Removal Methods

There are four general methods used for the removal of iron:

A. The primary method involves oxidation, precipitation followed by solid transfer (sedimentation and filtration).
B. The second method involves ion exchange.
C. The third method involves stabilisation of iron in suspension using dispersing agents to prevent the deposition of iron.
D. Sub-surface aeration.

A. Oxidation, Precipitation followed by Flocculation, Sedimentation and Filtration

The most popular method of iron removal involves oxidation of more soluble iron (II) to relatively insoluble iron (III) and subsequent removal of the precipitates thus formed by sedimentation and filtration.

The Kinetics of Iron Oxidation

- Rate of ferrous iron oxidation is of the first order with respect to ferrous iron concentration and the partial pressure of oxygen.
- Rate of oxidation remains unaffected by DO concentration, if the concentration exceed 5mg/l.
- Reaction rate are strongly pH dependent and there is a second order relationship, quite slow at pH 6.00 and very rapid at pH >7.5. Solubility of ferric hydroxide decreases with increasing pH only upto about 10.0.
- Oxidation reaction is incomplete and very slow for low alkaline water (<130 mg/l as $CaCO_3$). Within a pH range of 7.49 - 7.78 an increase of alkalinity from 395 to 610 mg/l as $CaCO_3$, causes a 10 fold decrease in half time.

- Rate increases about 10 fold for a 15°C increase in temperature.
- Chloride and sulphate ions have a significant retarding influence on the rate constant in the pH range from 6.5-7.2.
- Organic materials form complexes with ferrous iron which is resistant to oxidation, even in the presence of DO.
- For a given pH and DO concentration, the addition of as little as 0.02 mg/l of Cu^{2+} reduces the oxygenation time by a factor of 5.

Solubility of Iron

Iron is chemically reduced, **soluble**, invisible in **ferrous form (Fe^{+2})** and may exist in tubewell waters or anaerobic reservoir bottom water under the following conditions:
-- In absence of DO, at high CO_2 concentration, at low pH, low alkalinity and complex with organic materials.
Iron is oxidised, **insoluble**, visible in **ferric form (Fe^{+3})** under the following conditions:
-- In presence of DO, at low CO_2 concentration, at high pH, high alkalinity and in absence of organic materials.

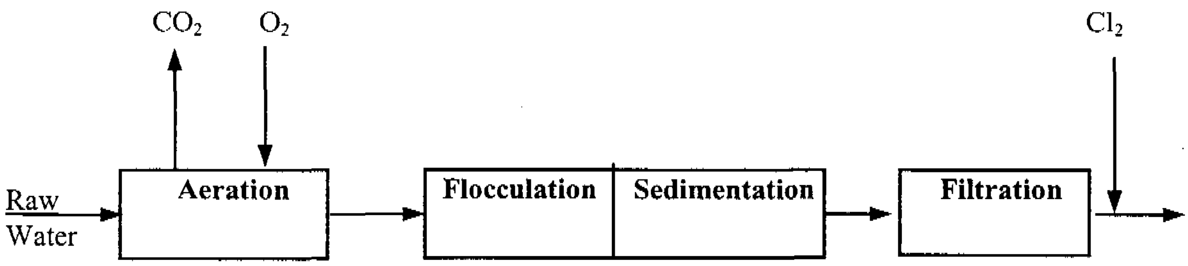
(a) Oxidation through Simple Aeration

The simplest form of iron oxidation is plain aeration. Stoichiometrically 0.14 mg/l of O_2 is required to oxidise 1.0 mg/l of Fe.

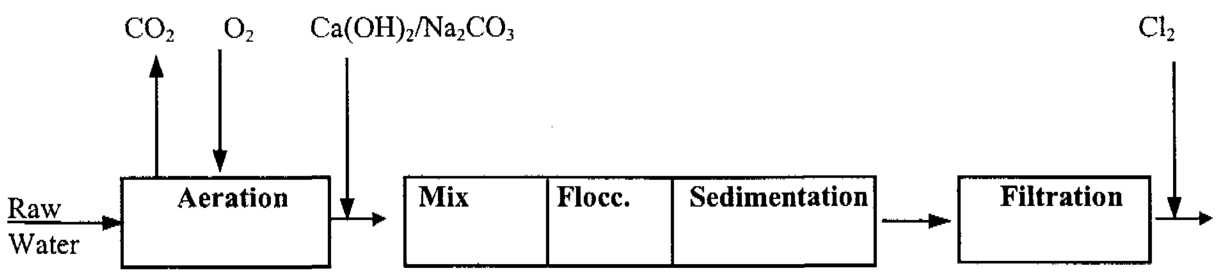
$$4Fe(HCO_3)_2 + O_2 + H_2O \rightarrow 4\ Fe(OH)_{3(s)} + 9CO_2$$

Removal under different environmental conditions:

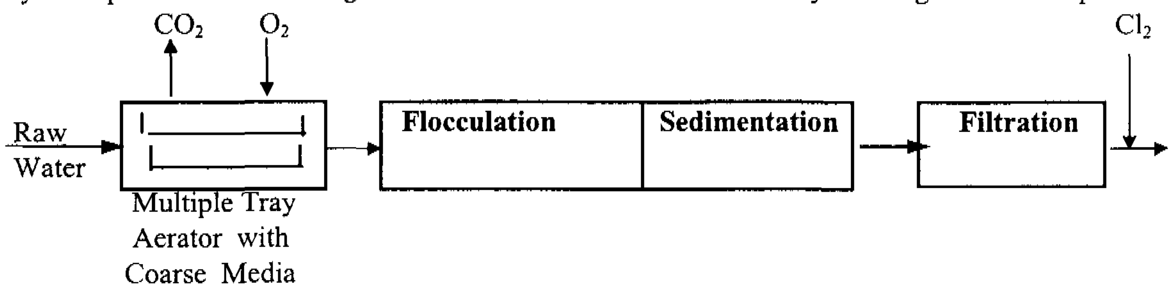
1. Iron alone in ground waters which **contains little or no organic matter with reasonable alkalinity** when aerated CO_2 and H_2S are released raising the pH and oxidised to insoluble iron.



2. **Low alkalinity** water (< 130 mg/l as $CaCO_3$) needs some chemical additive to raise both pH and alkalinity like lime [$Ca(OH)_2$], soda ash [Na_2CO_3] etc. If the water is softened by addition of lime, additional benefits include removal of iron. Aeration prior to lime addition reduces the cost of chemicals through CO_2 reduction.

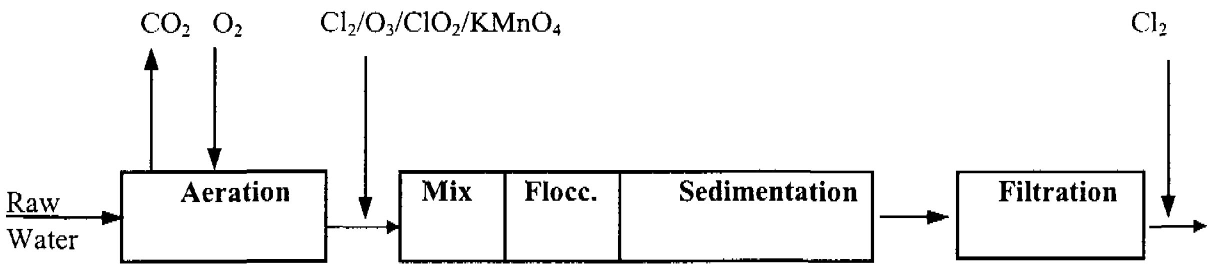


3. If the water **contains organic matter** such as humic or fulvic acid and if **the alkalinity is low,** aeration is sufficiently rapid only if it is catalysed by accumulation of oxidation products (Fe_2O_3) on a porous bed (aeration tower containing trays with coarse media). Iron is removed from solution by adsorption on the bed. Organic material interferes with removal by forming soluble complexes.



(b) **Aeration and Chemical Oxidation**

Preliminary aeration strips out dissolved gases and adds oxygen. In low alkaline or organic content water, the application of strong oxidising agents such as chlorine, ozone, chlorine dioxide, or potassium permanganate can serve to modify or to destroy the organic material and to oxidise iron more rapidly. 0.94 mg/l of potassium permanganate and 0.64 mg/l of chlorine is required per 1.0 mg/l of iron respectively.



(c) **Biological Oxidation**

Gallionella ferruginea , *Leptothrix* and other iron bacteria are capable to oxidise iron.

Solid transfer:
Effective flocculation, sedimentation and filtration following chemical oxidation is essential, since a significant amount of the flocculated metal oxides are not heavy enough to settle by gravity. Direct filtration is not always recommended to avoid frequent clogging of filter bed, particularly when the concentration of iron is high (> 5 mg/l).

B. Ion Exchange

Manganese zeolite is natural green sand coated with manganese dioxide that removes soluble iron from solution. After the zeolite becomes saturated with metal ions, it is regenerated using $KMnO_4$. Cation-exchange resins will remove iron, but care must be taken to ensure that it remains in the reduced state, otherwise, it will form coating on the resin reducing the exchange capacity

C. Stabilisation

Sodium hexa-metaphosphates at dosages of 5 mg per mg of Fe and Mn are used for this purpose. This process is limited for Fe + Mn concentration upto 1.0 mg/l.

D. In-situ (Sub- surface) Aeration

Iron may be treated in situ by pumping oxygenated water into a metal-rich aquifer. The iron is evidently oxidised and precipitated within the aquifer and are deposited upon the sand in a manner, which does not cause clogging.

Manganese Removal

Manganese is much more slowly oxidised through aeration than iron. In fact, the rate is negligible at pH levels below 9.0. Chemical oxidation of Mn requires a pH level above 8.5 and 1.0 mg of chlorine can oxidise 1.3 mg of Mn.

Microbial Quality of Water

Microbial Quality of Water

Microorganisms are commonly present in surface water, but they are usually absent from ground water, because of their filtering action of the aquifer. The most common microorganisms in water are bacteria, fungi, protozoa, helminths(worms),viruses and algae. Many communicable diseases are transmitted by water due to presence of these organisms.

Bacteria - are single celled organism with varying in shape and size from about 1 to 4 μm. Disease-causing bacteria are called pathogenic bacteria. The bacterial diseases include typhoid, paratyphoid, bacillary disentery, asiatic cholera, etc. *Escherichia Coli* are bacteria that inhabit the intestines of warm-blooded animals and humans are excreted with feces and their presence in water is taken as an indication that pathogenic bacteria may be present.

Fungi- are aerobic, multicellular, non-photosynthetic and chemoheterotrophic protists. Ecologically, fungi have two advantages over bacteria; they can grow in low-moisture areas, and they can grow in low-pH environments. Certain fungi, notably *Aspergillus,* are human pathogens.

Protozoa- They feed on bacteria and other microorganisms. Protozoans such as *Giardia* and *Cryptosporidium* can produce gastroenteritis and are very resistant to disinfectants.

Worm- Schistosomiasis is caused by a worm which may be transmitted through water via a snail carrier.

Viruses- are obligate parasitic particles, which do not have the ability to synthesize new compounds. Viral diseases associated with water include hepatitis, poliomyelitis and gastroenteritis etc.

Algae- can be a great nuisance in surface waters because they produce large floating colonies called blooms. Lakes with annual total nitrogen and phosphorus concentration greater than 0.8 mg/l and 0.1 mg/l. respectively, exhibit algal blooms and nuisance, weed growth during most of the growing season. They often cause taste and odor problems.

Sanitary Protection

Organisms, which cause infectious diseases, are normally spread through the fecal and urinary discharges of sick person and carriers. Protection of water supplies against these agents is thus normally a matter of preventing discharges of human wastes and inadequately treated waste water into the source.

Water Quality Improvement

(a) Natural Process

Most pathogens are accustomed to live in the temperatures and conditions found in the bodies of humans and animals. They do not survive well outside the body. Storing water for extended periods in open tanks or reservoir prior to treatment can accomplish some destruction of pathogens through sedimentation and natural die-off of the organism. More than 50% of the pathogen in water will die within 2 days and 90% will die by the end of one week.

(b) Conventional Treatment

Significant pathogens removal also occurs during the conventional treatment processes of coagulation, flocculation, sedimentation and filtration. Typical bacterial and viral reduction in coagulation- flocculation processes are 60-70% and addition of a filtration process increases the over all removal to close to 99%.

Coagulation Process (Sweep floc)

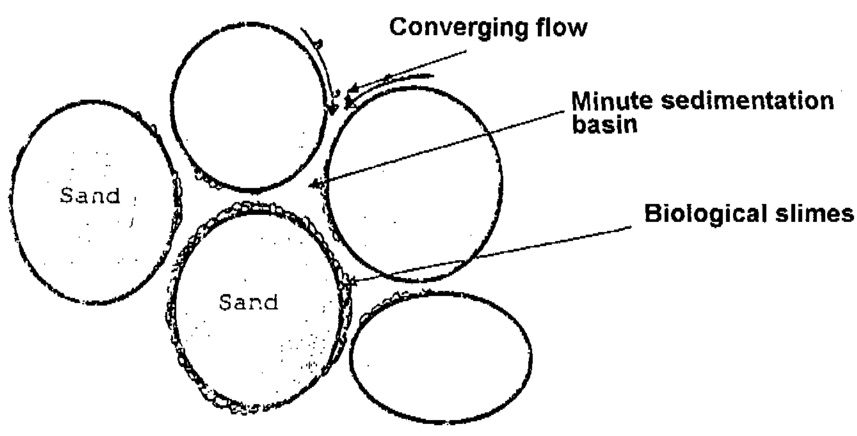
During coagulation and flocculation processes bacteria are entrapped in a floc or enmeshed by its 'stick' surface as the flocs settle at the bottom of the settle tank. Removal of *Giardia* in coagulation is closely associated with removal of turbidity (65 - 90%). Removal of hepatitis A virus and rotavirus are typically in excess of 90%.

Softening Process

Extreme values of pH, either high during softening process or low, during alum coagulation process can provide good bacterial kills.Precipitation of Mg (at pH value around 11.0) can give coliform reduction of more than 99.9%.

Filtration Process

The filter media are very efficient in retaining finer and colloidal particles including bacteria. Converging flow across the interstices, increases the probability of contact between the small particles to form flocs.The interstices between the sand grains act as a minute sedimentation basin in which the suspended particles, colloids,bacteria settle upon the sides of the sand grains and adhere because of the presence of gelatinous coating (biological slimes of SSF or coagulant floc layer of RSF)on filter media. Adhesion of bacteria on gelatinous coating (top layer) form a Zoogleal film around sand grain in which biological activities are carried out (detain bacteria and remove organic matter in SSF).



Slow sand filtration has been clearly demonstrated to be capable of complete removal of *Giardia* after ripening. In addition it provides excellent removal of coliforms, other bacteria and viruses. The length of filter run can be increased by pre-treatment by passing the water through a series of coarse gravel ranging from 6 - 20 mm, which can reduce the turbidity from over 100 to less than 10 NTU.

In Rapid sand Filter coagulated floc [$Al(OH)_3$] form a chemical layer on the filter media which is also gelatinous in nature. Bacteria are removed due to adhesion/adsorption on this layer.

(c) Disinfection

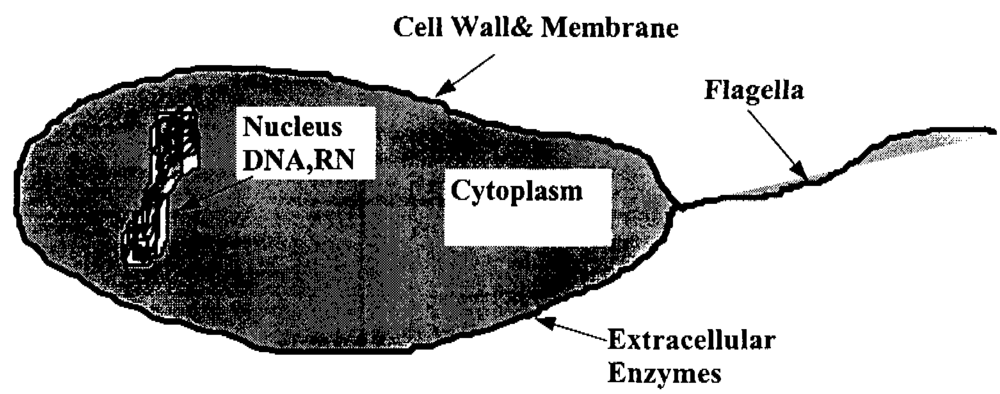
Is the killing of disease-producing micro-organisms. It provides additional protection against transmission of diseases. The rate of kill is a function of concentration of disinfectant and exposure time,

$$\text{Kill} \infty c \times t$$

Viruses, cysts, and ova are more resistant to disinfectants than are bacteria. Disinfectants include chemical agents such as the halogen group, ozone, or metallic ion; irradiation with gamma waves or ultraviolet light; and sonification, electrocution, heating, or other physical means.

Chlorination

Chlorination is the most common means of disinfecting water and usually performed as the final treatment process. The mechanism by which chlorine kills disease-causing organisms is uncertain. It is likely that the chlorine destroys the extracellular enzymes of the bacteria's and possible that it actually passes through the cell wall to attack intercellular systems.



At higher concentrations, oxidation of cell wall will destroy the organism. Other factors affecting the process are- form of chlorine (HOCL), pH(low), type of organisms, temperature and turbidity (low) of water.

Ozone

It is a strong oxidising agent. Unlike chlorine it requires a very little contact time. Contact times for virus inactivation are reported as little as 2 minutes. The disadvantage is that no residual remains in this process of disinfection.

Potassium permanganate

It is also a strong oxidising agent and exhibits germicidal properties.

Ultraviolet irradiation

With a wave length of 253.7 nm it is effective in killing all types of bacteria and viruses through the probable mechanism of destruction of nucleic acids (DNA,RNA). The UV energy is absorbed by the genetic material of the cells.

Ultrasonic waves

At frequencies of 20 to 400 kHz have been demonstrated to provide complete sterilisation of water at retention times of 60 minutes.

Metallic ions

Metallic ions, such as silver (0.05 mg/l), copper and mercury exhibit disinfecting action.

Heat

Heat can be used to disinfect water by boiling for 5-20 minutes.

(d) Control of Carbon & Nutrient Sources

There are four basic requirements of life. The growth of organisms can be stopped / ceased through controlling any one of these parameters.

Source of Carbon: Organic carbon(Heterotrophic), $\underline{C}_xH_yO_z$
Inorganic carbon (Autotrophic), $\underline{C}O_2$
Source of Energy: Chemical oxidation/reduction reaction (Chemosynthetic)
Sun light (Photosynthetic)
Source of Nutrient: N, P and other trace elements(Fe,Na,K,Ca,S etc.)
Source of Respiratory Oxygen(Aerobic): Molecular oxygen

Algae Control

The only effective means of preventing algae growth is nutrients (Nitrogen and Phosphorus) control. Nitrogen and phosphorus are mainly contributed to surface waters from man generated wastes (feces, urine,food wastes,synthetic detergents etc.) and run off from agricultural land (fertiliser). The general acceptable upper concentration limits for lakes free of algae nuisances are 0.3mg/l of inorganic nitrogen and 0.02mg/l of orthophosphate phosphorous at the time of spring overturn. Several temporary controls have been used to reduce the algae growth:

- Chemical control (algaecide)
  Both copper sulphate(usually 0.1-0.5mg/l) and chlorine(0.3-1.0mg/l) have been used to control algae.
- Artificial mixing / Artificial destratification.
- Algae harvesting.

Salinity in Drinking Water

Introduction

According to UNICEF and DPHE (1994), as of 1991, about 85% of rural Bangladesh households have access to safe drinking water within 150 m and in urban slums 98% households are within 150m of safe water sources. But in hilly areas and the coastal belt over 20% people have to go more than 200m to get clean water.

The main source of water for human consumption in Bangladesh is ground water. But the availability of ground water is however, not uniform throughout the country as various constraints prevent a more uniform development of ground water. In general, public tubewell coverage is very good, but in coastal belt, there are some pockets where people do not have good access to tubewell water. While in the high water table areas, there is one tubewell for 78 persons, the corresponding figure is 242 for the coastal belt where 11% of the total population of the country reside. In the coastal belt major obstacle in the use of ground water has been identified as high salt content (in excess of 1000 mg/l). It is however, been possible to pump sweet water from deep seated aquifers by the use of deep tubewell. Very shallow and deep shrouded tubewells have also been used to extract water from perched sweet water aquifer lenses found around the sweet water reservoir. These kinds of tubewells perform well but they can not completely solve the problem of sweet water shortage in the coastal areas since such aquifers are not always found at convenient locations. Even if available, pumping up ground water would be cost-prohibitive particularly for the rural areas of Bangladesh where per capita income is very low.

Thus it appears that the desalination of brackish water could be an effective solution to the problem of water supply in the coastal areas if cost effective technologies can be adopted. The cost of conversion of brackish water to fresh water by the membrane processes or by the use of solar energy is still relatively high with the present state of knowledge and technology. However, solar energy is renewable, inexhaustible and free of cost but available only in a form of low heat. Thus the application of solar distillation process has promising potentials because solar stills possess the advantage of having the least possible moving parts, no requirement for specially trained personnel for maintenance and operation where conventional water treatment methods may not be feasible especially to meet small scale demands of villages or isolated communities, and most important of all, operation costs are low because the source of energy is free.

Membrane Processes

These processes include a broad range of separation processes from filtration and ultrafiltration to reverse osmosis. Thus membrance processes include many different alternatives, such as:

- Reverse Osmosis (RO)
- Electro-dialysis (ED)
- Electro-dialysis reversal (EDR)
- Ultrafiltration (UF)
- Nanofiltration (NF)

The RO and ED/EDR processes are actively used in the water treatment field primarily for desalting or brackish water conversion.

RO is a pressure-driven process that retains virtually all ions and passes water. The pressure applied exceeds the osmotic pressure (**Figure 1**) of the salt solution against a semipermeable membrance, thereby forcing pure water through the membrance and leaving salts behind.

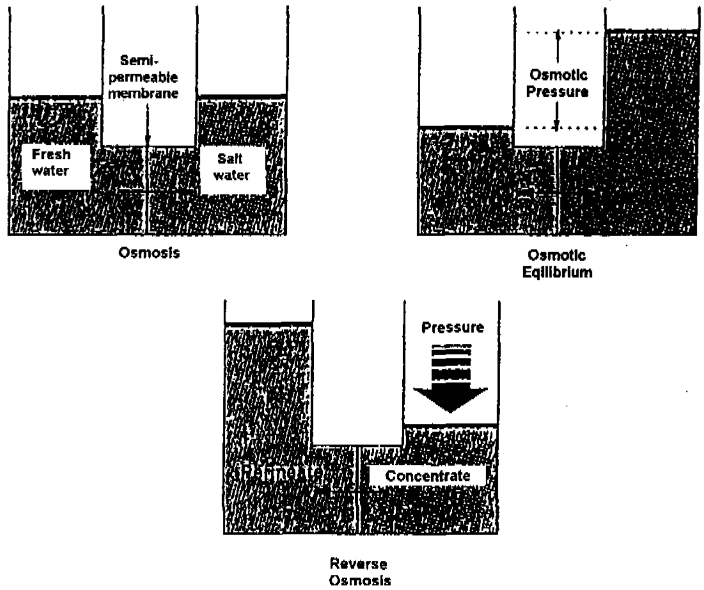


Figure 1 Principles of Osmosis

ED/EDR systems are often considered as an alternative to RO for brackish water conversion. In these processes selective cation and anion membrance are combined with a DC electric field to demineralize or deionize water. EDR is an ED process in which the polarity of the DC electric field is reversed periodically to reverse the direction of ions movement and provide automatic flushing of scale forming materials from membrance surfaces. However, ED/EDR systems, unlike RO process, are not effective for removal of dissolved organic and microbial contaminates.

Solar Desalination

Introduction

Solar distillation has been practise for a long time. The earliest documented work is that of the Arab alchemists in 1551. However, the conventional solar distillation approaches (commonly known as the solar still), was first designed and fabricated in 1872 near Las Salinas in Northern Chile by Carlos Wilson, a Swedish Engineer. A conventional solar still is simply an airtight basin with a top cover of any transparent materials (e.g. glass, plastic, etc.). Schematic diagrams of some of the common design of solar stills are shown in Figure 2 to 6.

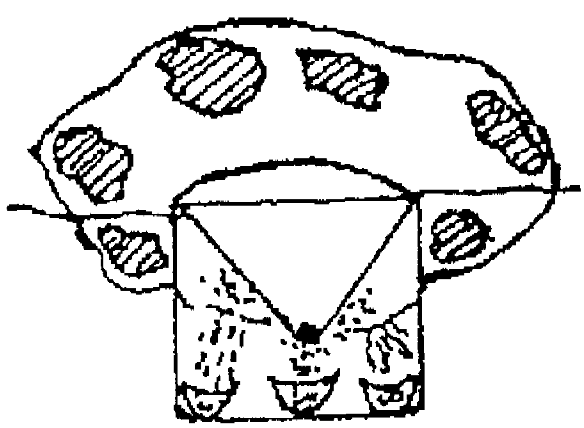


Figure 2 RYFO Pit Still

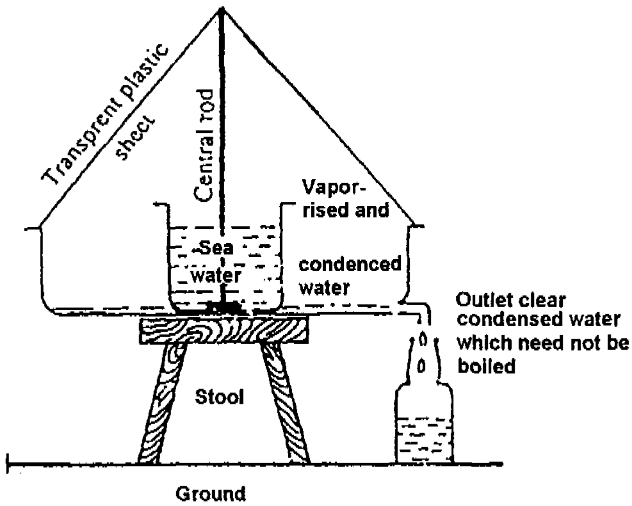


Figure 3 Ryan Foundation Still (table mode)

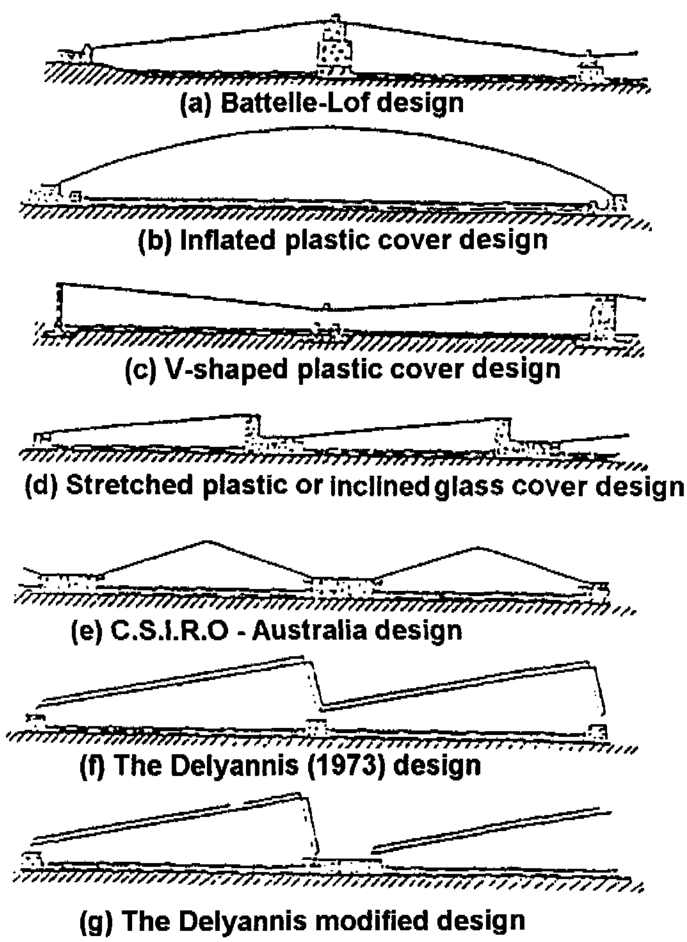


Figure 4 Different Solar Stills

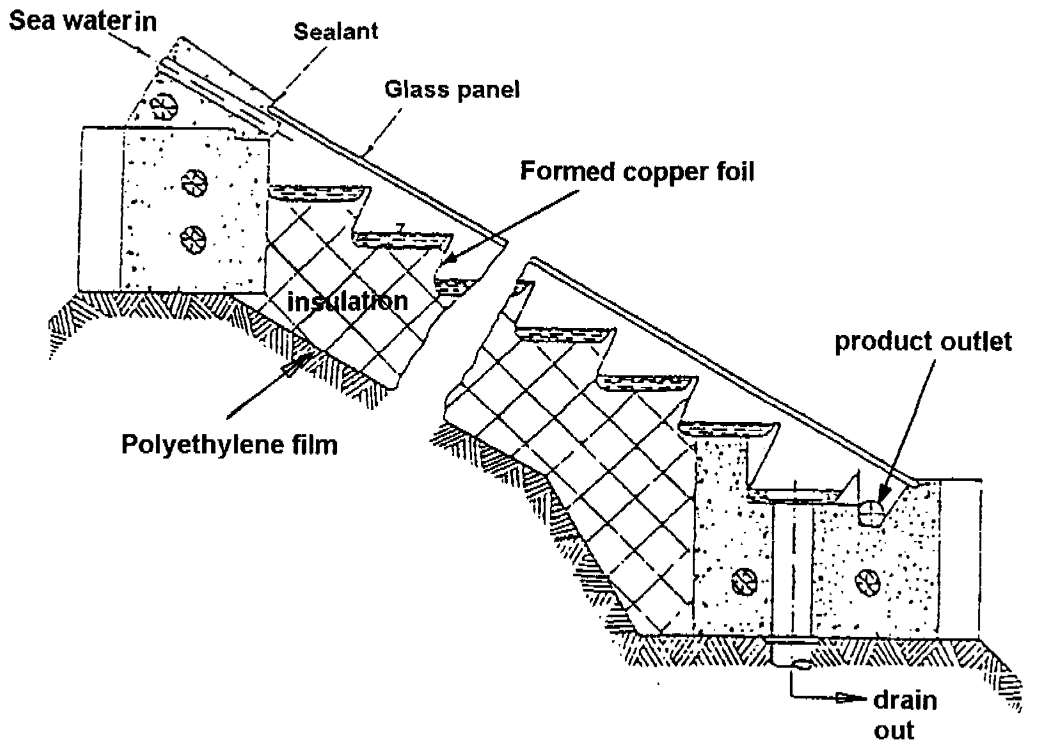


Figure 5 Cross Section of Tilted Tray Solar Still

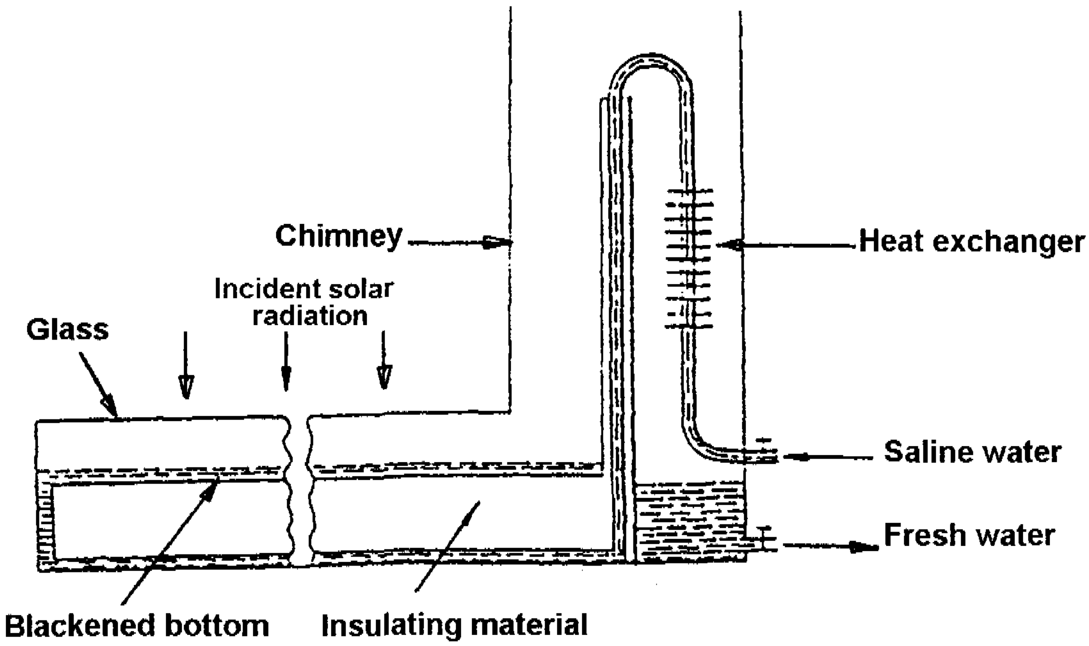


Figure 6 Chimney-type Solar Still

Some data of several major solar distillation plants are shown in Table 1.

Table 1 : Some Solar Distillation Plants*

Country	Location	Design	Year	M^2	Feed	Cover	Remarks
Australia	Muresk I	4e	1963	372	Brackish	Glass	Rebuilt
	Muresk II	4e	1966	372	Brackish	Glass	Operating
	Coober Pedy	4e	1966	3160	Brackish	Glass	Operating
	Caiguna	4e	1966	372	Brackish	Glass	Operating
	Hamelin Pool	4e	1966	557	Brackish	Glass	Operating
	Grifith	4e	1967	413	Brackish	Glass	Operating
Cape Verde Isl	Santa Maria	4e	1965	743	Seawater	Plastic	Operating
	Santa Maria	4e	1968				Abandoned
Chile	Lass Salinas	4e	1872	4460	Brackish	Glass	Abandoned
	Quillagua	4e	1968	100	Seawater	Glass	Operating
Greece	Symi I	4d	1964	2686	Seawater	Plastic	Rebuilt
	Symi II	4d	1968	2600	Seawater	Str. Plas.	Dismantled
	Aegina I	4lc	1965	1490	Seawater	Plastic	Rebuilt
	Aegina II	4d	1968	1486	Seawater	Str. Plas.	Abandoned
	Salamis	4c	1965	388	Seawater	Plastic	Abandoned
	Patmos	4f	1967	8600	Seawater	Glass	Operating
	Kimolos	4f	1968	2508	Seawater	Glass	Operating
	Misyros	4f	1969	2005	Seawater	Glass	Operating
	Fiskardo	4f	1971	2200	Seawater	Glass	Operating
	Kionion	4f	1971	2400	Seawater	Glass	Operating
	Megisti	4f	1973	2528	Seawater	Glass	Operating
India	Bhavnagar	4e	1965	377	Seawater	Glass	Operating
	Awania	4e	1978	1866	Brackish	Glass	Operating
Mexico	Natividad Isl	4d	1969	95	Seawater	Glass	Operating
Pakistan	Gwadar I	4f	1969	306	Seawater	Glass	Operating
	Gwadar II	4g	1972	9072	Seawater	Glass	Operating
Spain	Las Marinas	4la	1966	868	Seawater	Glass	Operating
Tunisia	Chakmou	4d	1967	440	Brackish	Glass	Operating
	Mahdia	4d	1978	1300	Brackish	Glass	Operating
U.S.A.	Daytona Beach	4a	1959	228	Seawater	Glass	Rebuilt
	Daytona Beach	4a	1961	246	Seawater	Glass	Dismantled
	Daytona Beach	4b	1961	216	Seawater	Plastic	Dismantled
	Daytona Beach	4b	1963	148	Seawater	Plastic	Dismantled
USSR	Bakharden	4e	1969	600	Brackish	Glass	Operating
West Indies	Potit St. Vincent	4b	1967	1710	Seawater	Plastic	Operating
	Haiti	4d	1969	1969	Seawater	Glass	Operating
India	Bitra	4c	1980	1980	Brackish	Glass	Operating (capacity 200 l/day)
	Kulmis	4c	1980	1980	Brackish	Glass	Operating (capacity 200 l/day)
China	Wuzhi	4c	1976	1976	Seawater	Glass	Operating
	Zhungjian	4c	1979	1979	Seawater	Glass	Operating

* After Delyannis and Delyannis, (1973).

Bangladesh Experience

In this study, (Rahman et al, 1997 and Rahman et al, 1996) different types of single basin solar stills were constructed. These designs differ in structure and materials of construction, but basically, incorporate common elements for different functions. The principal criteria for selection of materials and developing the design of still was local availability of materials and cost involvement, efficiency, and ease of construction and maintenance. The stills are characterised by a single basin (base and wall) to store saline water and one or more transparent covers on top of the basin (**Figure 7 & Figure 8**).

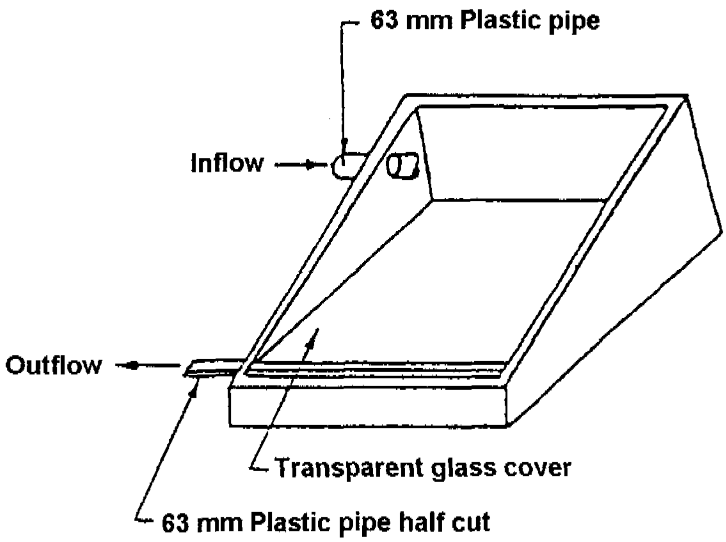


Figure 7 Single Basin Solar Still with Inclined Glass Cover Design

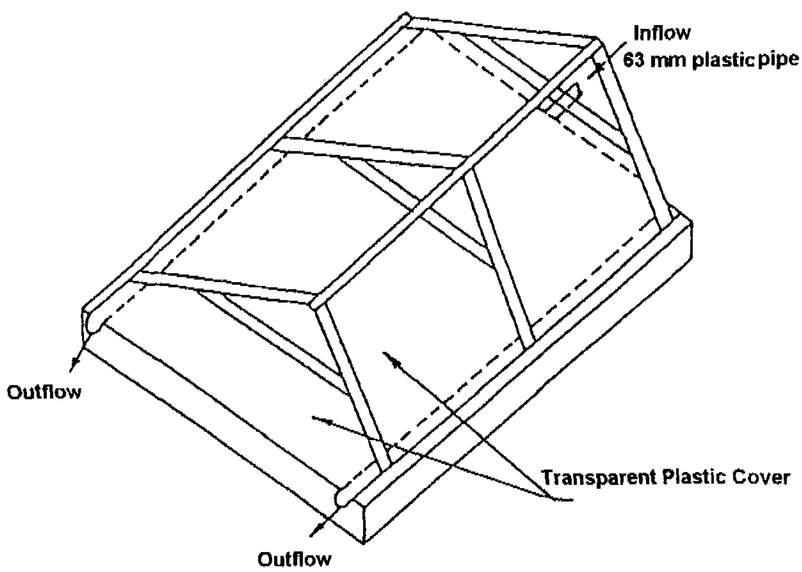


Figure 8 Single Basin Solar Still with Stretched Double Sloped Plastic Cover Design

From a review of the literature, at first attempt was made to construct stills as shown in Fig. 7 that can be fabricated with skilled labour and shipped to the remote areas for use. It was decided that mild steel, wood and Ferro-cement would be used to construct still basins. Experimental investigation with these solar stills indicate that their construction cost are much higher compared to their output (Mamtaz et al, 1996). Subsequently it was decided to construct still basins with brick and cement plastered clay. However, such type of still basins have a limitation that they have to be constructed at the site. This research has been implemented in two phases. In phase I, although different types of materials were considered for construction of still basins, only basins constructed with mild steel, Ferro-cement and brick were operated in BUET as these produced reasonable amount of yield. In phase-II, field investigations (in BUET) were commenced in the coastal belt and at the same time laboratory investigations were also continued. On the basis of market survey and detail analysis, the cost involvement of different types of solar stills along with a brief description of materials used for the construction of still basins and transparent covers are presented in Table 2. However, detail description of these plants are available in Rahman, et al (1996).

Table-2 : Materials and Cost Involvement of Different Stills

Still Type	Material Used	Installation Cost	
		BD Taka	US$
Mild Steel plant	Mild steel basin of 4.75 mm thick sheet. Glass cover. Constructed and operated at BUET.	4,090	93
Ferro-Cement Plant	Ferro-cement basin-cement ratio of 1:2, water cement ration of 0.6, 13mm sized wire mesh. Base and wall thickness are 25mm and 38mm. Glass cover. Constructed and operated at BUET.	3,000	68
Brick plant1	Brick basin. Base and wall thickness are 83mm and 89mm. Glass cover. Constructed and operated at BUET.	1,085	25
Brick plant2	Brick basin. Basin and wall thickness are 83mm and 89mm. Double slope plastic sheet cover. Constructed and operated at BUET.	800	18
Brick plant3	Same as Brick plant 1 but double layer of brick wall. Constructed and operated at BUET.	1,610	37
Brick plant4	Same as Brick plant 1 but constructed and operated at Field.	1,085	25
Brick plant5	Same as Brick plant 3 but constructed and operated at Field.	1,610	37
Clay plant	Clay and cement plastered basin similar to Brick plant2. Constructed and operated at Field.	435	10
Note : US$ 1 = Bangaldeshi Taka 44.00			

Experimental Work

In phase I, all experiments were conducted on the roof of the Civil Engineering Building of Bangladesh University of Engineering & Technology (BUET), Dhaka (the longitude latitude are $90^0\ 23'$ E and $23^0\ 46'$ N respectively). In phase II, some new plants were constructed and operated at BUET, Dhaka and at field, Kaligonj thana of Satkhira district which has a longitude and latitude of $89^0\ 01'$ E and $22^0\ 27'$ N respectively. The plants at the field were placed on the ground. The saline water was supplied to plants through their inlet pipes four times a day (at 9 am, 12 noon, 3pm and 5:30 pm) and the amount of the water supply was fixed based on the objective of maintaining 1 inch (25.4 mm) depth of water in the basin. Distillate amount, air temperature outside the still and on the glass cover, and water temperature inside the still were measured for four times a day (at 9 am, 12 noon, 3 pm and 5:30 pm). Schedule of data collection is shown in Table-3.

Table-3 Schedule of Data Collection

Still type	Start of Operation	End of Operation
Mild steel plant	January 1994	April 1994
Ferro-cement plant	January 1994	December 1995
Brick plant1	August 1994	December 1995
Brick plant2	September 1994	December 1995
Brick plant3	November 1994	December 1995
Brick plant4	March 1995	March 1996
Brick plant5	March 1995	March 1996
Clay plant	March 1995	March 1996

Result and Discussion

Table-4 shows the maximum, minimum and average yields and the cost per litre of yield on the basis of initial investment cost of all plants during their respective time of operation.

Table-4. Output of Still

Still type	Average Yield ($l/m^2/d$)	Range ($l/m^2/d$)	Cost/l/m^2 (Taka (US$))
Mild steel plant	1.1	0.21-2.1	3,718 (85)
Ferro-cement plant	1.0	0.1-2.2	3,000 (68)
Brick plant1	1.4	0.3-2.7	775 (18)
Brick plant2	0.9	0.3-2.1	889 (20)
Brick plant3	1.4	0.2-2.7	1,150 (26)
Brick plant4	1.0	0.2-2.1	1,085 (25)
Brick plant5	1.2	0.2-2.7	1,342 (31)
Clay plant	0.7	0.2-1.5	621 (14)
Note : US$ 1 = BD. Taka 44.			

The water obtained from the plants was totally free from salinity. The salinity of water in the coastal areas of Bangladesh varies in general from 1,000 to 2,000 ppm and the acceptable limit for drinking purpose is 600 ppm. Therefore, an equal amount of tubewell water may be mixed with the output of the plants to increase the stock of water (considering salinity of 1,000 ppm). The lowest cost (Tk.621 (US$ 14), Table-4) per litre of yield is obtained from clay plant. However, the yield of Brick plant 1 (1.4 $lm^{-2}d^{-1}$) is much higher than the clay plant (0.7 $lm^{-2}d^{-1}$). Again the basin constructed with bricks have the advantage that these are safe against natural catastrophe and unfavourable climatic conditions. Its life time will be much higher than then the clay plant.
The desalination plants with proper cleaning can also be used to collect rain water during the rainy season. Then a tap of Tk.10(US$0.23) has to be provided with the plant for collecting rain water to minimize contamination of storage water.

Recommendation

From the foregoing discussion, it appears that the Clay plant (cement plastered) performed well during the experimental investigation period, was easy to construct, operate and maintain and involved less cost. However, the yield was rather low. Brick plant 1 involved higher cost when compared with the clay plant but provided higher yield as well. Although cost per litre was lowest for Clay plant (cement plastered), the higher yield of Brick plant 1 made it a more convenient source of desalinated water. Further, clay as construction material is not as durable as brick and will therefore need more maintenance. Therefore, it can be recommended that, of all the plants studied under the project, Brick Plant 1 is the best-suited solar desalination plant for Bangladesh. This type of plant was constructed, installed and operated both at BUET and at the field (Brick Plant 4) and it performed satisfactorily at both places.

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Arsenic and Dearsination of Water

The Arsenic Problem

Arsenic and arsenical compounds are extremely toxic. Yet they are found in effluents and leaches from metallurgic industries, glassware and ceramic industry, dye and pesticide and fertiliser manufacturing industry, petroleum refining, rare earth industry and other chemical industries. In some part of the world arsenic occurs naturally scattered in the soil, from where it leaches to the groundwater.

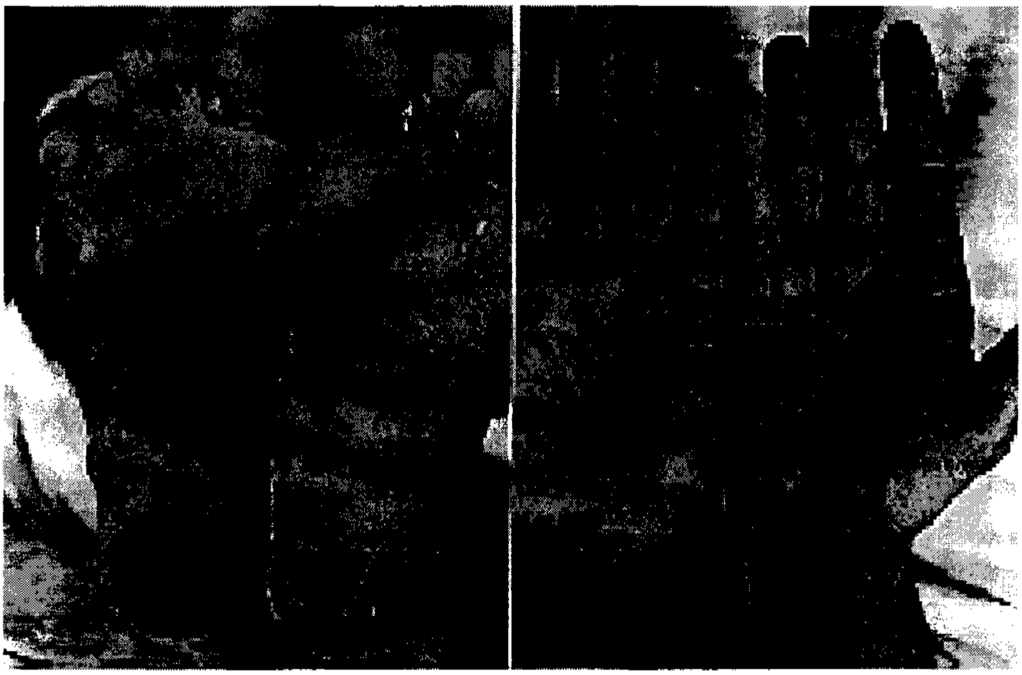

Figure 1 Typical Most Visible Symptoms of Arsenosis or "Blackfeet Disease"

In the recent years the spot wise occurrence of arsenic in the groundwater is increasingly acknowledged as a major health problem for the respective communities. Partly because of improved possibilities for monitoring the water quality, partly because of increasing utilisation of groundwater resources, the arsenic problems seem to be augmenting in many developing countries, e. g. China, Taiwan, India, Ghana, Chile and Bangladesh. Many West Bengali and Bangladeshi communities are considered to be at high arsenic risk. According to Mandal et al. (1997) about 34 millions people are "at risk" due to arsenic in drinking water in West Bengal. Similarly according to Dave (1997) about 23 million people are "at risk" in Bangladesh, cf. **Figure 2**.

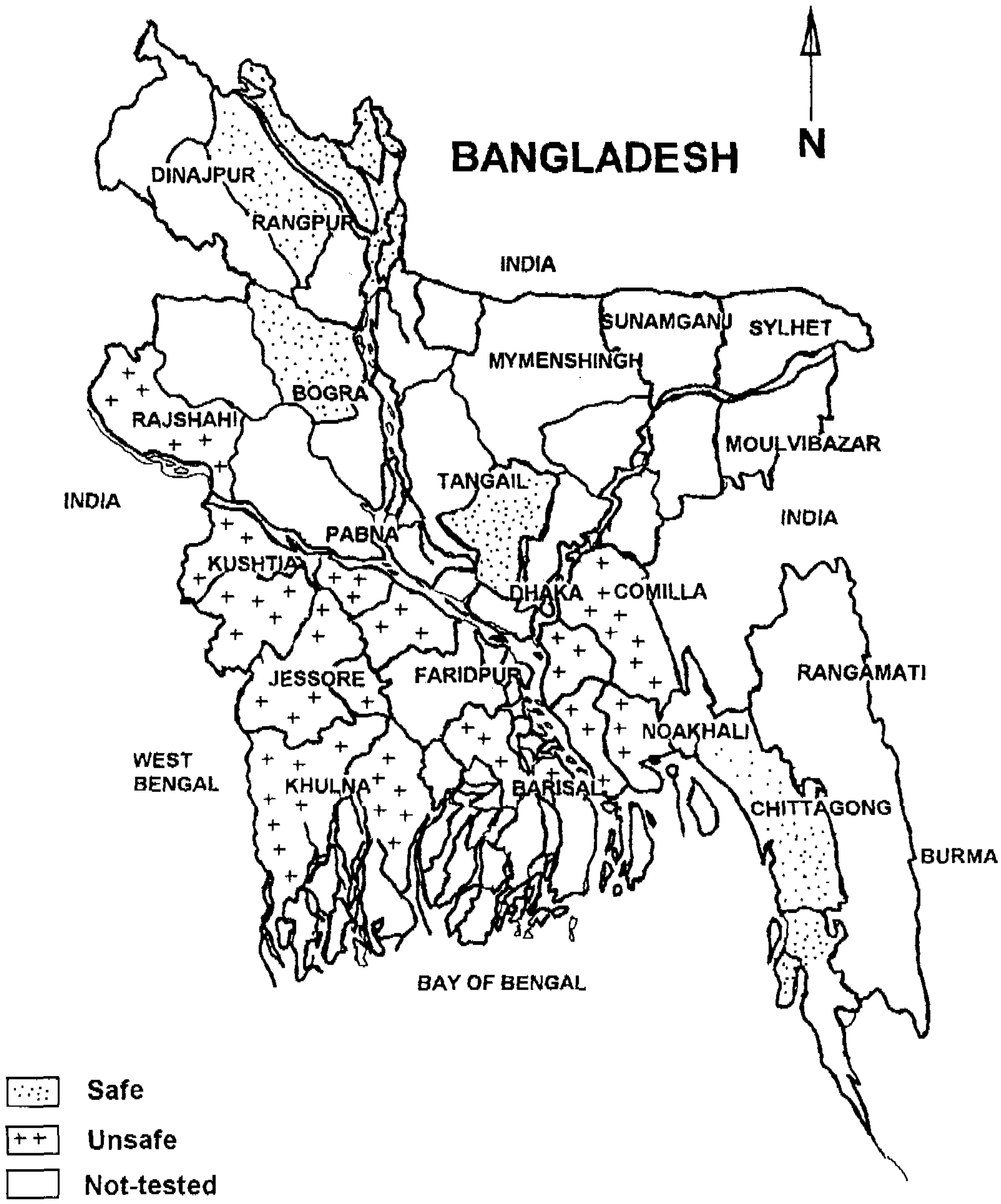

Figure 2 Map of Bangladesh Indicating Areas where Arsenic has been Detected at High Level in Groundwater (from Dhaka Community Hospital)

The precise dimension of the arsenic problems is yet to be measured in Bangladesh. This is not an easy task. Arsenic in water is tasteless, odourless and colourless. Furthermore its analyses are relatively complicated and not well established and its effects on the population are often delayed, diffuse and difficult to detect. However, there is no doubt that the arsenic problem is serious and has been hidden and/or ignored in many areas for too many years.

It has to be added, that the panic over-reaction to the arsenic problem may be more harmful to communities than the arsenic itself. Many communities, who have been educated to use the microbiologically safe groundwater may, without proper sizing of their arsenic problem, change their habits back to the use of the surface water, which most often is contaminated with pathogenic microorganisms. It has to be borne in mind that the health significance of water related infectious diseases is much higher than that of arsenic, even among the above mentioned communities at high arsenic risk.

Arsenic Chemistry

Arsenic occurs in water in several different forms, depending upon the pH and the redox potential, E_h. Some of the most important compounds and species are shown in Table 1.

Table 1 Arsenic compounds and species and their environmental and toxicological importance in water.
Data from: Stueart et al. 1996, Kartinen & Martin 1995, WHO 1996,

Compounds	*Example*	*Aquat. Environment*	*Toxicity*
Arsine	As^{3-}	Minor importance	Most toxic As species
Elemental arsenic	As	Minor importance	Least toxic As species
Trivalent arsenic	As(III)	Anaerobic	10 x more than As(V)
Arsenite, Inorganic	H_3AsO_3,	pH = 0-9	
	$H_2AsO_3^{1-}$,	pH = 10-12	
	$HAsO_3^{2-}$,	pH = 13	
	AsO_3^{3-}	pH = 14	
MMAs(III)	$CH_3As(III)O_2^{2-}$	Several fungi & bacteria	Less than inorganic
DMAs(III)	$(CH_3)_2As(III)O^{1-}$	can methylate As(III)	As(III)
TMAs(III)	$(CH_3)_3As(III)$		
Organo-As(III)		Minor importance	
Pentavalent arsenic	As(V)	Aerobic	10 x less than As(III)
Arsenate, Inorganic	H_3AsO_4,	pH = 0-2	
	$H_2AsO_4^{1-}$,	pH = 3-6	
	$HAsO_4^{2-}$,	pH = 7-11	
	AsO_4^{3-}	pH = 12-14	
MMAs(V)	$CH_3As(V)O_3^{2-}$	Methylation through	Less than inorganic
DMAs(V)	$(CH_3)_2As(V)O_2^{1-}$	reduction of As(V) to	As(V)
TMAs(V)	$(CH_3)_3As(V)O$	As(III)	
Organo-As(V)		Minor importance	

Because the solubility of arsine and elemental arsenic is extremely low, these species may occur in the underground, which most often has a low redox potential, without appearing in the groundwater. Both arsenic (III) and (V) are more soluble. But as the redox potential is never high in the underground, As(III) would be the most dominant arsenic species in contaminated aquifers.
The arsenious (arsonic) and arsenic (arsinic) acids are dissociated according to the equations:

Arsenious Acid Dissociation:

H_3AsO_3	$= H^+$	$+ H_2AsO_3^-$	pKa = 9.22	eq. 1
$H_2AsO_3^-$	$= H^+$	$+ HAsO_3^{2-}$	pKa = 12.3	eq. 2

Arsenic Acid Dissociation:

H_3AsO_4	$= H^+$	$+ H_2AsO_4^-$	pKa = 2.2	eq. 3
$H_2AsO_4^-$	$= H^+$	$+ HAsO_4^{2-}$	pKa = 7.08	eq. 4
$HAsO_4^{2-}$	$= H^+$	$+ AsO_4^{3-}$	pKa = 11.5	eq. 5

Thus within the range of natural waters, where pH most often is between 6 and 9, trivalent inorganic arsenic is found primarily as non-dissociated arsenious acid, while the pentavalent arsenic is primarily found as ionised di-hydrogen arsenate and mono-hydrogen arsenate. As most treatment processes are most capable to remove ions, the trivalent arsenic is more difficult to remove from the water than the pentavalent (Kartinen & Martin 1995).

Arsenic Toxicology

Arsenic is 20[th] most abundant element in the earth's crust and the 12[th] most abundant element in the biosphere, where it is said to be an essential element at least for some animal species, but not for human (Kartinen et al. 1995, WHO 1996). Table 2 indicates the approximate environmental concentration levels and human exposure through the air food and water.

Table 2. Approximate environmental concentration levels and human exposure through air, food and water.
Data from WHO 1996.

Medium	*Concentration*	*Daily intake*	*D. Exposure*	*Remarks*
Air	0.4-30 ng/m^3	20 m^3	0.01-0.6 µg	May be much higher in industrial areas
Food	0.4-120 µg/kg	1 kg	0.4-120 µg	75 % is organic As 25 % is inorganic As
Water, generally	1- 2 µg/L	2 L	2-4 µg	Mainly inorganic As(III), most toxic
Water, up to	12000 µg		24000 µg	

Ingested elemental arsenic is not soluble and therefore poorly absorbed from the gastro-intestinal tract. As(V) and organic As are rapidly and almost completely eliminated via the kidney. In the contrary to these, the soluble arsenic compounds are rapidly absorbed. Inorganic As has tendency to accumulate in skin, bone, nails, hair and muscles. Its half time in human is estimated to be between 2 and 40 days. Arsenic(III) in its non-methylated form is eliminated from the body by rapid urinary excretion. Furthermore Arsenic(III) is in part detoxificated in the liver to monomethylarsenious acid and dimethylarsenic acid.

Arsenic is not mutagenic in bacterial and mammalian assays. But it is proven to be carcinogenic for both humans and animals. It is known to be teratogenic and to induce chromosome breakage and sister chromatid exchange in a variety of biological cells.

Table 3 Toxicological effects of arsenic reported due to exposure to high arsenic concentrations in the drinking water.
WHO 1995. Wadud Khan 1997.

Effect	*Symptoms*	*Remarks*
Blackfoot Disease Arsenical dermatosis	Dermal lesion, Peripheral neuropathy Keratosis, Hyperkeratosis, Hyperpigmentaion	May necessitate operation
None specific	Nausea, Abdominal Pain, Diarrhoea, Vomiting, Conjunctivitis, Oedema.	Mainly due to acute intoxication
Pregnancy disorders	Spontaneous abortions, miscarriages	-
Heart Disease	Coarctation of aorta, Cardiovascular disturb.	Among children
Cancer	Bladder, Kidney, Skin & Lungs, Liver & Colon	-
Mortality	-	Mainly due to cancer

In a population drinking arsenic contaminated water, a great variety of specific as well as none-specific symptoms may be observed at a large biological variations and interactions (Mazumder et al.

1997). Table 3 shows some of the effects of arsenic reported to be due to exposure through drinking water. There is still no well established guidelines about how to measure quantitatively the severity of arsenosis in a population. Thus the correlation between the severity of the disease and the contamination levels of the consumed water are yet to be established. Also a convincing correlation between the concentration of arsenic in the drinking water and the concentrations of arsenic in the urine, hair and nails are yet to be established (Mazumder et al. 1997).

Guidelines for Arsenic

The Tolerable Daily Intake, TDI, is an estimate of the amount of substance per kg of body weight that can be ingested daily over a life time without appreciable health risk. For a proven human carcinogen chemical like arsenic it is generally accepted that the threshold values, TDI, do no exist. This is because, theoretically, there will always be a probability of harmful effect, i. e. risk, at any level of exposure (Galal-Gorchev 1997).

Estimated risks are normally based on 60 kg person, drinking 2 L of water per day, for a life time of 70 years. The WHO guideline value for substances in drinking water is the concentration corresponding to an upper-bound estimate of an excess lifetime cancer risk of 10^{-5}. In other words ***GV*** is the concentration expected to give one additional cancer case per 100,000 people ingesting the water for 70 years.

On this basis the arsenic concentration for acceptable skin cancer risk is calculated to be 0.17 µg/L. For practical limitation in available analysis methods, cf. table 4, only a ***provisional*** guideline value of ***GV = 10 µg/L*** is established. Thus the estimated excess lifetime skin cancer risk associated with exposure to 10 µg/L drinking water concentration for a lifetime of 70 years is:

$\mathbf{P = (10\ \mu g/L \cdot 10^{-5}) / 0.17\ \mu g/L = 6 \cdot 10^{-4}}$;

i.e. 6 additional skin cancer cases per 10 000 exposed.

For comparison the national standards adopted are 10 µg/L in the European Union, 25 µg/L in Canada and 50 µg/L in the US EPA (Galal-Gorchev 1997).

From table 4 it may be concluded that monitoring and surveillance of the water resources, especially in rural areas of developing countries is a huge task to deal with. Figure 6 shows one of the available field kits (the Indian type). Several others are available. Even these field kits would need some kind of lab training.

Table 4 Simplified overview of analysis methods for testing arsenic.

Methods	*Advantages*	*Disadvantages*
1 Flow Injection-Hydride Generation-Atomic Absorption Spectrometry	• Most sensitive, down to 1-4 µg/L. • Least interference. • Most reproducible.	• Very high cost of investment. • Very high cost of O & M. • Dependency of foreign company specific spare parts. • Dependency on imported chemicals. • Dependency on expert technicians.
2 Hydride Generation-Scraper-Spectrophotometry	• Medium sensitivity, e. g. 10-30 µg/L. • Medium reproducibility. • Normally low interference. • Relatively low cost of investment, apart from spectrophotometer.	• High cost of investment. • High cost of O & M. • Dependency on imported chemicals. • Dependency on trained technicians.

Methods	*Advantages*	*Disadvantages*
3 Hydride Generation-Scraper-Indicator Paper-Field Kit		
	• Relatively easy to use to field. • Low investment costs. • Low chemical costs. • Easy to train on use.	• Quantitative indication of occurrence • Low sensitivity. • Low reproducibility. • Risk of false negative response. • High interference (solar irradiation) • Dependency on imported chemicals. • Dependency on trained technicians. • Not yet tested and standardised.

Arsenic Removal

Experiences on dearsination of water are extremely limited, especially when it comes to implementation in rural areas of developing countries, where the problems are at most.

The methods available today are based on old well known techniques supplemented with oxidation of As(III) to As(V) as a pre-treatment in order to increase the removal efficiency.
Broadly the methods can be categorised in three groups:

- The coagulation / co-precipitation techniques.
- The sorption techniques.
- The membrane techniques.

Alum Coagulation

In the alum coagulation process aluminium sulfate, $Al_2(SO_4)_3, 18H_2O$, is dissolved and added to the water under efficient stirring for one to few minutes. Rapidly the aluminium hydroxide micro-flocs are produced and gathered into larger easily settling flocs. Hereafter the mixture is allowed to settle. During this flocculation process all kinds of micro-particles and negatively charged ions are removed by electrostatic attachment to the flocs, eq. 8 -11.

The treated water can be decanted. Safety filtration is however required in order to ensure that no sludge particles are escaping with the water.

As the trivalent arsenic occurs in none ionised form it will not be subject to significant removal. Oxidation of As(III) to As(V) is thus required as a pre-treatment. This can be achieved by addition of any chlorine product or by addition of permanganate, eq. 6 & 7. The chemical equations may be shown as follows:

As oxidation with Cl_2:

$$H_3AsO_3 + HClO = HAsO_4^{2+} + Cl^{1-} + 3H^+ \qquad \text{eq. 6}$$

As oxidation with permanganate:

$$3H_3AsO_3 + 2\,KMnO_4 = 3HAsO_4^{2+} + 2\,MnO_2 + 2K^+ + 4H^+ + H_2O \qquad \text{eq. 7}$$

Alum dissolution:

$$Al_2(SO_4)_3, 18H_2O = 2Al^{3+} + 3SO_4^{2-} + 18H_2O \qquad \text{eq. 8}$$

***Aluminium precipitation** (Acidic):*

$$2Al^{3+} + 6\,H_2O = 2Al(OH)_3 + 12\,H^+ \qquad \text{eq. 9}$$

***Co-precipitation** (None stoichiometric, not defined product):*

$$H_2AsO_4^- \quad Al(OH)_3 = \text{Al-As complex} + \ ? \qquad \text{eq. 10}$$

Ph adjustment:

$$6Ca(OH)_2 + 12\,H^+ = 6\,Ca^{2+} + 12H_2O \qquad \text{eq. 11}$$

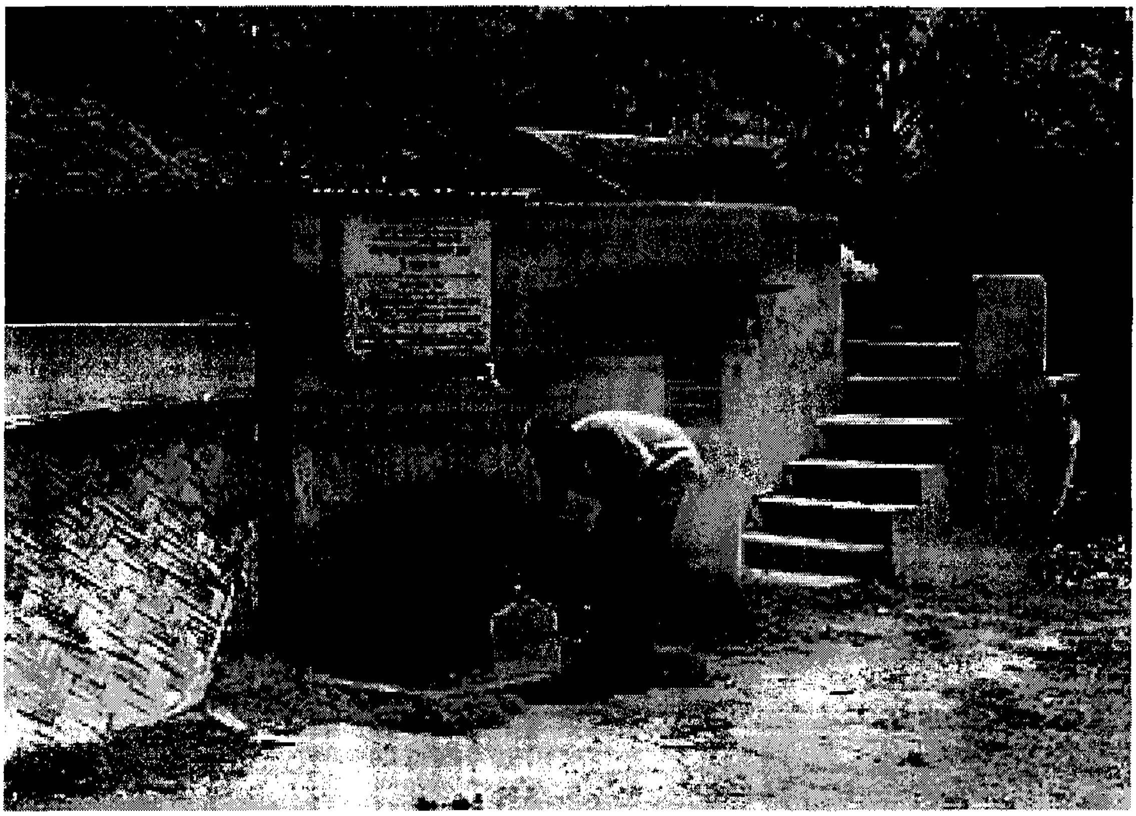

Figure 3. Village Level Alum/Iron Dearsination Plant as Developed by the All India Institute of Hygiene and Public Health.

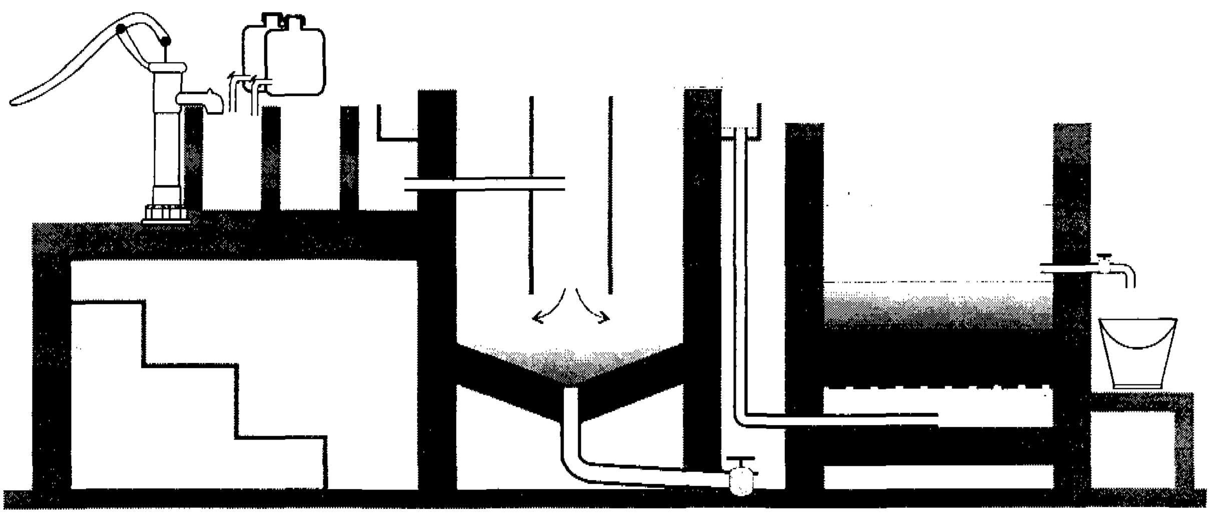

Figure 4. Diagram of The Plant Illustrated in Figure 3 Based on Addition of Sodium Hypochlorite and Alum Solutions, Mixing Flocculation, Sedimentation and Up-flow Filtration)

The alum dearsination is thus based on pre-oxidation + conventional flocculation techniques. It has been tested as well at household level as at village handpump level. For initial As concentrations of 300 μg/L and dosage of about 30 mg Alum/L removal efficiencies about 90 % can be achieved, provided pH is not higher than 7 and not lower than 6 (Katrinen & Martin 1995). See also table 10.5.

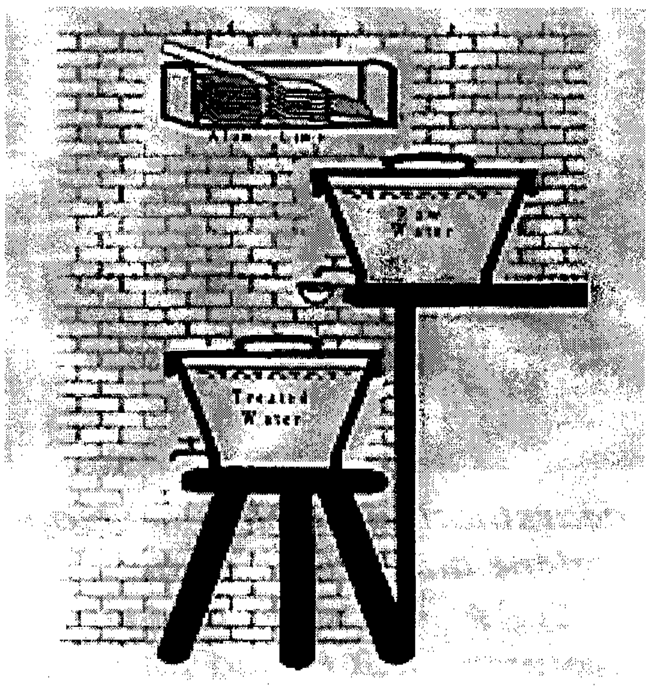

Figure 5 Arrangement of Coagulation of Water at Household Level as Developed for Defluoridation. For Dearsination Chlorinated Lime should be used in order to Oxidise As(III) to AS(V). From Dahi et al. (1996)

Iron Coagulation

The iron dearsination resembles the alum method. In stead of Alum, ferric sulfate $Fe_2(SO_4)_3$ or ferric chloride $FeCl_3$ are added. In general 30 mg/L are comparable to 100 mg/L alum. For initial As concentrations of 300 μg/L and dosage of about 30 mg ferric sulfate/L removal efficiencies about 95 % can be achieved, provided pH is not higher than 8.5 and not lower than 6 (Katrinen & Martin 1995). See also table 5.

Table 5 Removal of As(V) achieved at laboratory conditions for given initial pH and dosage of alum and ferric sulphate. Both coagulations were followed by sedimentation and sand filtration.

Data from Gulledge & C'onnor1973.

Dosage Mg/L	*Removal by alum coagulation %*				*Removal by ferric sulfate coagualtion %*			
pH:	*5.0*	*6.0*	*7.0*	*8.0*	*5.0*	*6.0*	*7.0*	*8.0*
10	59	75	65	19	97	97	94	89
20	82	89	82	39	97	98	97	90
30	91	91	84	47	96	98	97	97
40	93	89	91	67	95	99	99	96
50	92	94	91	66	99	98	98	97

Lime Softening

Lime softening implies addition of fresh calcined lime, calcium oxide, CaO. The precipitated calcium hydroxide acts as sorbing flocculant for arsenic. Excess of lime would not be dissolved, but remains as a thickener and coagulant aid, which has to be removed along with the precipitated through a sedimentation/filtration process.

Experiences have shown that the arsenic removal is relatively low, between 40 and 70 %. The highest removals are achieved when the end pH of the water is as high as 10.6 to 11.4. Obviously this would require a secondary treatment in order to readjust the pH. Simple acidification may no be enough, buffering of the water may ultimately be required. The lime softening can be used as a pre-treatment to be followed by e. g. iron coagulation.

Activated Alumina

Activated alumina is aluminium oxide, Al_2O_3, grains prepared in a way that grains have sorptive surface. When the water passes through a packed column of activated alumina, pollutants and other components in the water are adsorbed to the surface of the grains. Eventually the column becomes saturated, first at its upstream zone. Later, as more water is passed through, the saturated zone moves down streams and in the end the column get totally saturated. The total saturation means that the concentration of the pollutant under consideration in the effluent water increases to the same value as the influent water. The different pollutants and components of the water get saturated at different times of operation, depending upon the specific sorption affinity of medium to the given component.

The total saturation of the column must be avoided. The column is only operated to a certain break point, where the effluent concentration is e.g. 50 μg/L. The time between the start of operation and the break point of the column is presented by the volume of treated water V. When dividing V with the bulk volume of the activated alumina packed, a standard parameter is obtained; i.e. the number of Empty Bed Volumes, EBV, or just Bed Volumes, BV. BV is a expression of the capacity of treatment before the column medium needs to be regenerated. It is an operational measurement of the specific sorption capacity of the given activated alumina towards arsenic.

Regeneration of the saturated alumina is carried out by exposing the medium to 4 % caustic soda, NaOH, either in batch or by flow through the column, resulting in a few BV of caustic high arsenic contaminated wastewater. Residual caustic soda is then washed out and the medium is neutralised with a 2 % solution of sulfuric acid rinse. During this process about 5-10 % alumina are lost, and the capacity of residual medium is significantly reduced, 30-40 %. After only 3-4 regenerations the media has to be replaced. Alternatively, in order to avoid on site regeneration, the saturated alumina can be recycled to a dealer, who can take care of standardising the capacity of the activated alumina using an appropriate mixture of fresh and regenerated media.

As with the coagulation processes, the pentavalent arsenic is removed far more efficient that the trivalent arsenic. Hence the use of pre-chlorination improves the column capacity dramatically. It has been reported that 23000 BV of pre-chlorinated synthetically contaminated water at a level of 100 μg As/L could be treated to a break point of 50 μg/L. Without pre-chlorination of the water, only 300 BV could be treated. Similarly, 16000 BV of pre-chlorinated authentic water could be treated, compared to 700 BV for non-chlorinated water. The optimum pH is found to be 6. Deviation from this pH is found to reduce the capacity of the activated alumina dramatically, (Kartinen & Martin (1995).

Ion Exchange

Ion exchange is normally used to demineralise, to soften and de-nitrate the water. The process is similar to that of activated alumina, just the medium is a synthetic resin of more well defined ion exchange capacity. As the resin become exhausted, it needs to be regenerated. The principal regenerated agent is chloride, i.e. a salt solution:

Arsenic exchange (R = Resin):

$$2R\text{-}Cl + HAsO_4^{2-} = R_2HAsO_4 + Cl^{2-} \qquad \text{eq. 12}$$

Regeneration:

$$R_2HAsO_4 + 2\,Na^+ + 2Cl^- = 2R\text{-}Cl + HAsO_4^{2-} + 2\,Na^+ \qquad \text{eq. 13}$$

Capacities of 4000 BV has been reported (Stueart et al. 1996). The arsenic brine is produced from about 2 BV of 1 N NaCl. The removal capacity is however much dependent on the contents of sulfate in the raw water, as sulfate is ion exchanged before arsenic. One minor advantage of the ion exchange process is that the performance is less dependent on pH.

The efficiency of the ion exchange process is also radically improved by pre-oxidation of As(II) to As(V). This, however, has the drawback that the excess of oxidant has to be removed before the ion exchange in order to avoid the damage of the resin.

Other Sorption Media

Several other sorption media has been reported to remove arsenic from water, e.g. activated carbon, kaolinite clay, hydrated ferric oxide, activated bauxite, aluminium oxide, titanium oxide and sand (silicium oxide). The results demonstrate much discrepancies, probably due to great variation in the tested media and the experimental conditions. It must be mentioned that indications of the removal efficiencies obtained under laboratory conditions, as most often found in literature, can be most misleading as a criteria for evaluation of the sorption methods (Stueart et al. 1996).

Comparative studies, where the removal capacities are obtained for natural water containing "normal" contamination levels are yet to be carried out.

Membrane Techniques

Reverse osmosis and electrodialysis are capable of removing all kinds of dissolved solids from the water, thus resulting in demineralised water not suitable for drinking, unless reconditioned.
It is a precondition that the water does not contain suspended solid and that arsenic is in its pentavalent state. Most membranes however, can not withstand oxidising agents. Moreover, these methods are already of no interest in developing countries, because of their nature as high tech and high cost.

Figure 6 Field Kit for Qualitative Testing of Arsenic in Water.

Table 4 Overview of dearsination methods and their advantages and disadvantages. Membrane methods are considered as none appropriate.

Method		*Advantages*	*Disadvantages*
Coprecipitation:		❑ No monitoring of a break through is required. ❑ Relatively low cost simple chemicals. ❑ Low capital costs.	❑ Serious short and long term problems with toxic sludge. ❑ Multiple chemicals requirement. ❑ Operation requires training and discipline.
	Alum coagulation	Durable powder chemicals normally available.	Efficient pre-oxidation is a must.
	Iron coagulation	More efficient than alum on weigh basis.	Medium removal of As(III).
	Lime softening	Most common chemicals	Re-adjustment of pH is required.
Sorption techniques:	❑ No daily sludge problem.	❑ Requires monitoring of break through or filter use. ❑ Requires periodical regeneration or medium shift.	
	Activated alumina	Relatively well known and commercially available.	Re-adjustment of pH is required.
	Iron coated sand	Expected to be cheap. No regeneration is required.	Yet to be standardised. Toxic solid waste.
	Ion exchange resin	Well defined medium and hence capacity.	High cost medium. High tech operation & maintenance. Regeneration creates a sludge problem.
	Other Sorbents	Plenty of possibilities & combinations	Not yet properly studied.
Membrane techniques:		❑ Well defined performance. ❑ High removal efficiency. ❑ No solid waste. ❑ Low space requirement. ❑ Capable of removal of other contaminants, if any.	❑ High running costs. ❑ High investment costs. ❑ High tech operation and maintenance. ❑ Toxic wastewater. ❑ Re-adjustment of water quality is required.
	Reverse osmosis		Membrane does not withstand oxidising agents.
	Electrodialysis		Membrane does not withstand oxidising agents.

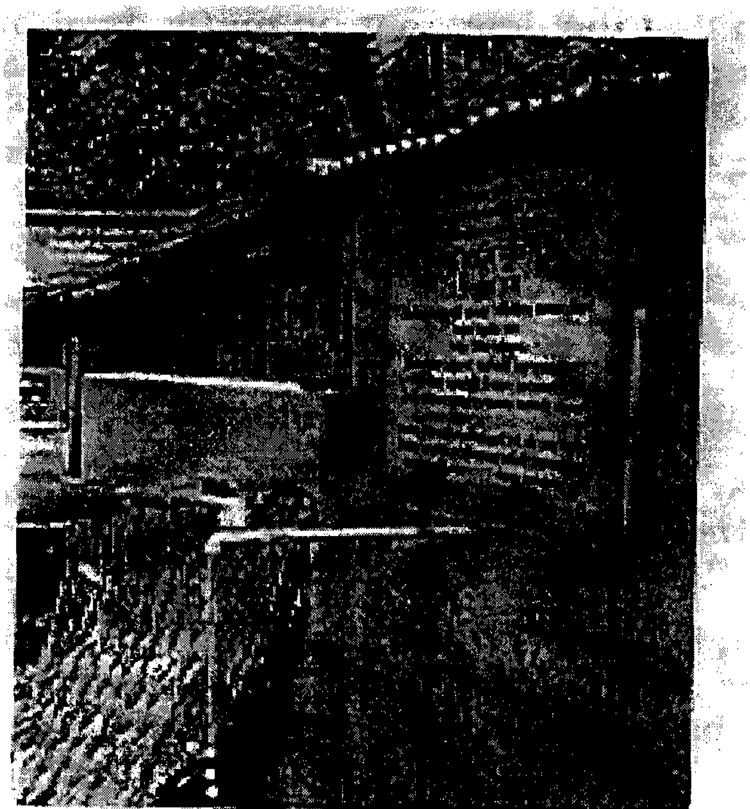

Figure 7. Dearsinated Water is The Ultimate Target, but only in Situations where Alternative Safe Sources can not be Provided.

Avoidance

In the West Bengal-Bangladesh arsenic contaminated belt, ground water occurs in both confined and unconfined aquifers. The aquifers are recharged mainly through rainwater infiltration and seepage of irrigation water. Broadly the aquifers are classified in three groups:

- The shallow aquifers; less than 50 m bgl.
- The intermediate aquifers; between 50 and 150 m bgl.
- The deep aquifers; more than 150 m bgl.

The experiences gained in West Bengal shows, in general, that the arsenic is detected is the shallow and intermediate aquifers. As a rule, the arsenic contents decreases with increasing depth. Excessive withdrawal of groundwater during summer when the recharge is low, and the seasonal groundwater drawdown, is speculated to facilitate exposure of underground formations, which may contain arsenic immobilised as arsenopyrite, to atmospheric oxygen. Such an oxidation would lead to mobilisation of the underground arsenic to the ground water.

According to this theory, the large scale irrigation from shallow tube wells may in the long run extracts large amounts of geologically fixed underground arsenic, bringing it up to the surface, and subsurface, to the shallow and intermediate aquifers and hence to the biosphere, Acharya 1997.

At a village level, however, the occurrence of arsenic is highly scattered, even when the wells are draining the same shallow aquifer. Thus much can be achieved though proper monitoring, even at decentralised level, for the avoidance of arsenic contaminated water.

From table 4 it may be seen that the dearsination methods, though available, do have severe disadvantages. Probably much have to be investigated, before more appropriate methods can be developed. Avoidance of the arsenic sources, is therefore the methods of choice, as far microbiologically safe alternative sources can be provided.

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Operation and Maintenance & Sustainability of WSS Services

Introduction

The main source of drinking water supply in Bangladesh is groundwater. Different kinds of tube wells and some other technologies are extracting it. Drinking water supply normally consists of hand tubewells (HTWs) and piped water supply system. HTWs are aimed for the poor people living in the rural areas and urban fringes. Piped supply system is constructed for both poor and rich people living in the core areas of urban centres. Characteristics of the two systems are different particularly in terms of investment, operation and maintenance costs.

The defecation practices in our country are still traditional and unhygienic. About 38% of the rural population use sanitary latrines including home-made latrines. Overall urban sanitation coverage is 42%. This includes different types of latrines. Solid waste management is still not a problem in the rural areas, but it is becoming a great environmental threat to urban centres, especially in big cities.

Investment Costs

The cost of investment for HTWs is relatively less than that of piped water supply system. The per capita investment cost for shallow, deep and TARA varies from Tk. 50 to 80, Tk. 500 to 600 and Tk. 100 to 150 respectively. On the other hand, per capita investment cost varies from Tk.15, 000 to 40,000 for having water supply system with production wells, pipe lines, overhead tanks, iron removal plant etc. It has also been observed that in many towns the current demand for new house connections is very limited. The cost for sanitary latrines also varies widely depending on the type.

Facilities Providers and Users

The value of investment on fixed assets was never accounted for and no provision for depreciation was made. The hardware for water supply were mainly installed by Department of Public Health and Engineering (DPHE) under different projects financed by the Government or donors with the understanding that Pourashava or the users will take over the responsibility of O&M of the system. In practice, no Pourashava actually takes the responsibility of O&M. But as an utility service, the pumps are kept running by DPHE without taking into account the O&M cost recovery.

Shallow hand tubewells are already popular in high water table areas and being installed and maintained by local mechanics in the private sector. But Deep HTWs and TARA are still financed by the public sector including maintenance.

Cost Recovery for Sustainability

With these backgrounds, emphasis has been given on cost recovery for sustainability of water supply. Therefore, Pourashava Water Supply Section (PWSS) must be organized in all towns and accounting system should be implemented. At the same time, performance of the PWSS needs to be increased to reach the sustainable level.

In the beginning, most of the facilities were provided by the government and donors free of cost. But availability of facilities did not ensure utilization and proper maintenance of these facilities. It had been seen that once the facility went out of order, it remained out of order. There was no fund for repair and maintenance of the same. That resulted needs for rehabilitation and caused more scarcity. The facilities must be constructed and optimally used before it is replaced.

Sustainability of WSS Systems

Sustainability of water supply and sanitation system must be considered for achieving good health for all and keep the environment healthy. With the increase in population we are facing extreme crisis of all resources including water. With the passage of time, drinking water is becoming scarce and environmental pollution is increasing.

The water supply and sanitation system will be called sustainable when the users can have guaranteed supply of safe water and sanitation facilities according to the demand. The main parameters for sustainable WSS system are considered as:

- Recovery of investment cost from the users as depreciation that is required for meeting future demand and replacement of the facilities.
- Recovery of operation and maintenance cost to keep the facilities in serviceable conditions
- Community participation in sharing the cost and undertaking operation and maintenance
- Community mobilization for use of safe water and sanitary facilities.
- Participation of women in decision making, operation, maintenance and repairing.

Sustainability may be defined as the ability to meet the required operation and maintenance cost and to generate small surplus money to undertake replacement and extension work for improving service delivery.

For sustainability, at least some percentage of depreciation cost should be added with the tariff that would be required for replacement of major components, emergency maintenance and small extension work.

Estimated Cost for Water Supply and Sanitation Facilities

The estimated investment and monthly operation and maintenance cost of different kinds of facilities are shown below:

ITEMS	ESTIMATED COST PER UNIT IN TAKA	
	Investment cost	**O&M Cost/Month**
HAND TUBE WELLS		
Deep HTW	50,000 to 70,000	50-75
Shallow	5,000 to 8,000	50-75
TARA	10,000 to 20,000	50-100
Pond sand filter	20,000 to 30,000	100-500
Shrouded Tubewell	10,000 to 20,000	100-500
Iron removal unit	5,000 to 10,000	100-200
PIPED WATER SUPPLY		
Pipe line / km	8,00,000 to 12,00,000	5,000-6,000
Production well	15,00,000 to 20,00,000	15,000-20,000
Treatment plant	100,00,000 to 15,00,000	20,000-30,000
Overhead tank	60,00,000 to 100,00,000	1,000-1,500
House connections	3,000	200-300
Street Hydrants	3,000	200-300
LATRINES		
Home made	100 to 200	20-30
Single Pit (1 ring + 1 slab)	225 to 300	20-30
Single Pit (5 ring + 1 slab)	1200 to 1500	20-30
Double pit (10 ring + 1 slab	2500 to 3000	30-50
Full sanitary latrines	20000 to 50000	100-200

The estimated cost shows the importance of cost recovery. For any facilities some one should bear the cost for installation as well as operation and maintenance. There is no way to treat the investment as free of cost. Similarly if the facilities are to be optimally used it must be maintained properly. In the urban centres the poorer people should also be served with the pipe water supply and sanitation facilities. The key point is to share the cost by the users. Community participation and skill development is very important.

Operation and Maintenance Cost

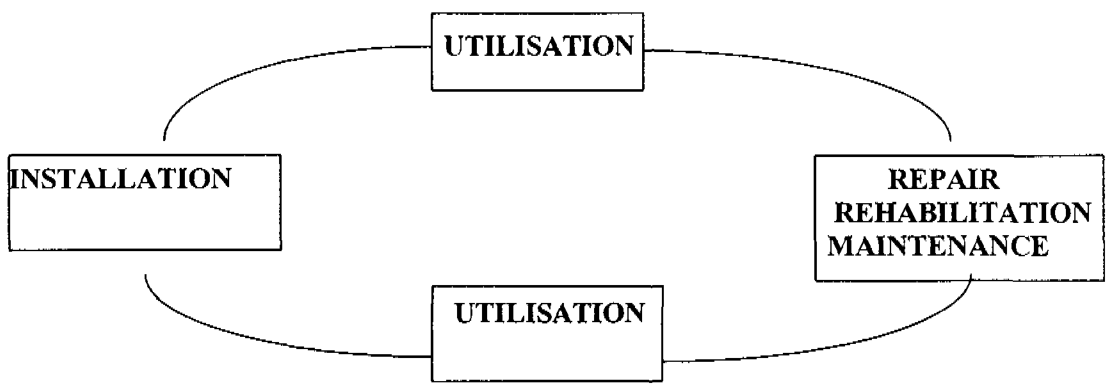
The main items of operation and maintenance cost of water supply are:

- Electricity bill
- Salary of staff
- Repair and Maintenance
- Office expenses

There is no operation cost for HTW but incur small amount of maintenance cost. The piped water supply system incur large amount of operation cost such as electricity bills, salaries of staff as well as maintenance costs such as repair and replacement of parts, components. Because of differences in the total investment cost the depreciation cost also vary widely between the HTW and piped water supply system.

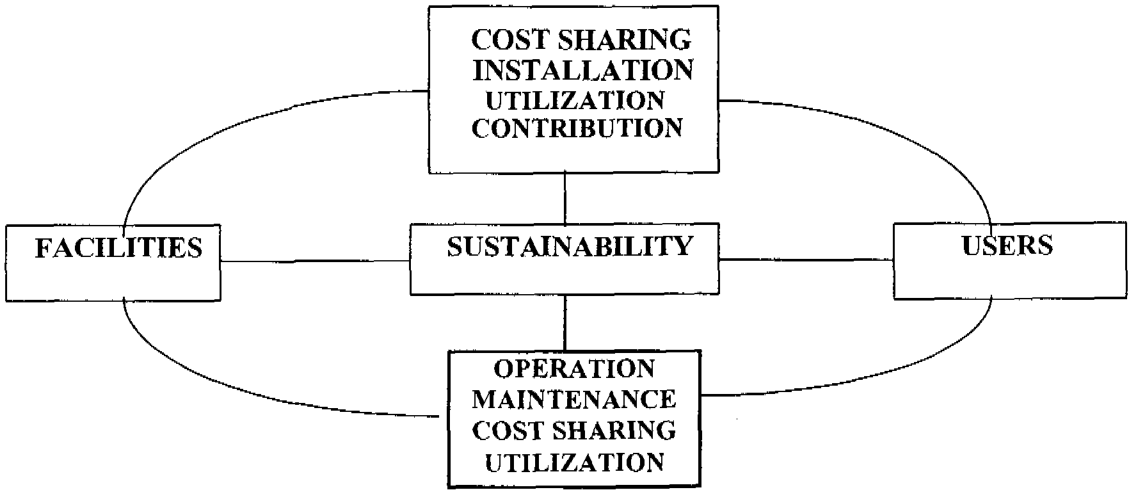
The number of house connections and the corresponding water tariff are not enough to generate sufficient revenue for meeting the O&M costs. For many towns it would not be possible for payment of the electricity bill which is about Tk. 10,000 per month per pump for 12 hours operation in a day. The salaries amount to Tk. 15000 to 25000 per month depending on the no. of staff.

Most of the facilities failed to serve the purpose because of poor maintenance. If the users are trained for minor operation and maintenance of the facilities then they can keep it in good order by themselves. The installation, utilization and O&M are to be linked together to achieve sustainable WSS system.



Relationship between Installation, Utilisation and Maintenance

The monthly operation and maintenance cost for small pipe water supply system amounts to several lacs Taka. For HTWs and other technologies the charge would be at lesser rate. This amounts to be realized from the users if the Pourashava or the agencies provide the maintenance. In other case the users may pay to the caretaker for buying and fixing the materials for HTWs. In case of pipe water supply they can generate fund for payment of water bills. Thus the key to sustainable water supply and sanitation is full involvement of the users in the system. The linkage between the users, the facilities and sustainability is shown as:



Lessons from the successful project suggest careful project design and financial rules to be followed right from the beginning towards sustainability (follow figure in page 5).

Adopting Project Rules and Procedures - Financial Policy

Phase	Rules	Lessen
Pilot	Users contribute 20% of capital costs in cash or in kind. Users bear 100% of O&M costs. Multiple subsidy ceiling applied based on technology type and basic level of service. Users to bear any incremental cost of service above the basic level.	Community willing to contribute unskilled labour and local materials. 20% community contributi8on in-kind for unskilled labour is low. Cost-sharing rule could be revised for community to contribute 100% of unskilled labour and local materials. Multiple subsidy ceiling is complex and difficult to apply. Users requested higher service levels for protected wells; revised economic analysis justified reduction of distance to water point.
Small Scale	Revised cost sharing arrangement (in addition to a minimum of 20%) includes 100% of unskilled labour and local materials. Introduction of a universal subsidy ceiling irrespective of technology type for basic service level. Construction contracts with Pos and CBOs provide for reimbursement of only actual cost of skilled labour and goods.	Community contributions average 28%. Actual cost subsidy of scheme is less than the subsidy ceiling. Wider range of technology mix results in greater community satisfaction. Project can also cover difficult and complex schemes/villages
Large Scale	Maximum subsidy ceiling relaxed for villages to introduce new technology options such as rainwater harvesting or rope pump. Continue to apply the same financial policy as in small-scale implementation.	Community contribution continues to average about 28%. Actual cost of scheme less than the estimated cost. Actual cost subsidy below the subsidy ceiling. Necessary to review the subsidy ceiling, however, difficult to change as financial policy is communicated to the villages in all the districts.
Consolidation	Continue application of same financial policy as in the large-scale phase.	Subsidy ceiling needs to be revised and lowered. Need to explore new financial policy to enable scheme prioritization based on higher community contributions and lower subsidy ceiling.

Community Participation in WSS Project

Introduction

People's participation in decision making and local ownership results in effective and sustainable development process. This belief has played a central part in the shift in institutional strategies from supply-driven to demand-driven approaches (see box at the end), which respond to the felt needs and aspirations of users, especially the poor. However, quantitative evidence of the efficacy of participation in determining project effectiveness, relative to other factors, has been missing.

In most developing countries, public sector agencies provide rural infrastructure. Poor public sector performance has led to a widespread search for institutional alternatives and means to increase the accountability of the public sector. In the rural water sub-sector, the search has been for strategies to increase users' "exit" and "voice" options and to restructure the sector so that suppliers have incentives to match the demand of users.

The problematic issue therefore is not technology and construction but rules and regulations-institutions- and organisation. The first challenge for agencies is to create an incentive for staff to work in partnership with hundreds of communities. The second task for agency staff is to enable communities to make informed choices, and manage and choose from a menu of water supply options (technology and management) that the agency offers.

Although the agency task has changed dramatically over the years, that fact has seldom been recognised or acknowledged by the agencies themselves. Hence, the agencies and their competency, organisation, structure, and management-by-blueprint style have remained largely the same. The mismatch between the task and the mandate, ability, and competence of the agency has resulted in many unsuccessful government attempts to induce participation. The key question, then, is: How can organisations change to induce participation in collective action?

Beneficiary participation can be brought about in several ways: directly, through participation in decision making; indirectly, through leaders; or through representation on committees or boards. Participation of beneficiaries can be facilitated through extension workers, local government units, non-governmental organisations (NGOs), and the private sector. Many factors influence beneficiary participation, including the immediate and broader policy context; client characteristics (including felt need); and agency characteristics, such as flexibility, responsiveness to clients, and willingness to invest in the sound organisation of communities. In this regard, the following questions are to be addressed:

- Does people's participation contribute to project effectiveness?
- How important is this contribution, relative to other factors?
- What factors and strategies influence participation in collective action?
- What are the lessons for the design of large-scale project?
- What are the implications for policy reform?

What Is Participation?

Participation is a process through which stakeholders influence and share control over development initiatives and the decision and resources, which affect them. Participation is also a voluntary process by which people, including the disadvantaged (in income, gender, ethnicity, or education), influence or control the decisions that affect them. The essence of participation is exercising voice and choice.

Definitions of participation abound (Cohen and Uphoff 1977, Korten 1980; Paul 1987; and Ghai and Hewit de Alacantara 1990). All of them include in some measure the notions of contributing, influencing, sharing, or redistributing power and of control, resources, benefits, knowledge, and skills to be gained through beneficiary involvement in decision making. There is also many debates among practitioners and in the literature about whether participation is a means or an end, or both (World Bank 1992; Picciotto 1992).

Defining Community Participation

How community participation is defined will depend upon on the objectives and the needs and possibilities for participation. No matter whether a maximum or minimum community involvement is developed, some central questions will have to be answered and tested in the field: who participates in which phases and decisions, how and to what degree, and what effects are desired for the programme and the community? These questions are not yet generally considered by the agencies solely responsible for the planning and implementation of water supply and sanitation programmes.

Some of the international organizations have taken the working definition of community participation from three dimensions. These are involvement of all those affected in decision making about what should be done and how; Mass contribution to the development effort, i.e. to the implementation of the decisions; and Sharing in the benefits of the programes (WB, 1976) *[1]
Since equitable share of benefits is essential, community participation can be defined by involvement of the local population actively in the decision-making concerning development projects or in their implementation.

Involvement of population in the physical works of implementation of project is also sometimes treated as participation. This kind of involvement prescribed passive acceptance of services and provision of supports in cash or kind, in giving money for a pump, digging a well for a water supply, or laying bricks for a health center. The dynamics of changing society, however, demand much more than mere acceptance, allegiance, and unpaid labour.
The new type of involvement requires identification with the movement, which grows only out of involvement in thinking, planning, deciding.

This conception does not assume that there is an ideal level of participation varies, but over the long run sustainability will depend on minimising transaction costs in horizontal and vertical interactions. Participation is viewed as a means to defined ends, not as an end in it; the goal therefore is to optimise participation to achieve the desired project goals, not simply to maximise participation. The desired goals in rural water supply projects include achieving improved water supply systems and developing the human, organisational, and management capacity to solve problems as they arise in order to sustain the improvements.

The principle underlying participation- to give people a voice- is constant, yet the choices that people make vary infinitely. Thus, a community may decide to subcontract maintenance to an independent mechanic rather than to undergo training and take turns doing the work. A water users' group may choose to dissolve the organisation or to define new goals after the first ones have been met. For example, when construction is complete, a water committee may transform itself to undertake sanitation itself to undertake sanitation construction, to build a football field, or to branch into children's education, depending on the community group may divide into smaller,

[1] A fourth element is sometimes considered: namely, local participation in evaluation. However, this may be considered part of the decision making process

functional subgroups, with the larger group meeting only occasionally. Alternatively, people may informally nominate leaders to represent their interests.

Necessity of Community Participation

The reasons that advanced the concept of and necessity of community participation in all the development interventions including WSS are shown in the following box.

The Reasons Advance for Community Participation

1. With participation, more will be accomplished
2. With participation, services can be provided more cheaply
3. Participation has an intrinsic value for participants
4. Participation is a catalyst for further development
5. Participation encourages a sense of responsibility
6. Participation guarantees that a felt need is involved
7. Participation ensures things are done the right way
8. Participation uses valuable indigenous knowledge
9. Participation frees people from dependence on other's skills
10. Participation makes people more conscious of the cause of their poverty and what they can do about it.

The Forms of Community Participation

1. Consultation
2. A Financial Contribution by the Community
3. Self-help Projects by Groups of Beneficiaries
4. Self-help Projects by Involving the Whole Community
5. Community Specialized Workers
6. Mass Action
7. Collective Commitment to Behaviour Change
8. Endogenous Development
9. Autonomous Community Projects
10. Approaches to Self-sufficiency

1. Consultation

The basic means of giving the community some voice, involving it in decision-making. Main rationale: to ensure that the project or programme introduced by the outside by the outside agency is adapted to meet the needs of community members, and to avoid difficulties in implementation. It may involve:

1a. Consultation with community representatives or leaders only. It may well be considered that such consultation does not amount to real community participation unless the community is one where the decisions formally made by representatives or leaders are the result of wider consultation and consensus within the community, and unless the community is thereby involved in decision-making on significant aspects of the project which is being introduced.

1b. Consultation with all sections of the community. This is primarily a matter of ascertaining the views of those sections of the community, which may normally be excluded from decision-making (women, certain ethnic minorities or low caste groups, the poorer sections), whose interests may not be genuinely represented in the existing processes of decision-making in the community. The rationale: to ensure that the project meets their needs also. This is not always easy, and there are differing views on the emphasis, which can or need be given to it.

Sample Checklist of Uses for Water and Relevant Requirements

	Use of Water (Not exhaustive)	Objective requirements for health (minimal)	Requirements for Convenience (Community preference etc.)
1.	Drinking by babies, sick people	Assured purity (boiling may be specified)	Practical/ Customary constraint: is water boiled or only heated?
2.	Drinking by healthy children and adults	Purity	Taste: will boiled or deep well water be rejected?
3.	Rinsing mouth, cleaning teeth	Purity (perhaps less stringent)	Is there a custom of using surface water which is suspect?
4.	Food preparation-uncooked food	As above	Is there a custom of using surface water which is suspect?
5.	Dishwashing	As above	Preference for running water?
6.	Cooking		Taste: colour and clarity
7.	Personal hygiene (washing body without immersion)	Abundance. Use with soap or heated	
8.	Bathing, swimming (immersion)	No schistosome organisms (cercadiae)	Seclusion (for women)
9.	Washing cloths	As above	Softness (economy of soap)? Preference for running water? For sociability?
10.	Watering of domestic animals		Requirements of each type of animal: dispersion of sources to avoid overgrazing?
11.	Vegetables gardens	Sullage acceptable but sewage only after some treatment	Space near house? Damage by pigs or other animals?
12.	Irrigation of food crops	Care to avoid schistosomisasis: sewage only after treatment	Equitable share of water as major resource
13.	Other irrigation or fish culture (including irrigation of pastures, tree crops. non food crops)	Care if sewage is used (e.g. to cook fish or meat well); protection against parasites while working in water	

This checklist is only a sample: it will be needed to be modifying in local circumstances. In the third column, many more concerns will certainly be apparent in each community. The suggested requirements for health are not to be taken as authoritative but only as a sample list of concerns.

2. A Financial Contribution by the Community

Cash collections made by and within the community, generally prior to or at the time of implementation of a project, usually as a contribution to capital construction. Excluded, as not really constituting community participation, are cases, which amount to a payment by individual families for service, even when it is an advance payment.

3. Self- help Projects by Groups of Beneficiaries

In these projects a specific group of local inhabitants contribute their labour (and perhaps other inputs) to its implementation, while there is also the assistance of an external agency.

Reduced fees for the services they receive, while non-members pay more will recompense those who contribute.

4. Self- help Projects Involving the Whole Community

Projects in which every family in the community is expected to make a contribution (usually in labour), while there is also input from an external agency. Food-for-work projects may perhaps be included here, though the element of community participation may be considered slight if it consists only of labour, which is paid, in cash or kind.

5. Community Specialised Workers

The training and appointment of one or a few community members to perform specialised tasks (e.g. as community health worker, or operator of a community water supply system). The training and technical supervision are carried out by an external agency, but some form of community authority is usually also exercised over the specialised workers.

6. Mass Action

Collective work in the absence of a major input from an external agency. Often such actions are directed at environmental improvements (e.g. to drain wastewater).

7. Collective Commitment to Behaviour Change

Cases where a community makes a collective decision to change customs or personal habits, and collective social pressure is exercised for the realisation such changes. Examples range from penning of domestic animals to construction and use of latrines, or to the reduction of excessive expenditures in connection with weddings, funerals, etc. While changes of behaviour may of course occur in other ways, community participation is involved when an explicit decision is collectively taken.

8. Endogenous Development

Case in which there is an autonomous generation within the community of ideas and movements for the improvement of living conditions – as opposed to stimulation by outside agents. The community may, however, have recourse to external agencies to help with implementation, or indeed press for such help. On the other hand, where this is simply pressure for services to be provided, it hardly qualifies for the term "community participation", though in a wider sense this is an example of political participation.

9. Autonomous Community Projects

The ambiguous "self-reliance" is often understood in this sense: projects where any external resources are paid for by the community with funds raised internally, including the hiring of any outside expertise or professional staff. Such projects are therefore under community control.

10. Approaches to Self-sufficiency

Projects in which the objective is to satisfy local needs as far as possible by using local materials and manpower directly, not by purchasing goods and services from outside. "Self-reliance" is also sometimes understood in these terms.

Levels of Participation

Participation is a multidimensional, dynamic process, which takes varying forms and changes during the project cycle and over time, based on interest and need. Samuel Paul (1987) usefully distinguishes among levels of participation; all four of which may coexist in a project. The first two categories present ways to exercise influence; the other two offer ways to exercise control. The levels comprise information sharing, consultation, decision making, and initiating action.

Information Sharing

Project designers and managers may share information with clients to facilitate collective or individual action. The information flow is one-way, from agencies to communities. Although it reflects a low level of intensity, information sharing can positively affect project outcomes by enlarging clients' understanding of specific issues (for example, by explaining hygienic practices or how ground water is polluted). Information sharing may also be one-way in the other direction, in the form of baseline or feasibility studies wherein information (but not necessarily opinion) is gathered from beneficiaries. Many such studies tap local knowledge but do not consult the local clients.

Consultation

When project designers and managers not only inform clients but also seek their opinions on key issues, a two-way flow of information develops. This two-way flow presents some opportunities for clients to give feedback to project designers or managers, who can then use the information about preferences, desires, and tastes to develop designs and policies that achieve a better fit between agency programs and community demand. Examples of consultation include methods that tap indigenous knowledge and organisational forms, such as socio-economic surveys, beneficiary assessments, and willingness-to-pay studies.

Decision Making

Information sharing and consultation generally do not lead to increased local capacity or empowerment of local people and institutions, although they can lead to more effective programs. Client involvement in decision making, however, either exclusively or jointly with the external agency, is a much more intense level of participation, which often promotes capacity, building. Decision-making may be about policy objective, project design, implementation, or maintenance, and different actors may be involved at different stages of the project. Thus, the decision to participate in a project may be made by the community, and the choice of technology may be made jointly, after the costs and benefits of the various technological options have been explained by the agency and understood by the community.

Initiating Action

Initiating action, within parameters defined by agencies, represents a high level of participation that surpasses involvement in the decision making process. Self-initiated actions are a clear sign of empowerment. One client is empowered, they are more likely to be proactive, and to take initiative, and to display confidence for undertaking other actions to solve problems beyond those defined by the project. This level of participation is qualitatively different for that achieved when clients merely carry out assigned tasks.

Institutional options for rural water supply depend on whether water is treated as a public, private, or common property good, and on the resultant degrees of excludability (the degree to which other users can be excluded) and jointness or subtractability (the degree to which use by one affects the overall production cost of use by some-one else). Similarly, the most appropriate level of participation depends on who owns the water and on who manages the extraction and distribution of water. The degree to which water can be managed collectively depends on the ability to exclude some, but not others. The degree of jointness adds complexity to and determines the participants in the negotiations. (for example, in the development of a system for piped water, users at the top and at the bottom of the distribution ladder need to be involved in negotiating rules and regulations for the distribution of the water). Moreover, the moment external agencies intervene to improve the quantity and quality of water, or to make water more accessible, issues related to rural infrastructure and technology choice come into play and ad another layer related to rural infrastructure and technology choice come into play and add another layer of complexity to issues of decision making and participation.

Despite continued government investment, the state of infrastructure has deteriorated, especially in developing countries (Israel 1992). This decline has led to a renewed attempt to focus on the reliability and maintenance of infrastructure. To help identify the role that participation plays in infrastructure effectiveness; it is useful to look at the decision-making phases and takes involved in the construction of rural infrastructure.

Rural infrastructure is developed in five board phases:

- Design or planning
- Implementation
- Institutionalisation
- Operation
- Maintenance.

In practice, work overlaps and shuttles back and forth among those steps. For the purpose of undertaking a rural water supply project, the categories of issues confronting the rural infrastructure concern:

Decisions to join, ownership issues, and conditionality

Choices of technology and service levels

- Decisions about design and construction
- Tariff management
- Water allocation

- Operation and maintenance
- System expansion and replacement.

These categories clearly suggest that clients and agency personal can be involved to varying degrees in influencing or determining the many different choices to be made in any given project. The tendency in the past was for agencies to dominate over community or client choice, sometimes with disastrous results.

Planning and Design

Planning and design is defined as that phase of the project in which the details are worked out as to how to implement the set goals and objectives.

Evaluations of most of the existing development projects suggest that those projects which were built on the needs of the local population, have a higher chance of success than those who do not adhere to this principle. Therefore, to enhance the chances of success and sustainability of projects, it is an imperative to start people's participation by involving people in defining their WatSan related needs, i.e. discussing the welfare of better use of WatSan infrastructure around and collecting proposal for developing the future project concept.

To identify people's needs and opinions a need assessment survey has to be carried out. This survey should aim at identifying the ideas of different interest groups about the present situation, the existing problems and their thoughts about potential solutions. To get an unbiased view of the real life situation, it is considered necessary to focus on management issues and including the aspects which are directly and indirectly related to WatSan resources.

The output from the need assessment will have to be used by the planning team to draw up a number of alternative options for developing the water and sanitation system of the area. Those options included input from the different sector specialists. This was an attempt at cross-fertilisation between local and specialised knowledge.
All possible *systems* are to be presented to those concerned for feedback during the consultation process. The opinions of the local people and their representatives will accord much weight in the process of deciding which system to recommend for implementation.

The output from the consultation process will have fed back again into design and planning. Technical interventions would then be adjusted and fine-tuned on the basis of these meetings.

Implementation

Implementation is defined as the actual building of technical structures, i.e., site selection, resource mobilisation, setting of pumps etc. Implementation involves people in two ways; through local resource mobilisation and through labour input. All the labour intensive works are to be awarded to the existing people's group. Community Based Organisations (CBOs) and other voluntary organisations are to be informed and activated in he interested of the common people.

Institutionalization

Development is a continuous process in which the people concerned participate in a decisive way. It starts with identification of the existing issue based related problem and possibilities, followed by planning, design, construction, operation and maintenance. It is therefore necessary to institutionalise the people's participation in people's centred development projects.

Institutionalisation of people's participation in development activities follows the process approach rather a project approach. The local Government system, societal tradition and customary norms and values, cultural pattern is to be considered for institutional structure. Objectives of the development plan and participation mood and willingness of the stakeholders are the determining factor for structuring the institutional pattern.

Operation

Operation is defined as those activities that make use of the technical interventions. Operation of the system depends on the sincere willingness of the stakeholders to keep it workable and running. Technicalities of the interventions also are to be designed in a way that the stakeholder can afford the systems of operation.

The involvement of all people concerned in operation is deemed crucial to the success and sustainability of any project. Involving the people in the operation of development projects is expected to solve many of the local and regional conflicts that have hampered WatSan. Projects in the past.

Maintenance

Maintenance is here defined as all activities and procedures necessary to keep all the technical interventions and related infrastructure in good working order.

Sustainability requires maintenance. In the past, maintenance was assumed to be the responsibility of the implementing agency, i.e. in the case of WatSan projects the DPHE, LGED, and LG. This practice is now considered too costly and ineffective. The beneficiaries are now given the chance to operate and maintain their advantage, and they are likely to reap considerable benefits. They are therefore expected to have a direct interest in maintaining the infrastructure provided, and will be encouraged to take over the responsibility from the implementing agency for proper maintenance.

The Problems of Disadvantaged Groups

It has been remarked in almost all project context that the poorer section of the society might not get proper share from the WSS projects, rather their position become marginalized. The following checklist shown in box can be followed for understanding the same.

Ways in Which Water Supply Projects Might Possibly Lead to a Worsening of the Relative Position of the Poor

1. Dominant groups might get a subsidized which the poor do not receive, e.g. individual supply to their homes.

2. Access to the new water supply might be restricted or monopolized. This danger includes cases where the design of the project appears to cover the poor too, but actual flow is limited or diverted, so that the dominant group benefits, e.g. by use of water for farming purposes, in such quantities that the supply does not reach the homes of the poor.

3. Water used for agricultural or commercial purposes by dominant groups may increase their income in ways which are not available for the poor; this can than lead to changes which worsen not just the relative but also the absolute position of the poor- changes in land tenure, or others, such as the discontinuance or arrangements to share foods in time of disaster.

4. Removal of an employment opportunity in water carrying, well-digging or any other activity linked to the existing system, such as the manufacture of equipment used.

5. Equal contributions exacted from all inhabitants for the construction or running costs of the water supply may mean a charge, which poor families are not in a position to afford.

6. Voluntary work demanded at a peak time in the agricultural work cycle may lead to substantial loss of production.

The power of dominant groups may be increased by patronage available, e.g. in the form of selection of a water supply operator on a salary. At the least, the village- level organization of the programme, in collaboration with a powerful external agency, will be a political resource in terms of prestige.

People's Participation: Bangladesh Context

Involvement of the stakeholders in project planning and implementation has been practised in Bangladesh since 1960s with the rural development movement. However, immediate after liberation in 1973, national NGOs promoted the issue and showed the alternative of project implementation process. BRAC, Grameen Bank, Proshika (MUK), ASA, FIVDB, VERC, CCDB, GK are the pioneer in this regard. The Government of Bangladesh has also incorporated the concept in 80s decade and mostly projects wise.

Only in mid 1995, the GOB has endorsed a new dimension in planning of PPP (Perspective Planning Process) covering 15 years time period (1995 - 2010). Six different documents have been prepared based on the consultation meetings at district level and sector specific review by the ministries and departments. Stating about the PPP in the volume I it states ".... A planning process is genuinely replacing the traditional central planning exercise whose centerpiece is the local level participatory planning. Planning would be conceived at the local level for the local people by the local people. Sectoral programmes may receive only indicative allocations depending on projections for various scenarios within a general resource envelope."[2]

The Perspective planning was a felt need since late 70s at the highest planning body of the Government. The planning Commission issued a paper entitled " Preliminary thoughts on a

[2] A Participatory Perspective Plan for Bangladesh, 1995- 2010,Document I: The Socio Economic Agenda. Planning Commission, Ministry of Planning, Government of the Peoples Republic of Bangladesh, Dhaka, July 1995 (fifth draft)

perspective plan of Bangladesh, 1980-2000" and later in 1983 another paper named "Thoughts About Perspective Plan". As the mechanism of making the perspective plan a participatory one, attempt was taken to involve the stakeholder or beneficiaries where people at large, especially in the vast rural areas, would provide inputs to the future planning process of the country. People at the grassroots level must be allowed to speak out, they should have opportunity to give vent to their needs and problems and above all they should have a feeling of being associated, through their elected local bodies, in the process of integrating the local needs and priorities with that of the overall planning exercise of the country.

A number of selected teams composed of the officials of the Planning Commission, some research organizations have visited 64 districts, consulted the local representative bodies, community leaders, doctors, technicians, occupational groups and other professional groups about the local needs and priorities. At the same time the PC had listed the issues and problems and prospects of different areas forwarded by different ministries and departments. This was a step by step process and finally been produced as 64 separate documents for 64 districts (all the documents have not yet been published).

Three distinct elements separated the process from the traditional way of planning procedure. These are:

- participatory bottom up approach involving the local people in plan formulation;
- emphasis on augmentation of investments by the Govt. and private sector to attain the sustainable economic growth and reduction of poverty;
- an institutional framework at district level for implementation of the programs;

Despite all the limitations of the PPP, the documents prepared are of great importance to the future planning agenda to the planners, decision-makers as well as the population.

The Government, in collaboration with the leading NGOs and their national and local forums/ chapters, has been experiencing the unique result of participatory development practices. NEMAP (National Environmental Action Plan) is the example of such an attempt. The MOWR has been in the same process in many projects (CPP, SRP, EIP, CIP, MIP) since late 80s and has already formulated and approved the PPG (People's Participation Guidelines). The LGED and the DPHE also practice the same in many projects in the field of infrastructure development and WatSan.

Methodologies in Practice to Ensure Community Participation

Different techniques are followed to actively activate the community in project interventions right from the beginning. These methodologies and techniques vary from socio-economic and cultural context. However, some of the most popular and practiced techniques are given below.

<u>*Case Study*</u> is a qualitative research method that provides a detailed analysis of a single "case". A case study tries to give the "whole story" of a particular event or situation. A case study could be as broad as a certain community, a culture, or (in this case) selected household members that were involved in a sanitation and hygiene education program.

<u>*Key informants*</u> are individuals who are knowledgeable about particular domains of culture and are able to communicate this. Thus the caretaker of a tubewell might be well informed about water collection, while a mother might be well-informed about disposal of infant faeces. Individuals vary in the type and level of knowledge.

<u>*Focus Group Discussions (FGD)*</u> involve interviewing a group of 6-10 individuals who are not previously known to each other, but who share a common characteristic. A typical example would be a focus group discussion with female tubewell caretakers about water use. The group context allows for new issues to be raised, and the participants stimulate each other to discuss the topic.

Group Interview is similar to Focus Group Discussions except the participants are usually known to each other. For example, a group of school students or field extensionists might constitute such a group.

Semi-Structured Interviews entail the interviewer having a check-list of questions but lets respondents express themselves in their own terms, and records their responses in an open form rather than in a pre-coded format. The interviewer encourages respondents to expand on answers and explores them in depth. This allows the respondent to spontaneously raise issues and questions that might not have been predicted, but which are of direct relevance to the investigation.

Observation involves watching and recording particular behaviours in specific places, such as water collection at the tubewell for set periods of times at different intervals in a day. These can be structured or un-structured. In some cases a checklist is prepared and spot checks are made of different sites. Instruments are designed to allow observers to record what they see.

Participatory Rural Appraisal (PRA)/ Community Mapping: *Community Mapping* is a method which involves asking groups of respondents from a specific locality to draw a map using locally available resources such as a mud floor, beans and seeds or whatever is appropriate and easy to manipulate. The construction of a map of a locality can be the focal point for much discussion about the place and its community. It is a method that may rapidly yield information about an area and its population.

Conclusion

People's participation is necessary if one aims at sustainable development. Because it involves a major change compared with present practice, it will require both top level policy support as well as adjustments to the planning process, team composition, team management, budgets and time schedules.

Characteristics of a Demand-Based Approach

A demand -based approach is a strategy that empowers a community to initiate, choose and implement a water supply system that it is willing and able to sustain.

In a demand-based approach:

- The community initiates and makes informed decisions about service options and how services are delivered.
- The community contributes to investment costs relative to the level of service and has significant control on how funds are managed.
- The government has a facilitative role and sets clear national policies and strategies including the necessary legal frameworks and creates an enabling environment for all participating groups.
- The community owns and responsible for sustaining it's facilities.
- Community capacity is appropriately strengthened and awareness is raised to stimulate demand
- The approach promotes innovation and demands flexibility.

Adopted from structured learning in practice:
Lessons learned from Srilanka on community water supply and sanitation

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Project Cycle Management

What is a Project

The word "Project" originates from the Latin word "projicere", what means *to throw forth.* The original meaning has been modulated over the years and gives the following meanings: *A notion, speculative imagination, a projection, a scheme of something to be done; a proposal for an undertaking, an undertaking.* The last three of these meanings accord best with what is meant by a project in our present context. From implementation point of view, a minimum definition of a successful project has been agreed that *it should produce the intended result or benefits, be sustainable over a significant period of time, and operate at reasonable cost.*

Project Classification

Projects can be classified in many ways depending upon the criterion of classification (**Figure 1**). Can be used as an indicator of some of the yardsticks for such professional, sectoral divisions.

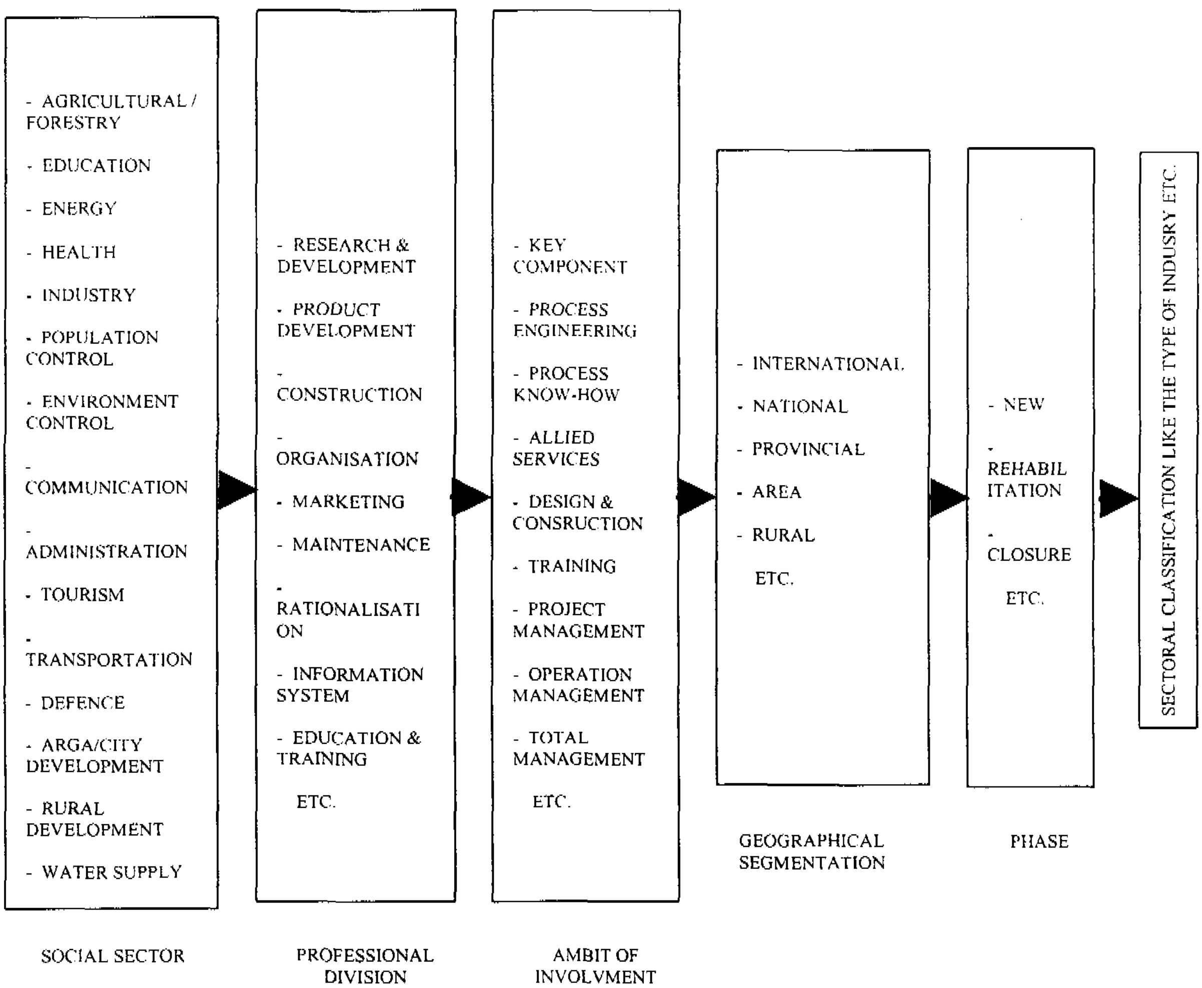

Figure 1 Project Classification

Project Life Cycle (PLC)

It is important to distinguish between Project Life Cycle and Project Product Life Cycle. The former has a shorter span than the later. While the project life cycle is only concerned with the short-lived project system, the project-product life cycle embraces the life of the product or output produced or contributed by the project efforts.

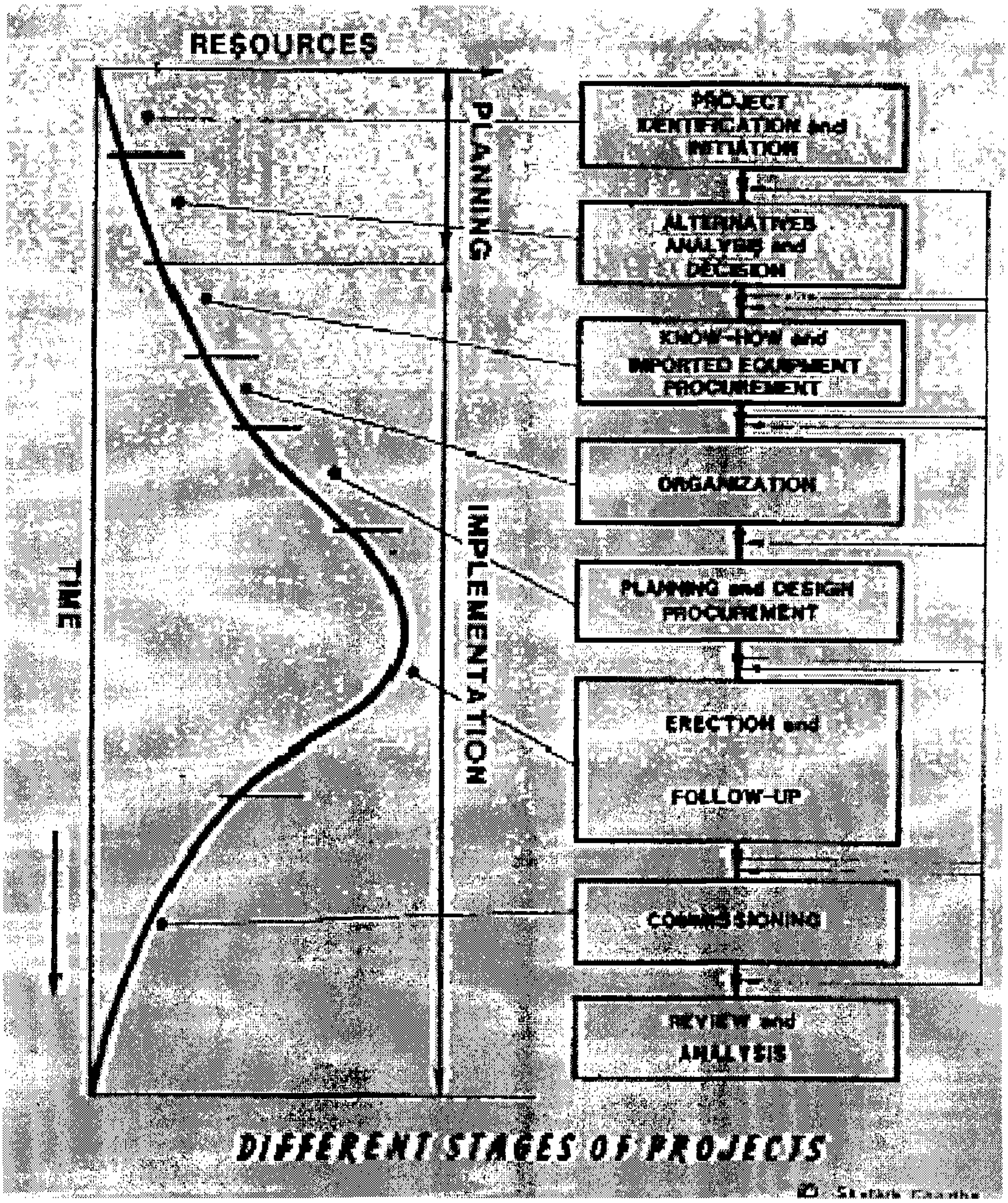

Figure 2 Different Stages of Projects

Project Product Life Cycle (PPLC)

The figure below shows an example of a project product life cycle of an identical type of project. The curve can also be termed as **Rat-Profile Curve (RPC)** due to its shape the stages are shown coupled with a simplified resources/time histogram. The different stages indicate only that the second stage can not be completed before the first stage and so on.

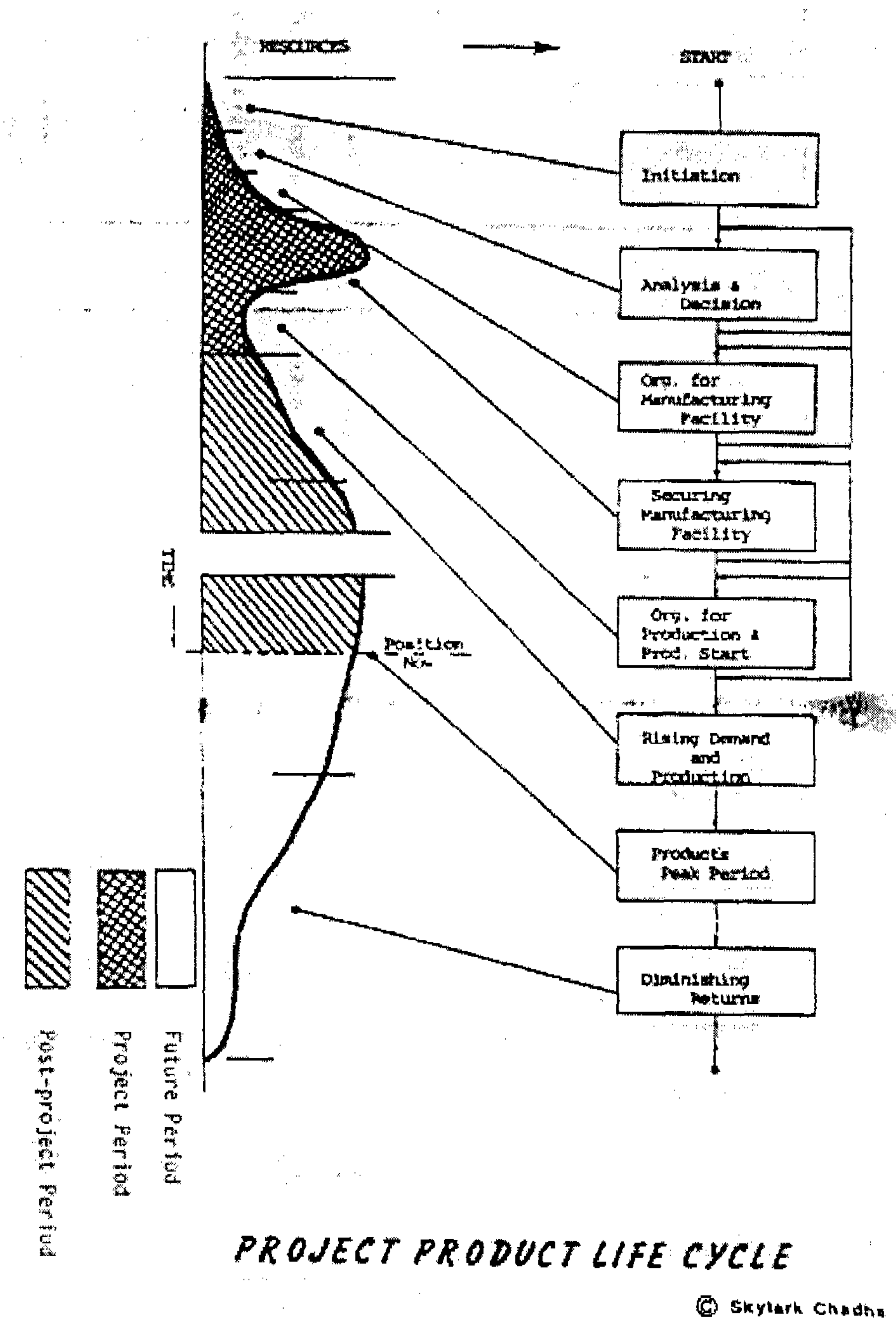

Figure 3 project Product Life Cycle

Project Management

Avoiding semantic jungle around the term "Project Management", it can simply and legitimately understood as follows:

- a management – educational discipline
- the direction part of a project organization
- the scientific art of management to achieve project objectives

The third meaning which is fundamental in our present context, can be explicitly defined as follows:

The management is the steering required for securing the various inputs. Processing them and transforming them into the desired outputs of the project system.

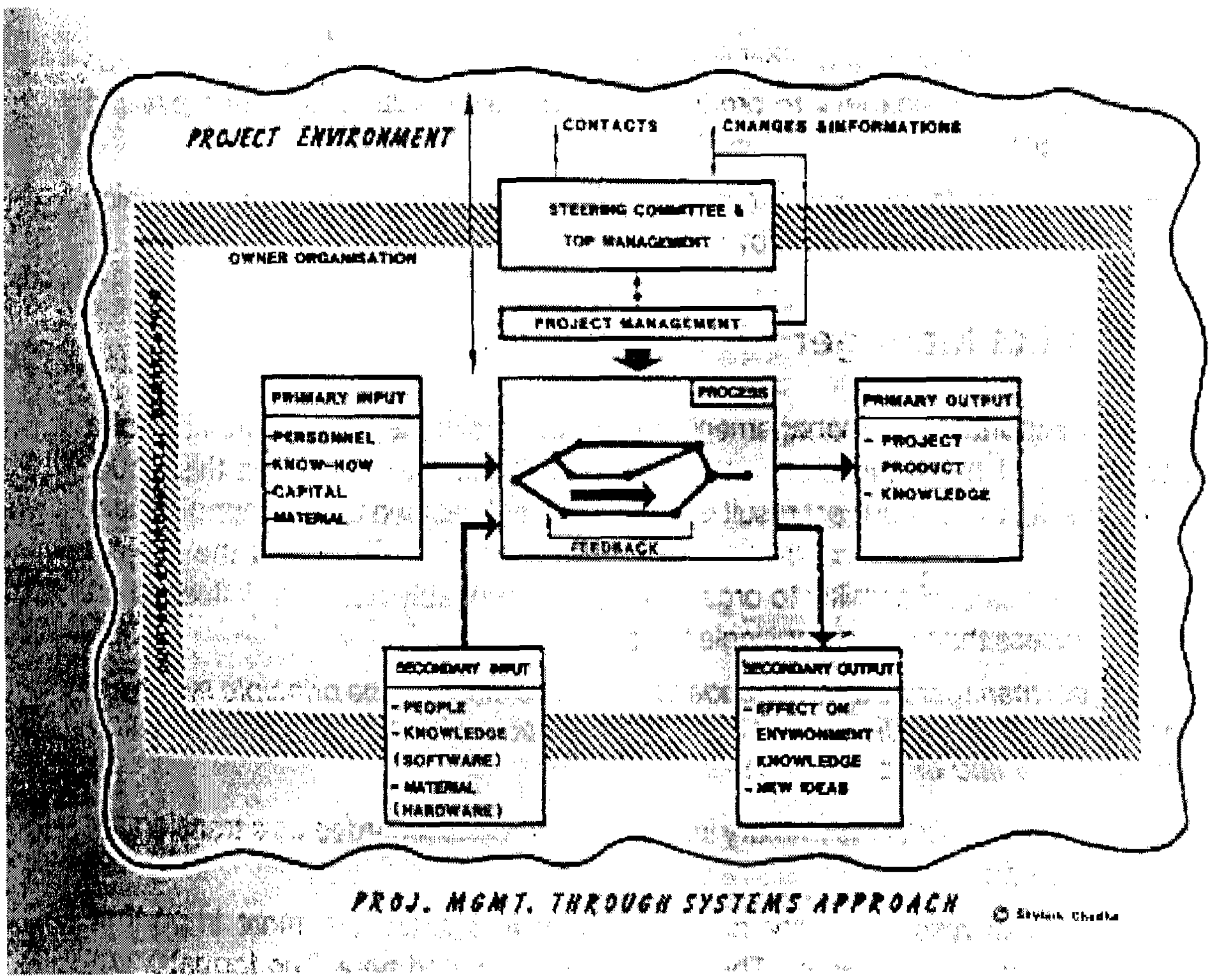

Figure 4 Project Management through Systems Approach

The above figure is self-illustrative and explanatory. A project when looked through the system approach as a tool of management is shown above. The above system can be simplified as shown in **Figure 5**.

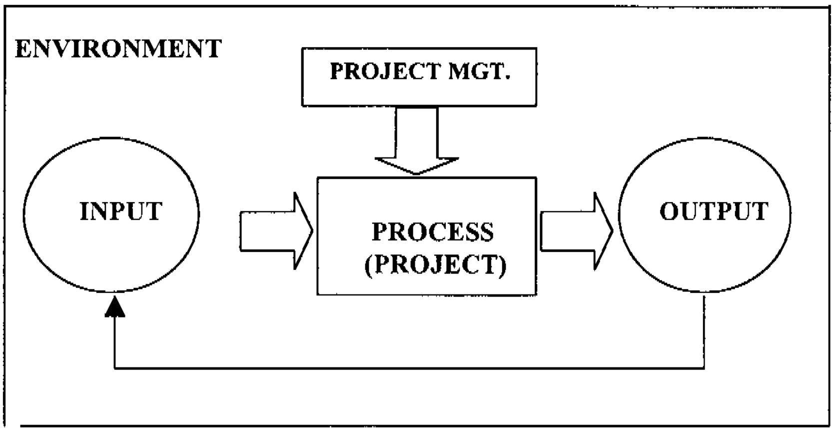

Figure 5 Simplified System View

It is very important for a project management to adopt itself to its environment as early as possible to enable it to produce best possible results under the prevailing circumstances.

Environmental factors are those affect the project progress but which project management can not legitimately change.

Project Preparation

Preparation of a project is not that simple now a day. Many considerations are to be taken into account in preparing a project. Such as, for who the project is, whether the beneficiaries do want the project, the project input and expected outputs strategic aspect and inclusion of beneficiaries in the project cycle with special attention to women, taking care of the environmental issues and above all, the future sustainability. Financiers of the projects, executing agencies and peoples forum are the actors right from the conceptual frame to detail design, implementation and monitoring.

Stages of Project Preparation

Clientele Group(s)

- Identify the population, which are expected to be served by the water supply and sanitation (WSSP) facilities.
- Identify the subgroups within this identified population whose participation is a key to the achievement of project objectives (e.g., landholders, landless workers, business owners, etc.).
- Prepare a socio-economic profile for each existing or potential water users association (WUA)[1]. The profile should provide information, which would enable the identification of the needs, demands, and absorptive capacities of each subgroup. Among other aspects, each profile should describe and quantify the population of each subgroup, differentiated by gender; number of households, household size and number of single-headed households; the location and types of housing in the area; describe the nature of occupancy in the houses (squatting, renting, owning, etc.); occupations, income and asset levels, levels of education and access to

11 See also Benefit Monitoring and Evaluation: A Handbook for ADB Staff of Executing Agencies and

Consultants, Appendix 6, Agriculture Department, ADB, March 1992.

education, health problems (especially those which are water-related), and access to health services; social organizations and group formation, water users groups, leaders and spokespersons; access to and utilization of WSS services, payments for these services, if any. Take account of the socio-cultural traditions of the client groups about water, sanitation and water-related health.

Clientele Needs

- Identify the existing sources of water supply (e.g., deep well, stream, roof drainage, etc.) of the proposed users group and assess the overall condition of the distribution facilities, if any. Assess the adequacy (e.g., how far a villager (or livestock) must walk to obtain water in the dry season, the amount of time spent in queuing up to obtain water, and quality of the water sources (e.g., portability).
- Assess the level of service desired (e.g., private house connections, public hydrant, communal bath/water hydrants the in village center, market, school, etc.)
- Assess the needs of the clients for components that may complement the services that are incorporated in the initial proposal of the project. For example, wastewater drainage, public latrines, health education, etc.

Clientele Demands

- Assess the demand for water services by examining actual expenditures and efforts to obtain water, and comparing these with the quantity and quality of WSS services they receive. Also, examine services obtained through private efforts; and assess problems experienced in obtaining access, cost, quality, quantity and reliability of services. Compare the cost and quality of these services with the with the cost and quality of services which are expected to be provided under the project.
- Assess the ability and willingness of members of the WUA to invest their own capital, provide the necessary labour for construction and undertake responsibility for the operation and maintenance of the water supply facilities.

Absorptive Capacity

- Assess the extent of knowledge and the influence of social and/or religious-based customs, which may influence practices relating to personal and public hygiene. This information would be used to assess the likely acceptance of recommended hygienic practices and/or identify the need for education.
- Describe any organized activities which individuals or groups have initiated to improve the WSS services they receive. Assess the capabilities of these entities in terms of maintaining and operating the water facilities. Assess the need for community organizers to mobilize and train the groups in operation and maintenance of the water supply facilities.
- Assess the appropriateness of the technologies proposed in terms of the WUAs' ability to use, operate and maintain effectively.

Gender Issues

- Assess the differing roles and activities which are performed by males and females (both adults and children) inside the household and in the community in terms of collecting, carrying and utilizing water within the household, and in relation to other WSS-related activities such as environmental health.

Topics to be Addressed in Project Design

Targeting

- Determine whether there are groups of persons who are not in the targeted clientele group but may wish to co-opt services which are not intended for them, and identify this group.
- Identify the possible methods or opportunities which persons in this group might exploit to co-opt these services, and assess the extent to which they might be able to do so.
- If the preceding analysis shows that there is a likelihood that persons who are not in the target group would be motivated and be able to co-opt services provided under the project, propose targeting and monitoring mechanisms which would ensure that the services are provided to the target group.

Participatory Development Processes

Nowadays it is hard to find anyone in the field of development who does not adhere to the need for more "people's participation" in the field of development. Government officials, desk officers from donor agencies, engineers, bureaucrats, ministers, elected representatives, consultants, they all agree; people's participation is a must! Definition of participation has also been in debate among the social scientist, policy makers, planers and implementers. However participation may be perceived as *a process through which stakeholders' influence and share control over development initiatives and the decision and resources, which affect them.*

To ensure people's participation, the following steps to be accommodated in project preparation.

- Incorporate arrangements for implementing the project, which provide for the potential WUA to apply for services before the agency examines the feasibility of providing the services or preparing the detailed design. During both feasibility study and detailed design, the desires of the WUA (e.g., in terms of water source to be developed, type and extent of water treatment, transmission, distribution, level of service, etc.) should be completely identified and explored.
- Based on the assessment of the WUA's absorptive capacity, assess the need for community organizers (COs) to mobilize and train the WUA, and facilitate the WUA's participation in the design, implementation and acceptance of the system.

Delivery Mechanisms

- Assess the capability of the executing agency to mobilize and train the WUA, and facilitate its participation in the design, implementation and acceptance of the system.
- If the agency does not have experience or staff who can perform this work, examine alternative arrangements for providing these services (e.g., through NGOs or community volunteers).
- Assess the interests of contractors who may provide construction services, and opportunities which they could exploit to the disadvantage of the WUA (e.g., opportunities to drill wells to only the depth of the water table in the wet season, and the inability of the WUA to obtain water in the dry season due to a lowering of the water table in the dry season).

- Describe activities, which NGOs may perform to augment delivery capabilities of the water utility. The functions may relate to assistance, which will help, the groups develop capabilities to articulate their demands, and to manage and operate WSS facilities. Identify criteria, which may be used to identify NGOs, which may be involved.

Benefit Monitoring and Evaluation[2]

- Identify a few indicators of the achievement of the project output(s), purpose(s) and goal(s) for each component which would be incorporated into the "Project Targets" column of the project framework table.[3]

- Assess existing management information systems (MISs) in terms of their adequacy to enable the executing agency to verify that the rural water supply systems have been correctly installed and are acceptable to the community, that the community is able to cooperage the system and provide periodic follow-up verify the system's continued operation and use.

- Specify indicators to monitor and evaluate the delivery and distribution of benefits to the target groups identified; and to identify adjustments required during implementation to meet the needs of groups more effectively.

Project Cycle Management

Why PCM is so Concerned

The experiences of various bilateral and multilateral donors illustrate the difficulty of learning from past experience in order to perform better in future. And yet this is precisely the objective of project cycle management (PCM).

Experience teaches us that such weaknesses fall into two categories:

- one or more essential factors for success are overlooked during preparation and implementation, and/or
- the discipline needed to make the right decisions at the right time over the project cycle is lacking.

The things that may be overlooked include:

- creation by the recipient country of a rational framework of sectoral policies;
- a clear and realistic definition of specific objectives that must always entail sustainable benefits for the recipients;
- the drawing of a clear distinction between objectives and the means of achieving them;
- the need to choose appropriate technologies, using, for example, locally renewable resources;
- environmental protection;
- respect for the socio-cultural values of the people involved;
- strengthening of the management capacity of the bodies, whether public or private, called on to run the projects;
- the need to emphasize the economic and financial viability of projects, not only during implementation but above all, afterwards;

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2 For more details, consult Benefit Monitoring and Evaluation: A Handbook for Bank Staff, Staff of Executing Agencies and Consultants, Appendix 6, Agriculture Department ADB, March 1992.

3 See the Project Framework: A Handbook for Staff Guidance, Agriculture Department, ADB, September 1993.

- provision for risks.

The Integrated Approach

The integrated approach is a method for managing the various phases of a project cycle. It covers the six phases of the project cycle by analysing the most important elements of each phase and the criteria for cohesion and sustainability applicable throughout the project cycle. It specifies the documents to be produced in each phase, which in turn provide the basis for the necessary decisions. These documents have the same basic format.

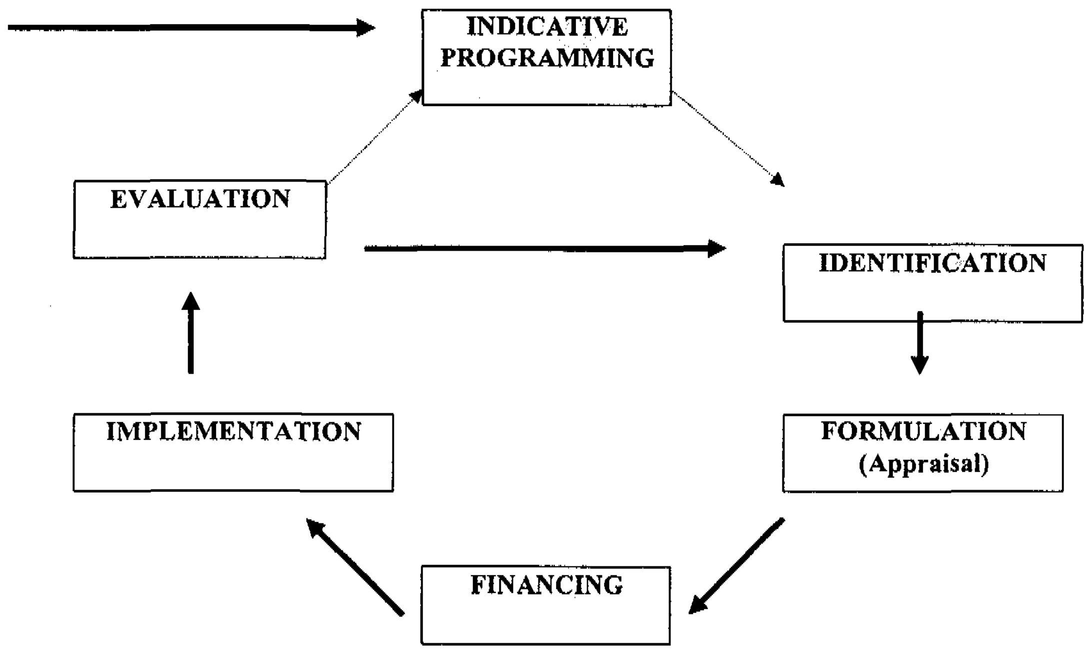

Figure.6 The Six Phases of the Project Cycle

Indicative programming

The establishment of general guidelines and principles for co-operation with the Community. It covers the sectoral and thematic focusing of aid in a country or region and may set out a number of ideas for project/ programmes.

Identification

Initial formulation of project ideas in terms of objectives, results and activities with the aim of establishing whether or not it is worth going ahead with a feasibility study. If so, the study's terms of reference are drawn up.

Formulation (Appraisal)

All the details of the project are specified on the basis of a feasibility study; internal examination by the Commission of the merits of the project and the way it fits in with sectoral policies. This leads to a decision on whether or not to draw up a financing proposal.

Financing

Drafting of the financing proposal; examination by relevant financing committee; financing decision taken by the Commission on approval by the committee; drafting and signing of financing agreement.

Implementation

Execution of the project by drawing on the resources provided for in the financing agreement to achieve the desired results and the purpose of the project drafting of Plan of Operation and monitoring reports.

Evaluation

Analysis of results and impact of the project during or after implementation with a view to possible remedial action and/or framing of recommendations for the guidance of similar projects in the future. If the financing agreement provides for a number of implementation phases, the start of the next stage will normally depend on the conclusions of the evaluation of the previous stage.

Stakeholders Participation in Project Cycle

Stakeholders are to be involved in the project cycle and the management as well. It is obvious in the modern concept of Management to *hear and fear* the *voice and choice* of the stakeholder, or in a broader sense, the beneficiaries who either would be suffered or benefited from the development interventions.

Right from the project identification to evaluation and reappraisal etc. people of the command area are to be consulted and kept in touch and well informed. Ways and methodological aspects of the same has been discussed and detailed in session 9, 10 and 17 of this training course.

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Health Education & Hygiene Promotion

Introduction

In our country about 44% of the rural population uses sanitary latrines. People are now conscious of using latrine and 61% of the total population are using some form of latrine. Overall urban sanitation coverage has risen from 20% to 42% since 1981. The commonly used options in rural sanitation are the 'home-made' and single pit latrines. Of the sanitary latrines in the rural areas, 60% are home made. In urban areas water borne sewerage system and a range of on-site options such as septic tanks, single and double pit latrines are used. Only Dhaka city has a limited sewerage system that covers only 18% of the population.

People in general have very poor understanding about the relationship between health and sanitation. Rural sanitation suffers much from poor understanding of the health benefits of sanitary latrines. Latrines are used for reasons of convenience and privacy rather than health reasons. In slum areas, situation is deplorable. The sanitary condition of slums is miserable and inhuman. Most of the slum dwellers have literally no latrines, only a few have pit or surface latrines. They often defecate in open fields, in the bushes, near the roads, in the drains or on the riversides. The problem is acute with female residents who have to wait till sunset for defecation or use a neighbour's latrine, if available.

It is easier to change technology than people's behaviour and practices. Keeping this in mind, any project related to water supply and sanitation should be designed giving more emphasis on hygiene education program and its relation with new technology.

It is necessary to encourage the community to actively participate in the planning and execution of the project and also take part in hygiene education.

Water-borne diseases, which are widespread in rural areas, are transmitted directly through contaminated drinking water. It can be controlled and eliminated by installing and using a safe, potable water supply. Through experience, it became evident that, appropriate technology is not enough to improve health, because it is more difficult to change people's hygiene behaviour. Therefore, it is essential to understand the people's perception of disease and design hygiene messages accordingly.

Community Leaders

Community leaders normally provide the encouragement and guidance for their communities to participate in a water supply and sanitation project and its hygiene education component. Before they will co-operate, these leaders must believe that projects will benefit people and not create conflict in the community for their own interest.

The project personnel must identify the leaders and meet them. Leaders are generally of two types; formal and informal. The formal leader is someone with a title who has been officially chosen for a position. Such leaders may be found in:

- traditional hierarchy
- local government
- religious or cultural organisations
- trade associations
- craft unions
- self-help societies
- social clubs
- educational institutions.

A second important category is the informal leader. These leaders have no special title and appear at first glance to be ordinary citizens. But the opinions, requests and suggestions of these people are well respected by the community. The quality of informal leaders comes from their personal qualities and abilities. Examples of informal leaders may be:

- The midwife who has years of experience delivering babies and raising children. She is directly involved in hygiene practices, and often prescribes curative and preventive remedies for illness. She also has the confidence of women in the community.
- A primary health worker or volunteer who has been selected by her community;
- A successful farmer or businessman;
- The oldest person in the community with a wealth of knowledge about the history and customs of the people, including those related to water and hygiene;
- The school teacher who may eventually be a valuable resource in teaching hygiene to the children.

Planning for Hygiene Education

The promotion of hygiene education will require a specific structure in the community through which planning and action can be co-ordinated. The community's water supply and sanitation committee may be able to do this work. Or, an existing group in the community, which is involved in development work, may be the likely candidate for planning hygiene education.

If there is no appropriate existing group, a committee can be formed drawing on people from representative groups and interests in the community, such as farmers' unions or market associations. In communities, which do not have any organisations like these, a completely new group might have to be formed. For the long-term benefit of the community, this new organisation should have the broad goal of community development, with water supply, sanitation and hygiene education as its first priority. It should be representative of the different ethnic, economic, religious and political sectors of the community.

Any committee formed to plan for hygiene education should involve women. Hygiene education is one of the principal roles of women within the household. It is essential that women, as individuals and in-groups, be involved as early and as fully as possible, if the expected changes in behaviour are to occur.

Involving Outside Agencies

Although one agency will be in charge of the water supply and sanitation project, other outside agencies may provide useful assistance in hygiene education. For instance, a public health centre may be able to teach mothers the proper way to dispose of their children's excreta. An agricultural extension agency could explain to men the health risks of defecating in open fields. All such agencies may be utilised. The community organisation responsible for the project may wish to invite representatives of these agencies to share ideas on hygiene education methods and assistance.

Implementing Hygiene Education

The project personnel should take care not to impose new models or organisations on existing structures in the community. In the case of hygiene education, the community efforts toward primary health care through local committees and volunteer workers must not be ignored. Even though it may not be an ideal solution, the decision about whether to organise a new group, and what rules, activities and structures it should adopt, should be left primarily to the community.

Community Awareness, Needs and Practices

A survey in the community helps project staff to understand *community needs, behaviours, beliefs, attitudes, values and resources*. At the same time, community members can begin to understand the alternative technologies available and how they relate to their needs. With this information the hygiene education team, which may includes the project personnel, government representatives and other technical professionals, can develop a program with the community.

Paying Attention to Community Beliefs

Project staff should play close attention to the habits, beliefs and taboos of the target population. This type of information, particularly when collected from the women, can provide a starting point for hygiene education messages to change the way people use water and dispose of excreta.

Staff Training

Subjects to train workers in hygiene promotion may include:

- communication and human relations skills;
- skills in making and using simple educational aids (stories, songs, posters, banners, role playing etc.), using local materials and people;
- knowledge of the correct and healthy ways for people to use the new facilities;
- knowledge of the effects on health of water use and sanitation practices;
- understanding of how local beliefs, values, customs and attitudes may affect water use and sanitation practices.

Who Should Get The Message

Reaching Women

Women have a special role in hygiene education and they need to be involved in the early stages of the program. The information and training planned for women should be closely related to the school's hygiene curriculum.

Low-cost teaching aids prepared for classroom instruction can be used in the special training programs for clinics and groups of women. The teaching techniques must be planned with the users in mind, and so must the location and time for these educational activities.

Reaching Parents through Health Centres

Maternal child health clinics and midwives should receive messages similar to those given to women. These types of clinics should be the first places in a community to have access to improved water supply and sanitation facilities.

Reaching Children in Schools

The hygiene curriculum should be in use while the project works in the community. In this way students will be knowledgeable about the new facilities and can practice their new hygiene skills as soon as the project is completed.

The curriculum committee should consider how to make low-cost teaching aids from locally available materials. Models of clay and wood, hand-drawn posters and stories are examples. Workshops can be held to show people how to produce these materials.

Children form a large group of water users and in some communities they do much of the labour involved in fetching water and disposing of refuse. The children can be taught at school to use water supply and sanitation facilities to improve their health. They can also help their mothers change the hygiene behaviour of their brothers and sisters. However, the mothers must also understand and appreciate good hygiene practices.

Reaching Parents through Schools

Parents may not listen to what their children tell them they have been taught in school. An active effort by the schools to reach the parents can help children introduce new ideas learned at school to their family. Some of the following activities may help educate and involve parents.

- Presentation at meetings by parents and teachers;
- Efforts to get contribution (money, materials, technical advice and labour) to help provide water supply and sanitation facilities for the school;
- Plays by the children about water, sanitation and hygiene practices presented to the parents;

How to Get the Message Across

Achieving the educational goals usually involves using various types of mass media and 'large group' educational techniques. Personal contact and locally relevant materials must reinforce these. The best results will be achieved by a mixture of communication methods that combines a presentation of information with instructions and demonstrations of how parasites spread, how to use the new sanitation facilities, etc.

Some of the communication methods may require electricity, literacy, or large audiences and may be more be more feasible in urban settings. For rural areas, traditional plays, story telling or festivals can be made part of the educational process.

Review of Hygiene Education

Here are some of the main points about hygiene education that have been discussed in these notes:

- Hygiene education must be a multi-disciplinary effort by the planning team, the implementing team and the community.
- The community must be involved in planning the hygiene education program.
- Hygiene education is a long-term activity- health improvements and changes in hygiene practices can take yeas to achieve.
- Good health and good hygiene are made possible by a combination of education, improvement in personal hygiene and appropriate water and sanitation technologies.
- Community needs and community development objectives can be related to better health and improved hygiene.
- Background information on a community is needed before planning can begin for the hygiene education program. Project staff should be aware of local leadership, local customs and which outside agencies and local institutions can assist in hygiene education.
- A detailed community survey must be carried out to determine local hygiene conditions, needs, perceptions of health and hygiene, local attitudes towards water use, defecation and choice of new facilities, and local resources for education.
- Project staff should identify community self-help organisations which can help promote hygiene education.
- Hygiene messages must be designed for their specific audience, particularly women and children.
- Hygiene messages can be passed on using many techniques- from hand drawn posters to short radio broadcasts.

Gender Issues in WSS

DEFINITIONS

SEX

A biologically determined set of differences between men and women.

GENDER

The social positions and relations of men and women as constructed by society. These differences are learned, changeable over time, and have wide variations within and between cultures.

Since women and women issues were put on the agenda in international development co-operation the emphasis has shifted regularly.

SEVEN STRATEGIES

SL	Period	Dominant focus
01	1960s - early 70s	*Family planning*
02	Mid 1970	The *basic needs* strategy demanding a radical shift in Development inputs
03	Late 70s - early 80s	*Equality* and
04		*efficiency*
05	later part of 80s	*Women In development (WID)*
06	Early 90	*Empowerment*
07	now	*Basic services*

Women and Gender

The issue is thus not how to integrate women, but how to transform the system so that dominant social and economic structures promote and secure women's basic human rights, including their economic rights. Instead of convincing women as a static, homogeneous,

Gender and Development (GAD)

A GAD approach focuses on social, economic, political, and cultural forces that determine how men and women participate in, benefit from, and control project resources and activities. It highlights women and men's often-differing needs and preferences. This approach shifts the focus from women as a group to the socially determined relations between women and men.

Gender Analysis

Gender Analysis examines the access and control men and women have over resources. This includes analysing the sexual division of labour, and the control women and men have over the inputs required for their labour and the outputs (benefits) of their labour. It also refers to a systematic way of determining men and women's often differing development needs and preferences and the different impacts of development on women and men. Gender Analysis takes into account how factors of class, race, ethnicity or other factors interact with gender to produce discriminatory results.

Gender Roles

In most societies low-income women have a triple role: women undertake reproductive, productive and community managing activities, while men primarily undertake productive and community politics activities.

Reproductive Role: child-bearing/ rearing responsibilities and domestic tasks done by women required to guarantee the maintenance and reproduction of the labour force. It includes not only biological reproduction but also the care and maintenance of the workforce (male partner and working children) and the future workforce (infants and school-going children).

Productive role: work done by both women and men for pay in cash or kind. It includes both market production with an exchange value, and subsistence/home production with actual use value and also potential exchange value. For women in agricultural production, this includes work as independent farmers, peasant wives and wageworkers.

Community managing role: activities undertaken primarily by women at the community level, as an extension of their reproductive role, to ensure the provision and maintenance of scarce resources of collective consumption, such as water, health care and education. This is voluntary unpaid work, either directly or indirectly, through status or power.

Community politics role: activities undertaken primarily by men at the community level, organising at the formal political level, often within the framework of national politics. This is usually paid work, either directly or indirectly, through status or power.

Gender Needs and Preferences

Since men and women have different gender roles, do different types of work, have different degrees of access to services and resources, and experience unequal relations, the needs and preferences of men and women may be different. Practical gender needs are the needs women identify in their socially accepted roles in society. They do not challenge, although they arise out of, gender divisions of labour and women's subordinate position in society. Strategic gender needs are the needs women identify because of their subordinate position in society. They vary according to particular contexts; are related to gender divisions of labour, power and control; and may include such issues as legal rights, domestic violence, equal wages, and women's control over their bodies.

Gender Desegregated Data

Statistical information which differentiates between men and women, e.g., "number of women in the labour force" instead of "number of people in the labour force." This allows one to see where there are gender gaps.

Gender Gap

The gap between men and women in terms of how they benefit from education, employment, services, etc.

Gender as a Social Construction

The way a society defines the characteristics, entitlements and powers of males and females and establishes their 'proper' responsibilities and domains is called its gender ideology. As opposed to biological differences between women and men, gender ideology is socially constructed and varies widely between different societies.

Gender relations are embedded in the specific values, aesthetics and socio-economic structures of a given culture. Gender ideologies are very powerful for those socialised within it. It is expressed and reinforced on many levels: from images of the divine, to beliefs about foliation. It defines ideas about what is clean and dirty, good and bad. It shapes systems of land inheritance. Ultimately, it reinforces how responsibility, authority and access are ordered within the family and society.

The Inside/Outside Dichotomy

One aspect of gender differentiation makes it particularly difficult to address through development assistance. Unlike differences in religion or economic status, the locus of gender differentiation lies *within* households and not *between* them. Gender ideology is deeply rooted in the private domain. Using this "inside/outside dichotomy," cultures define women's spaces- the public world of commerce and politics is marked as the sphere of men, while women's roles are restricted to the private domestic sphere. Even within a given culture, the boundaries of the female domain may vary with the social norms of the region, economic status of the household, the woman's age and stage of life.

Thus, the gender ideology of a given society is woven from strands of various interlocking systems of religion, kinship, ethics, psychology, politics and economics.

Some useful Terminology

In planning exercises, we often come across the following terminology. For easy understanding, short description on those can be followed as follows:

- **Gender neutral**
  Activities/ideologies that have the same impact on men and women as a group
- **Mainstream**
  Dominant social, economic and political process
- **Mainstreaming**
  To make part of a dominant social, economic and political process
- **WID- competence**
  Specialised skills in planning and/ or implementing development projects components in order to promote women's social and/ or economic standing
- **WID-specific**
  Development initiative that focuses exclusively on women in order to promote women's social and/ or economic standing.

Women have traditionally played a central role in the field of water and sanitation. Hence, they are important actors and a mainstream interest group within the sector. Without their active involvement and participation Water and Sanitation Project (hereafter referred to as the Project) risk being inappropriate and failing. This paper aims to provide Project staff with some initial tools for planning for a gender sensitive implementation. It should be seen as a "document in process" that is to say that continually evolving. Practical experience gained and lessons learned in the cause of implementation shall hopefully modify and change the content.

Women- to a lesser degree with the assistance from children- are most often the users, providers, collectors and managers of water in the households. They are usually the guardians of household hygiene. Consequently, they may have a great deal of knowledge about water sources, their quality and reliability, restrictions and advantages of their use, acceptable storage methods, etc.

Women also have the main responsibility for disposing of household waste, maintaining sanitation facilities and educating and training children in hygiene. Women and children are likely to be the most frequent users of the new or improved water systems, and women may well be the main disseminators of the new hygiene practices.

Gender Issues in WSS: Questions to be Answertes

a. Doing the Work

A hygiene education programme wants to improve health & hygiene

- Who does most of the hygiene work, women or men?
- Who decides on investments for hygiene, women or men?
- Who to target for effective change?

b. Making Decisions

For water supply and sanitation services:

- Who chooses the technology?
- Who decides how the project is designed?

c. Resources and Benefits

A water service supplies water for livestock (or irrigation) and domestic use

- Whose use gets priority, women's or men's?

d. Giving Information

A sanitation project uses local structures
To inform community members on it's range of improved systems

e. Control

In the implementation, operation and maintenance of WSS systems

- Who controls water use, women or men?
- Who controls finances to be invested for the above, women or men?
- Who sits in these local structures, women or men?
- Who has the greatest access to this information, women or men?
- Who has the greatest demand for toilets, women or men?
- Who controls the tools needed for operations and management, women or men?

Gender Policies

Ideas and practices concerning gender differences and gender relations are usually deeply embedded in the cultural and social structures of any society. Bangladesh are no exception.

However, this does not imply that these ideas and practices cannot be changed. If the Project implementation is to be successful, it is of crucial importance that the women, men and children are involved in local planning and implantation, sharing work and responsibilities. Women, in a number of respects a subordinate group, can easily be denied an active role. If serious gender inequality exist positive discrimination of women may be necessary. Consequently, it is important that the Project includes some specific policies for supporting women and overcoming possible disadvantages.

One type of specific policy addresses the practical gender needs of women and is related to the conditions of women in society. In this context the Project will aim at improving women's conditions through provision of safe water and quality and quality sanitary facilities within easy access.

Another type of policy addresses the strategic gender needs of women and are related to their position in society; their access to resources and decision making. When addressing these needs the Project aim to strengthen women's position in the local community by increasing their capacity to participate in planning, decision making and general implementation of activities. The Project must support the empowerment of women by encourage them to take part in all activities. Gender equality in decision making can lead to more shared responsibilities between men and women in implementation.

Increased access to safe water, sanitation facilities, information, knowledge and training for women results in increased ability not only to take decisions about their own lives but also to contribute to the development of the community as a whole. It is crucial that the male members of the communities understand the reasons and see the necessity for women's involvement in activities. It is essential that men become aware and recognize how women's empowerment can contribute to the development of the community.

A Gender Aware Project Policy

Gender specific questions shall not have a separate status but must be systematically integrated into the general Project planning, implementation and monitoring.

Project staff:

- must ensure that gender considerations are incorporated from the beginning. If the users views are not included from the beginning they are likely to be excluded at later stages as well;
- must take into consideration the differences in the needs and proprieties of men and women;
- shall encourage and support women as well as men to take part in local planning and decision making; training and skill development; taking up leadership and management roles;
- must ensure that implementation and planning is carried out in such a way that both men and women can benefit;
- must address possible constraints to women's participation and seek ways to overcome these; and
- shall ensure that the selected NGOs have adequate female personnel at all levels so that women can be reached directly and those gender issues can be addressed appropriately.

Gender Considerations in Project Implementation

1. The Project shall aim to contribute towards enhancing or fulfilling men's and women's practical and strategic gender needs.
2. Gender specific considerations must be reflected in the Project's Plan of Operation (PLOP), and in the Plan of Actions (PLACs) for the different sub-projects and individual work plans.
3. Progress shall be monitored and evaluated on a gender specific basis.
4. Implementation methods must be adjusted in accordance with monitoring results regarding gender aspects.
5. All Project and NGO staff, whether concerned with hardware or with software, should possess competence and knowledge on gender analysis, including the ability to translate gender understanding into practical development initiatives.
6. Staff should undergo gender sensitization and training programmes on reasons and practicalities of women's involvement.

The Users' Active Participation Improves Project Performance

A study on Water and Sanitation Projects, conducted by the World Bank, concluded that gender is not only an issue of equity but also of efficiency. Experience from other projects shows that if women and men actively participate in planning and implementation this will enhance efficiency. Facilities will function better, usage will be more hygienic, recovery of loans will be higher and sustainability in general will be ensured.

How to Support Women's Participation

Identify barriers and constraints :

- Are women overburdens by work?
- Do women have access to information? Are they aware of the Project? Do they need a separate Project Briefing meeting?
- It might be necessary to approach the male leaders and explain why the participation of women is important as tradition may otherwise inhibit women from taking part.

Always ensure that both men and women are approached

- To separately interview or discuss matters with men and women might permit freer discussions.
- Female staffs are likely to obtain better access and more accurate information from women than would male staff.

Make it easier for women to attend meetings

- In joint meetings, try to facilitate seating arrangements so that all participants feel comfortable.
- Facilitation of speaking out- is separate meetings necessary?

- Are the community members aware of the meeting and have they received invitations to attend?
- Time and place of meetings should be convenient for both men and women.

Include women in local planning and decision making

- Involvement of women in choice of caretakers and mechanics
- Involvement of women in selection of members to Ward Level WatSan Committees and different user groups.
- Ensure female representation in the Pourashava and Ward level WatSan Committees and different user groups.

Expansion of women's traditional tasks

- Operation & maintenance of new facilities.
- Imparting health and hygiene education.
- Collecting and managing funds.
- Taking part in construction of latrines and sinking of HTW.

Avoid a Blueprint Approach

A blueprint approach assumes that conditions are known, predictable and controllable. A sound water and sanitation project requires a demand-based, participatory approach that continuously assess what the users want and are able to or willing to pay for new facilitates, their active participation in implementation and decision making. It is essential to consider both men's and women's roles and interests when determining also increases the chances of the acceptance, proper use and maintenance of the new facilities and sustainability and the final impact of the Project. If achievement depends on getting local women men involved in decision making this implies that one has to accept a certain level of unpredictability.

Gender Analysis and Approach

Gender analysis at its simplest is asking questions about the differences between men's and women's activities, roles and resources to identify their needs. Assessing these differences makes it possible to determine men's and women's constraints and opportunities within the water and sanitation section. Analysis can help to ensure adequate provision of services that man and women want and that are also appropriate to their circumstances. This is a process and will begin with the however, the process is continuous and data collected during monitoring for example should be used to modify and if needed changing direction.

An underlying assumption of the gender approach is that the community-women and men- are the agents of their own development, with the Project in a supportive role. A gender approach means that attitudes, roles and responsibilities of men and women are taken into account, that it is recognized that both sexes do not necessarily have the same access to resources and that work, benefits and impacts may be different for different groups. When identifying needs and priorities of men and women, the gender specific data collected on health, environmental and socio-economic aspects and living conditions during the socio-economic Baseline Survey will be invaluable. For example, the health conditions of women may be very different from the health conditions of men. The same is true for the access to resources and the impact of the Project on women and men.

Some Reasons for why A Gender-specific Analysis is Relevant

1. Gender analysis helps to predict how different users will be affected by the Project activities.
2. The information obtained by gender analysis can help in anticipating if the Project will be as efficient, effective or equitable as possible.
3. Experience shows that project and programme planning which does not take into account gender-specific differences in a society is likely to fail or be less efficient as it tends to reach only male members of the community.
4. Poverty alleviation is the main objective of development programme where majorities of the poor are women.
5. Women in Bangladesh are the primary agents in managing natural resources such as water etc. and thus pivotal to the development strategies for protecting the environmental and ensuring *sustainable* development.

When formulating gender-specific strategies, the need for a gender approach cannot be over emphasized. A gender approach also seeks to prevent further overburdening of women and stress the importance of not automatically reinforcing and perpetuating traditional roles. It wants to increase women's decision-making capacities, empower them and achieve a more equal and just situation with reference to their workload. This implies that the needs and priorities of *men* also have to be addressed, since they are required to change their attitudes and behaviours to support women's participation.

Views and Preferences on Hardware

Seeking the users views about technology choices and design features helps when considering designs. Men and women often have different views and interests. If this is not taken into account it is likely that the systems will not be used properly. Designs may be technically sound might not be very practical for the women who shall use them. It is of crucial importance to listen to women's views about siting, safety and reliability; convenience; and time and energy demands of various hardware options.

Men's and women's preferences therefore affect not only their responses to the Project but also subsequent acceptance, use and maintenance of facilities.

Traditional and Non-traditional Roles

- Avoid placing extra work and/or financial burdens on the target group- if they are involved in decision making the possibility that this will happen decreases.
- Attempt to increase women's authority in management decisions in order to enhance their benefits.
- Traditionally women's involvement in water and sanitation projects has only been in health and hygiene education. Design of health education schemes must also focus on the need for men to support and adopt improved hygiene practices.

During the first stage of Project implementation, when decisions are made on the designs and siting of the new facilities, women as the main users must be consulted on the different options and on additional provision which may be required for washing, bathing etc. Project staff must share with women and men the information available on the technical, financial, managerial, health and workload implications of the various options.

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ITN-Bangladesh

The primary goal of **ITN-Bangladesh** is to achieve an improved human resource base in the water supply and waste management in Bangladesh. **ITN-Bangladesh** is sponsored by the Danish International Development Agency (**DANIDA**) and administratively assisted by the **UNDP-WB** Regional Water Supply & Sanitation Group-South Asia (**RWSG-SA**), Dhaka.

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