ITN-Bangladesh Course
on
Water Supply and Waste Management

	Day-I	Day-II	Day-III	Day-IV
8:30-9:15	Inauguration AR Course Introduction MR	Remedial Measures : Salinity HR	Aquacultural Utilisation of Waste ED	Women Participation in WSS HJ
9:15-10:00	Water, Waste & Health FA	Remedial Measures : Iron DH	Biogas as a Waste Treatment Option HR	Course Evaluation MR
10:00-10:30		***Tea***		
10:30-11:15	Technological Options in WSS MR	Remedial Measures : Arsenic AA	Hygiene Promotion MM	Preparation for Presentation
11:15-12:00	Socio-economic aspects in WSS MM	Microbial Quality of Water AJ	Communication in Social Mobilisation AZ	Group presentation Gr-I & Gr-II
12:00-12:45	Common Problems of Water Supply in B'desh BZ	Sanitation Practices and Problems in Bangladesh HJ	O&M and Sustainability of WSS AZ	Group presentation Gr-III & Gr-VI
12:45-13:30	Introduction to Group Assignment	Discussion on Field Assignment	Discussion on Field Assignment	Certificate Distribution & Closing
13:30-14:30		***Lunch***		
14:30-17:30	Field Assignment	Field Assignment	Field Assignment	

AR:	Prof. M. Azadur Rahman	FA:	Prof. M. Feroze Ahmed	MR:	Prof. Md Mujibur Rahman	HJ:	Hasin Jahan
ED:	Prof. Eli Dahi	AZ:	Md Akhtaruzzaman	DH:	Dr. M. Delwar Hossain	MM:	Md. Mohsin
HR:	Dr. M.Habibur Rahman	AJ:	Dr. Abdul Jalil	BZ:	Dr. ABM Badruzzaman	AA:	Dr. M. Ashraf Ali

ITN
Bangladesh

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BUET, Dhaka

21-24 July 1997

01. WATER, WASTE AND HEALTH

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. Fig. 1 shows a good correlation between infant mortality and sanitation coverage in developing countries produced by the World Health Organisation in 1981.

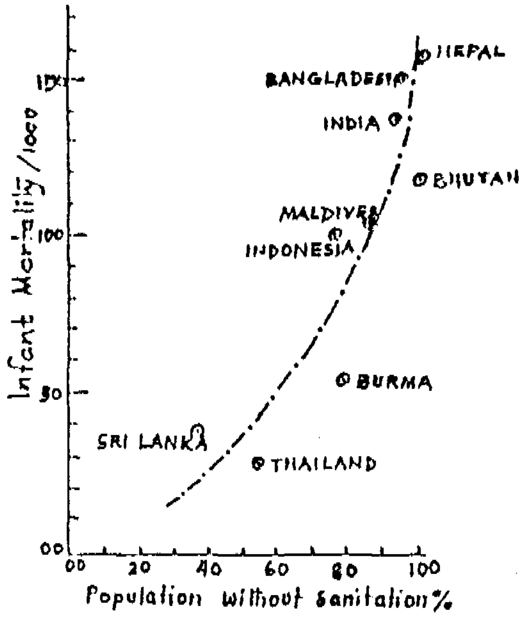


Fig.1 Infant mortality and sanitation coverage in selected south east Asian countries (WHO,1981)

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 Fig. 2.

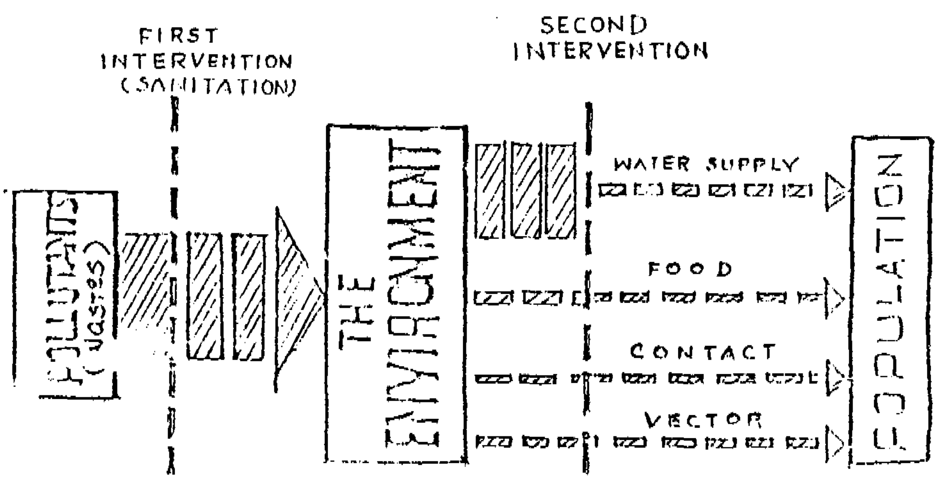


Fig. 2 Routes of propagation of Diseases and interventions

A model showing dose-response relationship of a community under varying exposure of enteric pathogens has been shown in Fig.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.

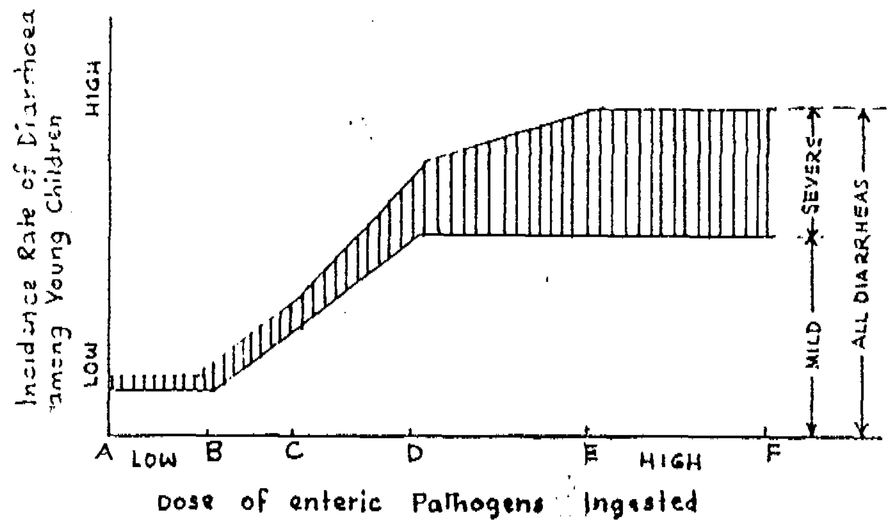
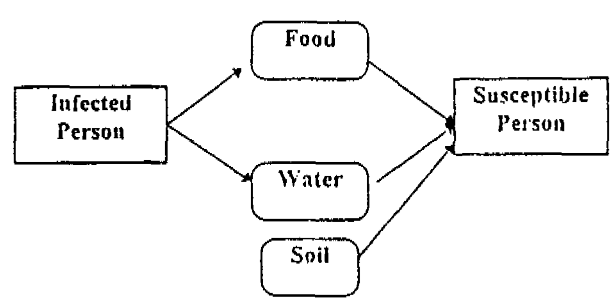
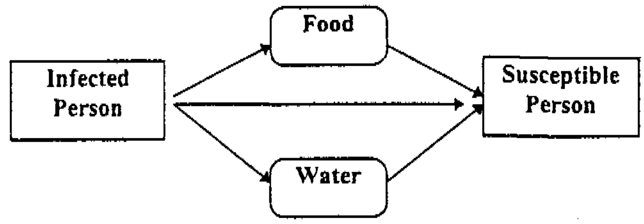
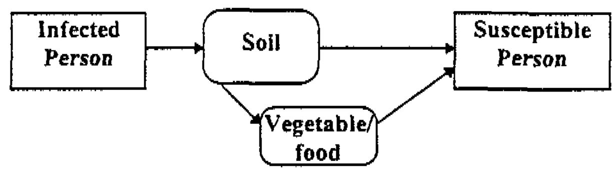
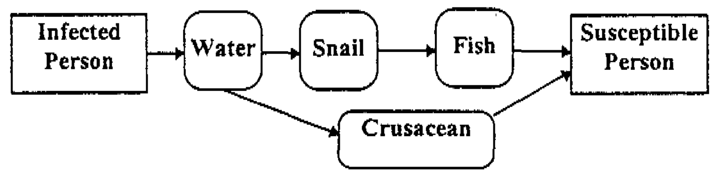
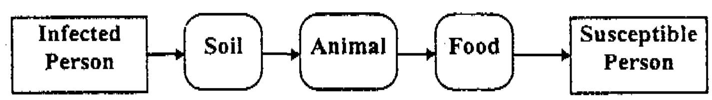
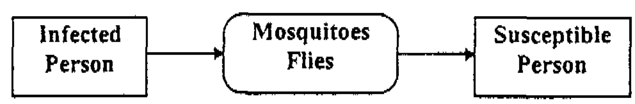


Fig.3 : The dose-response relationship under varying exposure to enteric pathogens (Esrey et al, 1985)

The diseases related to water supply, sanitation and waste management may be classified into five groups according to their transmission routes. 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 **Dysenteris:** • Amoebic dysentery • Bacillary Dysentery **Enteric Fever :** • Typhoid • Para-typhoid	

GROUP	DISEASES	TRANSMISSION ROUTE
II	Viral Diseases • Poliomyelitis • Hepatitis-A	
III	**a. Worm Infection with no intermediate host:** • Ascaris (round worm) • 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	

The infectious diseases are transmitted by various pathogens (disease producing microrganisms) present in human excreta. The four types of pathogens that cause diseases are viruses, bacteria, protozoa, and parasitic worms. The excreted pathogens exposed to the environment survive and sometimes mature to infect the new victim through different routes. The survival of many pathogens depend on the time and temperature as shown in Fig.4. It is evident from Fig.1 that human faeces should be kept in confined environment at least for a period of 1 year to destroy most of the pathogens. This period is also considered adequate to stabilise the organic pollutants present in human excreta into simple compounds.

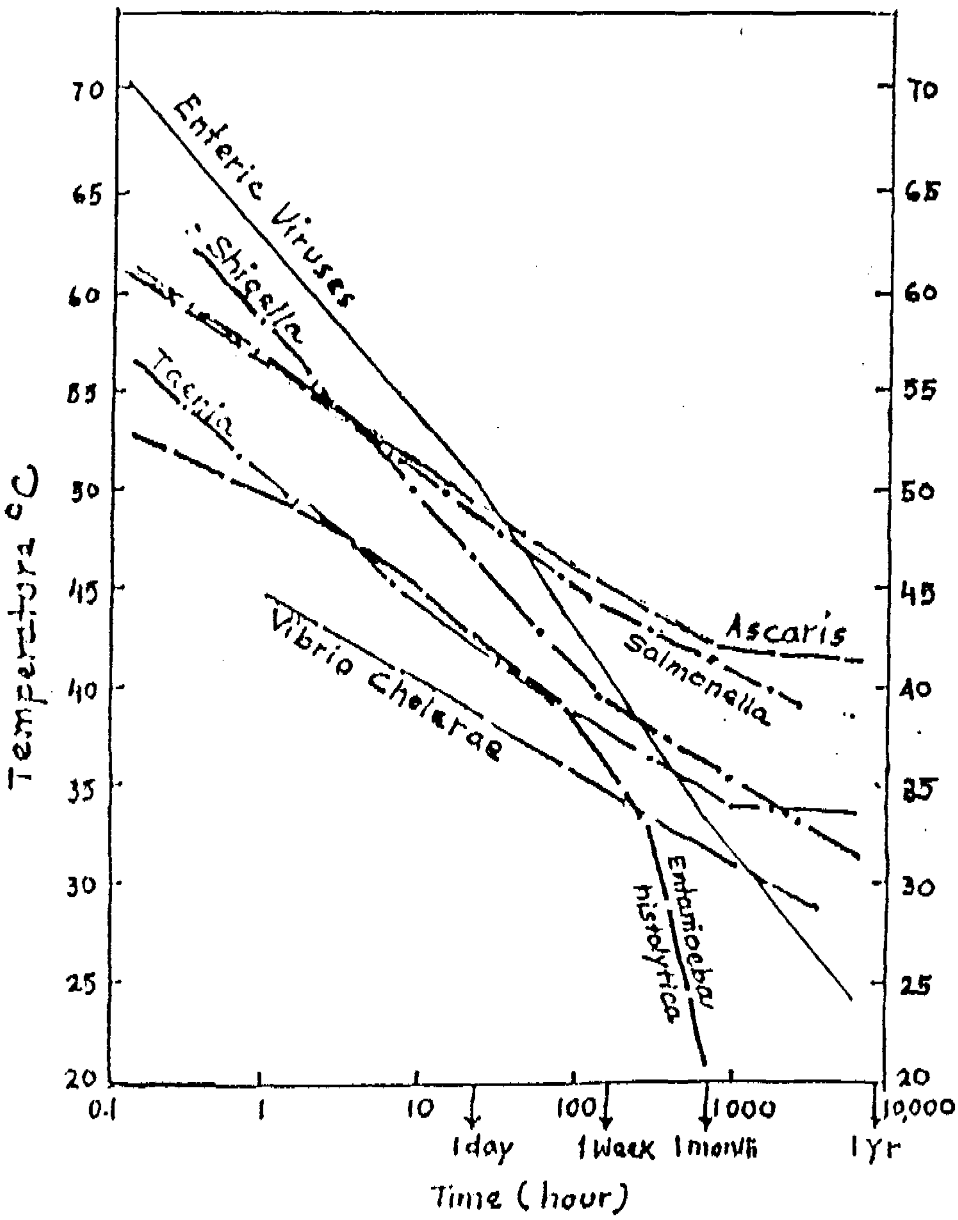


Fig. 4 : Influence of time and temperature on selected pathogens present in night soil and sludge (Feachem et al, 1981)

The percentage of diarrhoeal diseases in Bangladesh is shown in Fig 5.

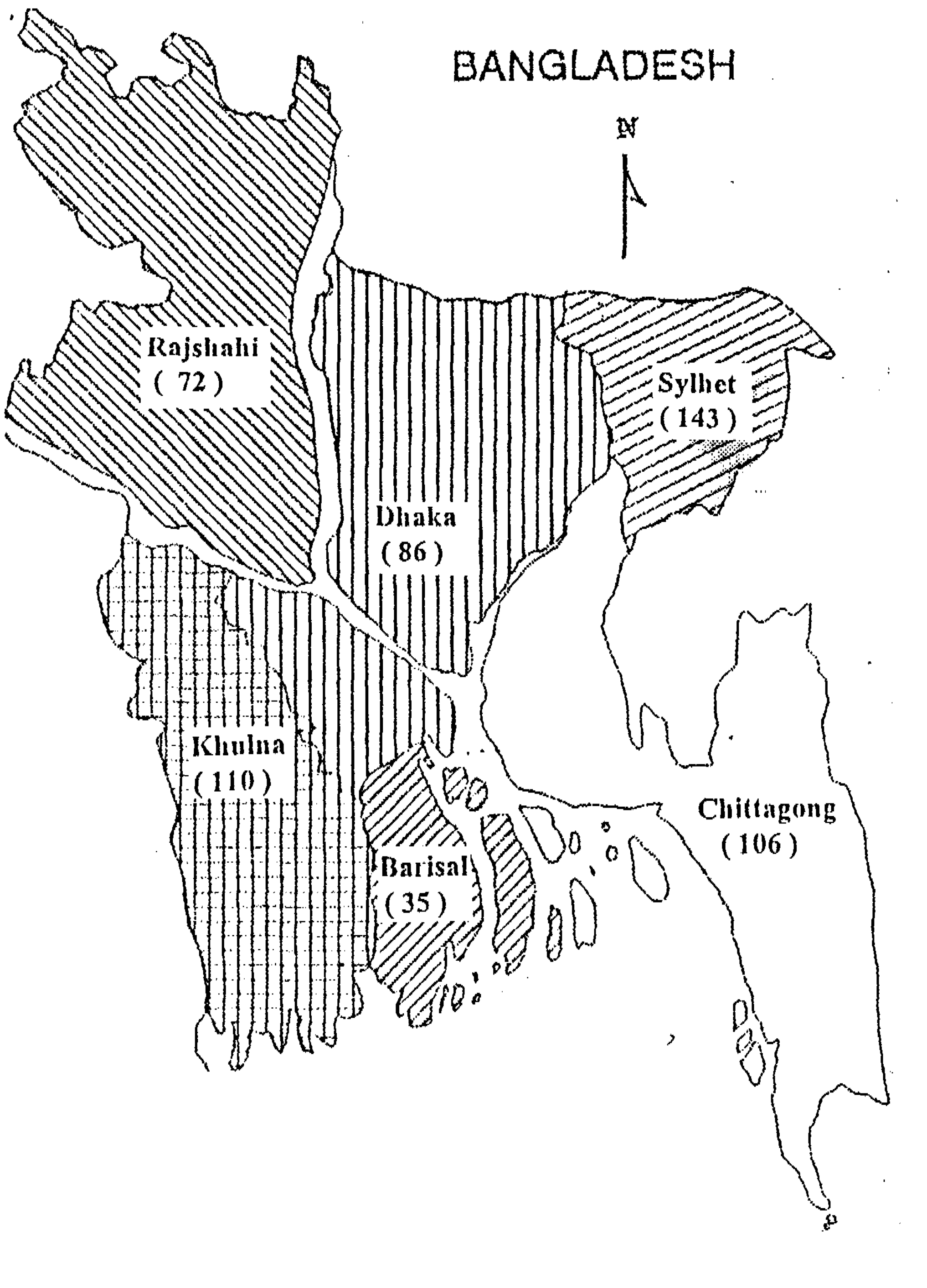


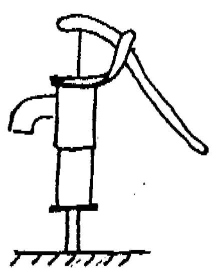
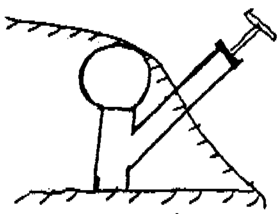
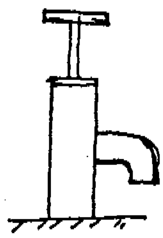
Fig. 5 : Prevalence of Diarrhoea in Bangladesh (Weekly Independent, 16 May 1997)

02. TECHNOLOGICAL OPTIONS IN WATER SUPPLY AND SANITATION

I. Water Supply

Drinking water supply in Bangladesh is based on ground water sources. Ground water is free from pathogens and require no treatment for domestic water supply. But ground water is rich in dissolved salt specially dissolved iron and hardness in ground water in relatively shallow aquifer are quite high which restricts the important domestic uses of tubewell water. The most common technologies used for the abstraction of water in Bangladesh are No.6 pump in high water table areas, Tara pump in low water table areas and in some very high water table areas Rower and Treadle pumps are used. Open dug wells are also used in some areas for domestic water supplies. The performances of No.6, Tara and Rower pumps are compared in Table 1.

Table 1: Comparison of different types of manually operated pumps used in Bangladesh

Parameters Compared	 **No.6 Pump**	 **Rower Pump**	 **Tara Pump**
Type	Suction Pump	Suction Pump	Force Pump
Stroke Length	240 mm	980 mm	300 mm
Hydrodynamics	Inertia effect exists	Inertia effect partially eliminated	Inertia effect exists
Lift	1 - 8 m	1 - 8.5 m	10 - 15 m
Flow	0.40 - 0.69 l/s 0.84 - 1.40 l/c	0.45 - 0.80 l/s 1.10 - 1.60 l/c	0.55 - 0.69 l/s 0.55 - 0.69 l/c
Operation	Ergonomically logical but tiring over longer period	Ergonomically comfortable, tiring over longer period.	Ergonomically unfavourable
Life	15 Yrs.	3 - 5 Yrs.	3 - 5 Yrs.
Sanitary Protection	Reasonable protected	Unprotected	Reasonably protected
Components need frequent change	Plunger and check valve	Cup seal, check valve and surge chamber	Cup seal and check valve

There are about 2.5 million public and private handpump tubewells in the rural area of Bangladesh operating under suction mode. Analysis of ground water level reveals that the ground water table in 35% of the area of Bangladesh will be beyond suction limit in the year 2000 as compared to 25% in 1993. This will make one hundred thousand hand pump tubewells operating under suction mode inoperational. A technological shift from No.6 to Tara pump would be required to maintain the existing water supply coverage in these areas.

There are also No.4 and No.2 manually operated pumps available where discharge requirements are low. The conventional tubewells according to their depth, arrangement and special uses are also termed as:

Deep Tubewell
Shallow Tubewell
Shallow Shrouded Tubewell (SST)
Very Shallow Shrouded Tubewell (VSST)

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 specially 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:

Slow Sand Filter (SSF)
Infiltration Gallery (IG)

These are low cost technologies but the main problems encountered include lack of maintenance by the beneficiaries.

The small scale community type Iron Removal Plants 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.

II. 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 Fig.1.

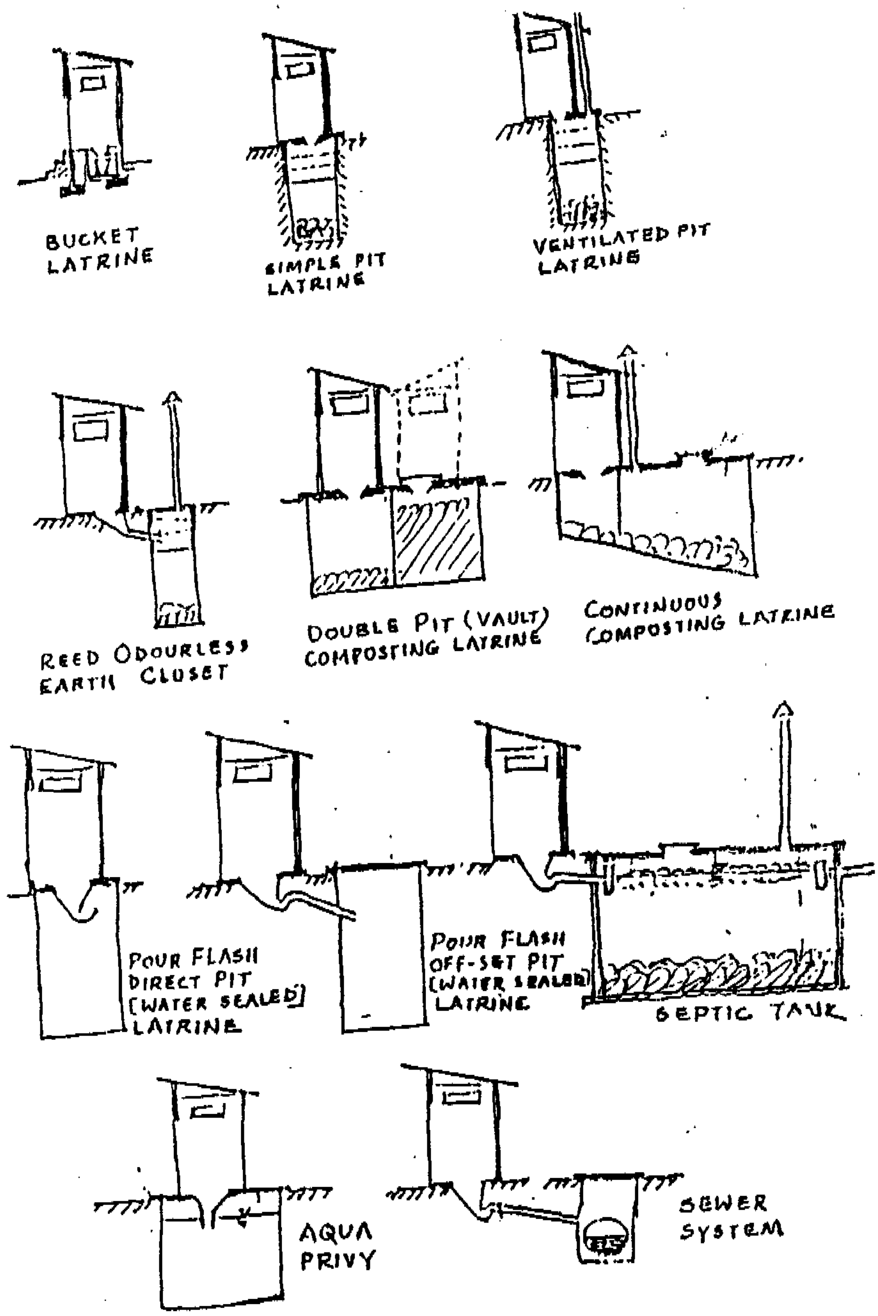


Fig.2: Alternative technological options for sanitation

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.

In Bangladesh water-sealed direct pit latrine shown in Fig.3 has been found suitable for rural areas and Water-sealed offset twin peat shown in Fig.4 has been reconmended for use in the small urban centres. Septic tank is the preferred option in large urban areas.

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

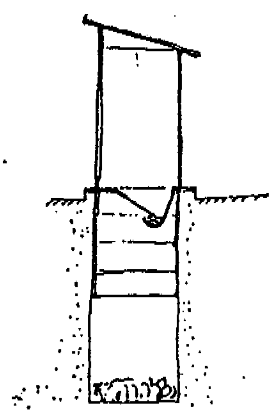


Fig.3 : Water-sealed direct pit latrine

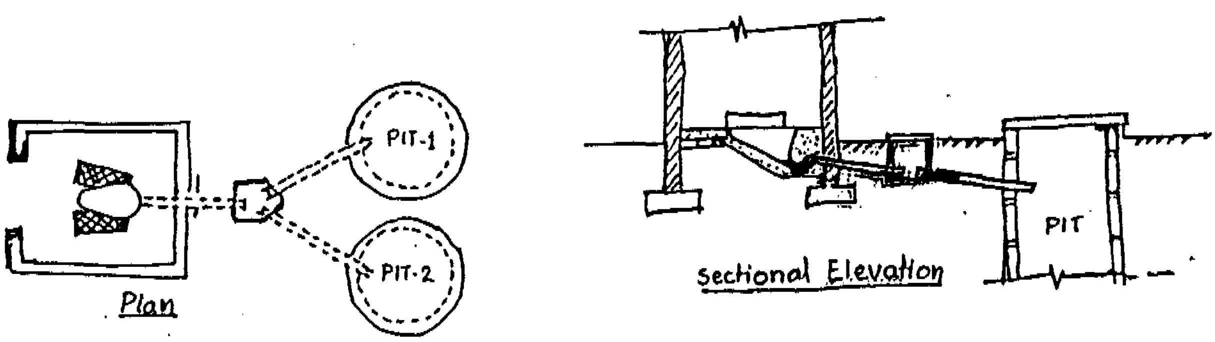


Fig.4 : Water-sealed offset twin pit latrine

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 3.

Table 3: 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 Latrines	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

APPROPRIATE TECHNONOLOGIES IN WSS

Definition

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. Some of them are :

Definition by ILO

ILO considered appropriate technology as:

- It has big capacity to expand employment.
- It firmly associates with local industry and meets a demand from the market.
- It needs small investment corresponding to the local income level.
- It can use local resources.
- It has higher productivity compared to that of traditional local technology.
- Its maintenance is easy.
- It is socially acceptable.

Definition by World Bank

An appropriate or alternative technology must:

- be effective : do whatever task it is designed to accomplish,
- be convenient : so people will be encouraged to use it,
- be acceptable to users : it should not conflict with people's beliefs and customs,
- use local materials and skills : a major way to lower costs and get people involved,
- be easily maintained : to avoid long breakdowns and allow local people to fix equipment.
- be adaptable : so it can be improved or modified to suit changing conditions,
- be affordable : so people will be encouraged to install the technology.

Definition by WHO

The appropriate technology element for water supply and sanitation is 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,
- technical efficiency.

Criteria for appropriate technology:

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

- Employ local skills.
- Employ local material resources.
- Employ local financial resources.
- Be compatible with local culture and practices.
- Satisfy local wishes and needs.

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:

- Particularly careful attention must be given to the proper balance among water supply, waste disposal, and hygiene education.
- Results in research in appropriate technology must be disseminated to all to help them consider 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 should be strongly oriented toward the development of institutions and institutional hierarchies that can reach large numbers of communities and beneficiaries effectively.
- Increased attention should be given 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 the 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 rest 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 shown in the table below:

KEY FACTORS	WATER SUPPLY	SANITATION
Technical	Availability of source of water Hydro-geological conditions Design of technology Capacity/output Installation cost Quality of materials Availability of Skill Availability of spare parts Cost of spares	Ground condition Design of technology Users number Installation cost Quality of materials Availability of Skill Location / site Source of water
Social	Ability and willingness to pay User friendliness Ease of operation Ease of repair and maintenance Operation cost Maintenance cost	Hygiene education Motivation to use Privacy Super structure Defecation habit Religious sanctions

03. Socio-economic Aspects in WSS

1. 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, as the course materials we will be limiting to some of the general 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.

2. Socio-economic profile of Bangladesh

2.1 Economic

With an area of only 144,000 square kilometers and a population of 111 million, Bangladesh is one of the most densely populated countries of the world (UNDP 1993). 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).

2.3 Demographic Trends

The population in 1991 was approximately 111 million, and is expected to grow to 131 million by the year 2000. The overall growth rate has dropped from 2.7% in 1970-1980 to 2.2% between 1980-1991. 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.

2.4 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 children are 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.

2.5 Emergencies

Bangladesh has 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.

2.6 Water supply, sanitation and health

At present, more than 90% of the rural people have access to a tube-well with 150 metres of their homes compared to only 40% in 1981. About 95% of the people drinks tubewell water. About 44% of the rural population uses 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 has 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) have indicated that physical provisions of services are not a sufficient pre-condition for improvement of health. Community involvement, hygiene education and social mobilisation are identified as indispensable for water and sanitation services to be effective.

2.7 Water Conditions

Bangladesh is a fertile 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.

2.8 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 spent 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

3. 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).

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 utilisation 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 unreflected in national income accounts as it is largely unpriced 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) recognises the importance of bringing women into the mainstream of development. Many programs administered by NGOs and community based organisations emphasise 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 realised. 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.

4. 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 reater incentive to use and maintain the facilities they purchase.

5. 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 emphasises 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,
- mobilisation of local resources,
- encouraging and supporting the growing contribution of the private sector to development efforts, and
- restructuring and reorienting administrative organisations 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.19 for this course (Project Management).

Reference

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04. Common Problems of Water Supply in Bangladesh

Economic, Demographic & Water Condition

- With an area of only 144,000 sq. km. & a population of 120 million Bangladesh is one of the most densely populated countries in the world.
- It is a fertile deltaic region criss-crossed by numerous rivers & subject to period and occasionally catastrophic flooding.
- *Hydrology is* characterized by the major international rivers, the Bramhaputra, 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 cm or more.
- *Rainfall* is abundant but seasonal. About 2/3 rd of the annual rainfall evaporates and 15% percolates *into the ground, raising the water table close to the ground level.*
- In the dry season the flood water recedes and ponds and water table falls, but generally, availability of water remain high in most part of the country.
- Irrigation water requirement during the dry season is very high. Depleting shallow wells and lowering of ground water table increase each year.

Water Supply in Rural Areas

- Significant work has been done in decade of the 1980s in the water supply sector in Bangladesh.
- During this decade population has increased from 90 M to 110 M.
- Access to safe drinking water has increased from 37 % to 96 % in rural areas. (SAFE 7777)
- In rural areas of Bangladesh, tubewell water is in great demand for drinking.
- There are about 2.5 million tubewells in the rural areas of Bangladesh.
- *Only 16% of all households use* tubewell water for their full range of water needs. Rest use it for drinking purpose only.
- Access to tubewells varies by ownership status, region of the country, condition of tubewell, and location.

Water Supply Technologies

A variety of technologies have been *developed to serve in different* hydrogeological conditions as well as to keep costs as low as possible. Some are listed below:

- **Shallow Tubewells:** Easily sunk and can lift water from about 7m below ground level. In rural areas 87% of public wells and 94% of private wells are Shallow Tubewells.
- **Deepset Handpumps:** It is employed where water needs to be lifted from eight or more meters below the surface. Traditional ones are very expensive. DS/Tara pumps are relatively less expensive and less complex.
- **Deep Tubewells:** These have casing *pipes from 150m to 300m. Usually used in saline* areas where drills have to go deep to find fresher water. These are expensive and takes much longer to install.
- **Very Shallow Shrouded Tubewells:** These are appropriate in saline areas or in isolated pockets in saline belt. These are very inexpensive and operates only where there are pockets of fresh water.
- **Pond Sand Filter:** These are also used in saline areas. This method requires use of handpumps to deliver pond water into a small sand filter unit in which the water quality is significantly improved. Simple to construct and operate. Requires user motivation and regular cleaning.
- **Subsidiary Technologies (Iron removal plants):** *High level of iron in much of the country's* groundwater lead the user to use pond water. Relatively low-cost technology to remove iron from groundwater has been developed.

Ground water quality

Salinity:

- In coastal areas and in the region north of Comilla between Bramhanbaria and Hobigonj, groundwater is generally saline down to about 250m.
- The saline belt extends upto 60 km inland.
- Consumer tolerance of salinity is high.
- Salinity is considered to be a problem if Chloride level exceeds 1000 mg/L. A value of 16,000 mg/L has been found in the ground water samples at Paikgacha (Khulna).
- There are 84 salinity prone thanas in the coastal belt with an affected population of 8 million.
- Ponds which store rain water are the principal source of water in these areas.
- Water from these ponds is used for all purposes and is susceptible to a high degree of pollution.
- Where feasible, VSSTs are installed beside the ponds. If VSSTs are not feasible PSFs are installed.
- In general, settlement pattern in the coastal areas are more scattered, making provisions for adequate water supply very difficult.

Iron:

- Although EQS has set iron standards to 1.0 mg/L, excessive presence of
- iron in groundwater and a high consumer tolerance have led to acceptance upto a level of 5 mg/L at problem areas.
- Some 170 thanas with a population of 15 million fall in the high concentration category.
- According to a national study in 1993, the regions most affected are hilly areas, in which 77% of the wells discharge water containing iron in excess of the standard.
- In regions with both low and shallow water tables, 43% of the tubewells discharge water containing iron over 5 mg/L.
- Excessive iron is associated with bad taste, discoloration of food, teeth and clothes, and stickiness in the hair.
- By comparison, pond water is relatively iron free and competes with groundwater as "physical clarity' is wrongly construed as 'purity'.
- Local drillers usually know at what depth iron content is lowest, but DPHE does not benefit from this knowledge.
- DPHE is in the process of identifying 'iron free' depths in the country.

Arsenic:

- Although Arsenic is considered to be a recent phenomenon neighboring country India has been having Arsenic problem in groundwater for a long time.
- The WHO standard for Arsenic in drinking water is set at 0.010 mg/L. Whereas, Both Bangladesh and the USEPA standards for the same is 0.050 mg/L.
- However, considering the carcinogenic nature of Arsenic the standard in both US and Bangladesh are under review.
- In Bangladesh, most of the North-western zone of Bangladesh is effected by Arsenic.
- New data are coming out with information on North-eastern zone of Bangladesh and the situation is almost as bad as the rest of the areas.
- Although believed otherwise the primary source of Arsenic is geologic formation.
- The current practice of removal of Arsenic by reverse osmosis or ion exchange is extremely expensive and are applicable for large quantities. Thus, cost-effect technologies applicable for small sources in rural areas need to be developed.

5. REMEDIAL MEASURES : SALINITY

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 (see Figure 1) of the salt solution against a semipermeable membrance, thereby forcing pure water through the membrance and leaving salts behind.

ED/EDR systems are often considered as an alternative to RO for brackish water conversion. In these processes selective caution 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 diagram of some of the common design of solar stills are shown in Figure 2 to 6. Some data of several major solar distillation plants are shown in Table 1.

In this study, 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 (figures 7 & 8). 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 . Some Solar Distillation Plants*

Country	Location	Design	Year	m^2	Feed	Cover	Remarks
Australia	Muresk I		1963	372	Brackish	Glass	Rebuilt
	Muresk II		1966	372	Brackish	Glass	Operating
	Coober Pedy	3.1e	1966	3160	Brackish	Glass	Operating
	Caiguna		1966	372	Brackish	Glass	Operating
	Hamelin Pool		1966	557	Brackish	Glass	Operating
	Griffith		1967	413	Brackish	Glass	Operating
Cape Verde Isl	Santa Maria	3.1c	1965	743	Seawater	Plastic	
	Santa Maria		1968				Abandoned
Chile	Las Salinas	3.1e	1872	4460	Brackish	Glass	Abandoned
	Quillagua		1968	100	Seawater	Glass	Operating
Greece	Symi I	3.1d	1964	2686	Seawater	Plastic	Rebuilt
	Symi II	3.1d	1968	2600	Seawater	Str. Plas.	Dismantled
	Aegina I	3.1c	1965	1490	Seawater	Plastic	Rebuilt
	Aegina II	3.1d	1968	1486	Seawater	Str. Plas.	Abandoned
	Salamis	3.1c	1965	388	Seawater	Plastic	Abandoned
	Patmos		1967	8600	Seawater	Glass	Operating
	Kimolos		1968	2508	Seawater	Glass	Operating
	Nisyros	3.1f	1969	2005	Seawater	Glass	Operating
	Fiskardo		1971	2200	Seawater	Glass	Operating
	Kionion		1971	2400	Seawater	Glass	Operating
	Megisti		1973	2528	Seawater	Glass	Operating
India	Bhavnagar	3.1e	1965	377	Seawater	Glass	Operating
	Awania	3.1e	1978	1866	Brackish	Glass	Operating
Mexico	Natividad Isl	3.1d	1969	95	Seawater	Glass	Operating
Pakistan	Gwadar I	3.1f	1969	306	Seawater	Glass	Operating
	Gwadar II	3.1g	1972	9072	Seawater	Glass	Operating
Spain	Las Marinas	3.1a	1966	868	Seawater	Glass	Operating
Tunisia	Chakmou	3.1d	1967	440	Brackish	Glass	Operating
	Mahdia		1968	1300	Brackish	Glass	Operating
U.S.A.	Daytona Beach	3.1a	1959	228	Seawater	Glass	Rebuilt
	Daytona Beach		1961	246	Seawater	Glass	Dismantled
	Daytona Beach	3.1b	1961	216	Seawater	Plastic	Dismantled
	Daytona Beach		1963	148	Seawater	Plastic	Dismantled
USSR	Bakharden	3.1e	1969	600	Brackish	Glass	Operating
West Indies	Potit St.Vincent	3.1b	1967	1710	Seawater	Plastic	Operating
	Haiti	3.1d	1969	223	Seawater	Glass	Operating
India	Bitra	3.1c	1980	-	Brackish	Glass	Operating (capacity 2000 l/day)
	Kulmis		1980	-	Brackish	Glass	Operating (capacity 3000 l/day)
China	Wuzhi	3.1c	1976	385	Seawater	Glass	Operating
	Zhungjian		1979	50	Seawater	Glass	Operating

*~~The designs correspond to Fig. 3.1~~. After Delyannis and Delyannis, (1973).

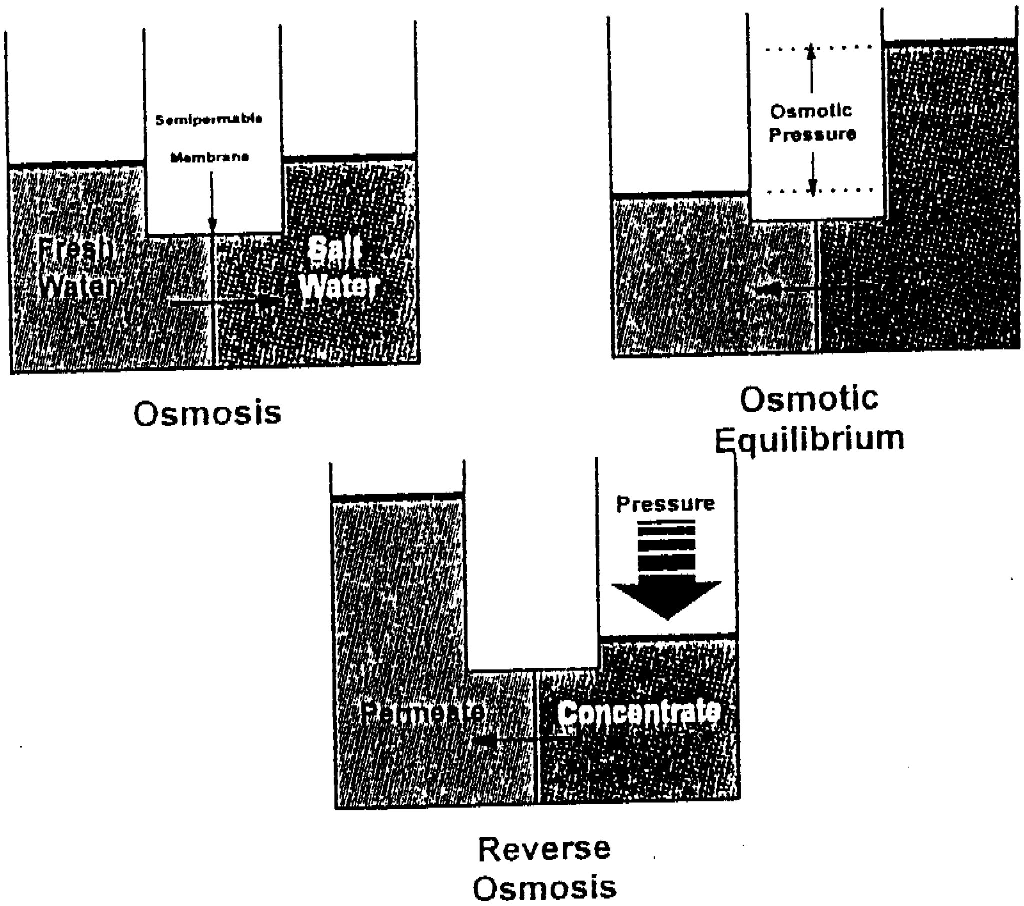
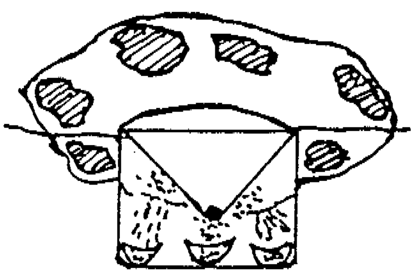


Figure 1 Principles of Osmosis



RYFO Pit·Still

Fig- 2

Ryan Foundation Still (table model)

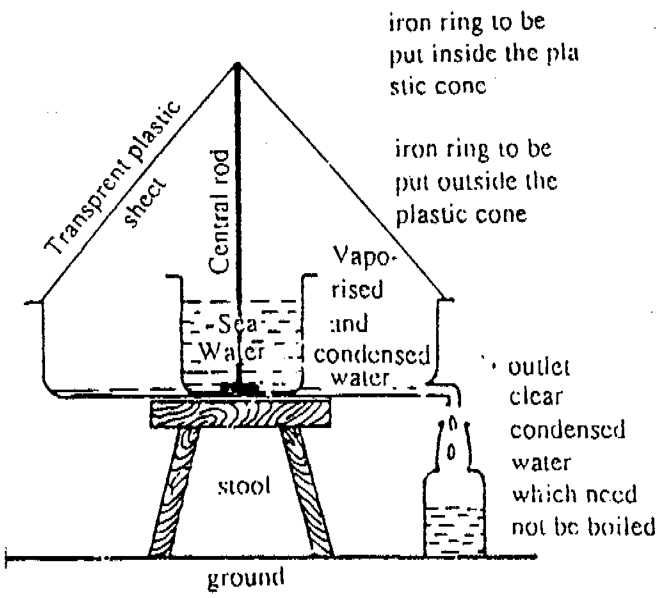


Fig.-3

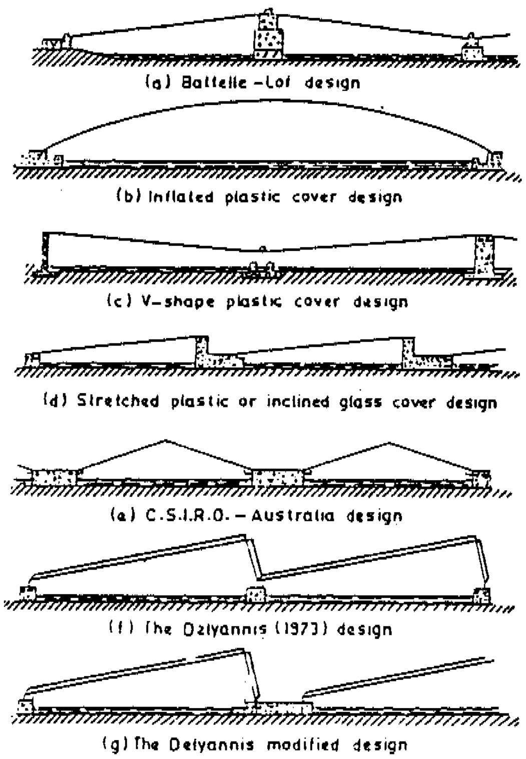


Fig. (After, Delyannis and Delyannis, 1973.)

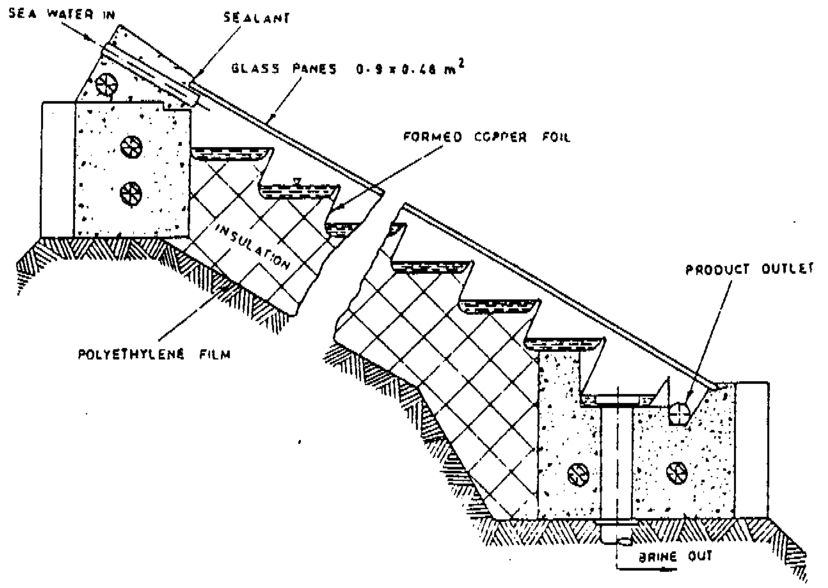


Fig. 3. Cross section of tilted tray solar still. (After, Cleimac and Howe, 1966.)

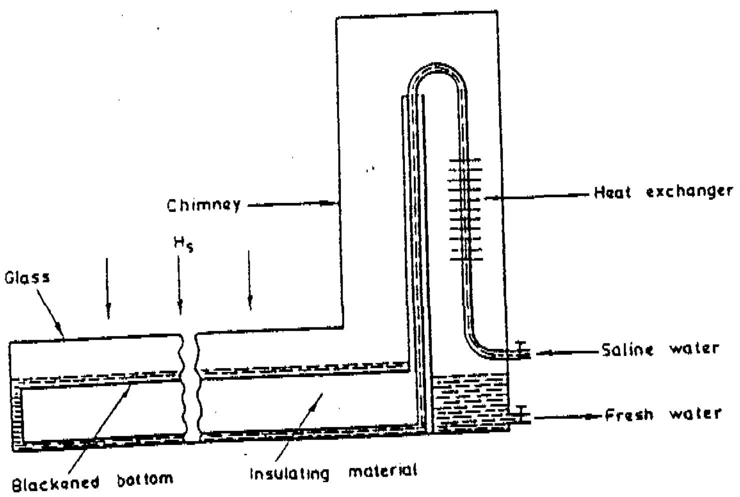


Fig. The chimney-type solar still. (After Bartali et al., 1976.)

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.

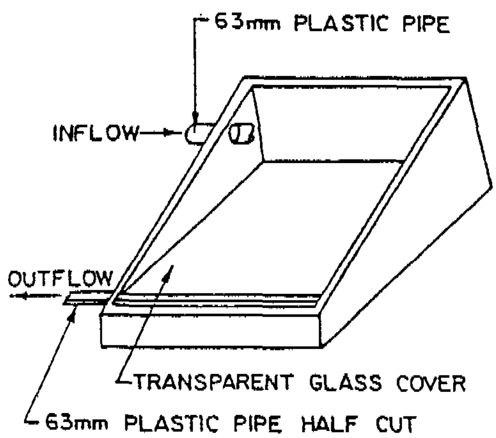


Figure 7: Single basin solar still with inclined glass cover design

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			

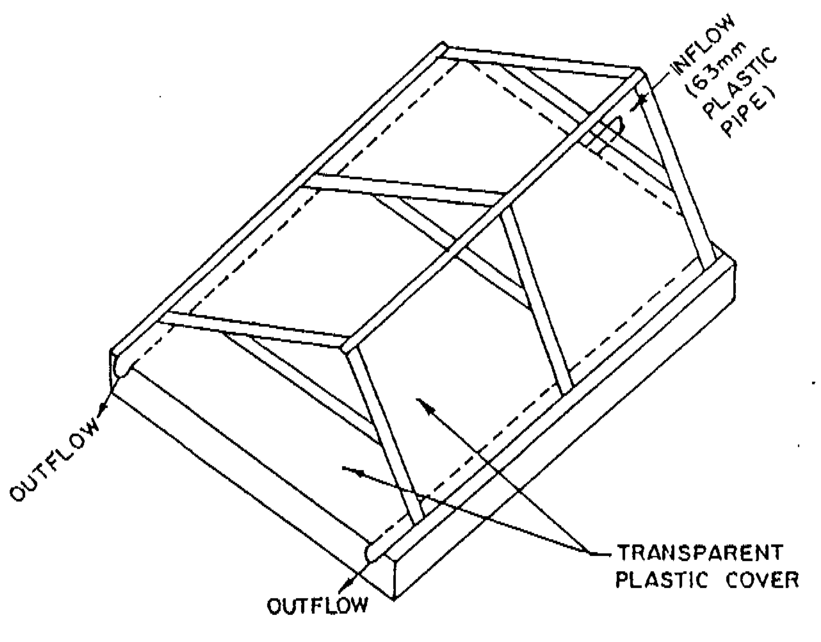


Figure-8. Single basin solar still with stretched double sloped plastic cover design

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. 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.

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

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 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.

06. Remedial Measures : Iron

I. Iron Problem in Ground Water 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 mainly dependent on ground water 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. Soap also don't response well if iron is present in water. Iron problem is acute in various places in ground water of Bangladesh, but there has been no thorough investigation on the iron content in ground water of Bangladesh. The present investigation was therefore carried out to study the iron content in ground water of Bangladesh, Suitability of ground water for drinking.

Analysis of the iron content in ground water 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 (Ground water 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 Shariatpur, Habigang, & Chandpur Districts. Location of the collected samples have been shown in figure-1.

Ground water 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 144000 Sq. km. area of 64 administrative districts were analysed for drinking. Inadequate information are 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. From figure 1, it is observed that there are iron problem almost all areas of Bangladesh. Ground water 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 ground water 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 is 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.

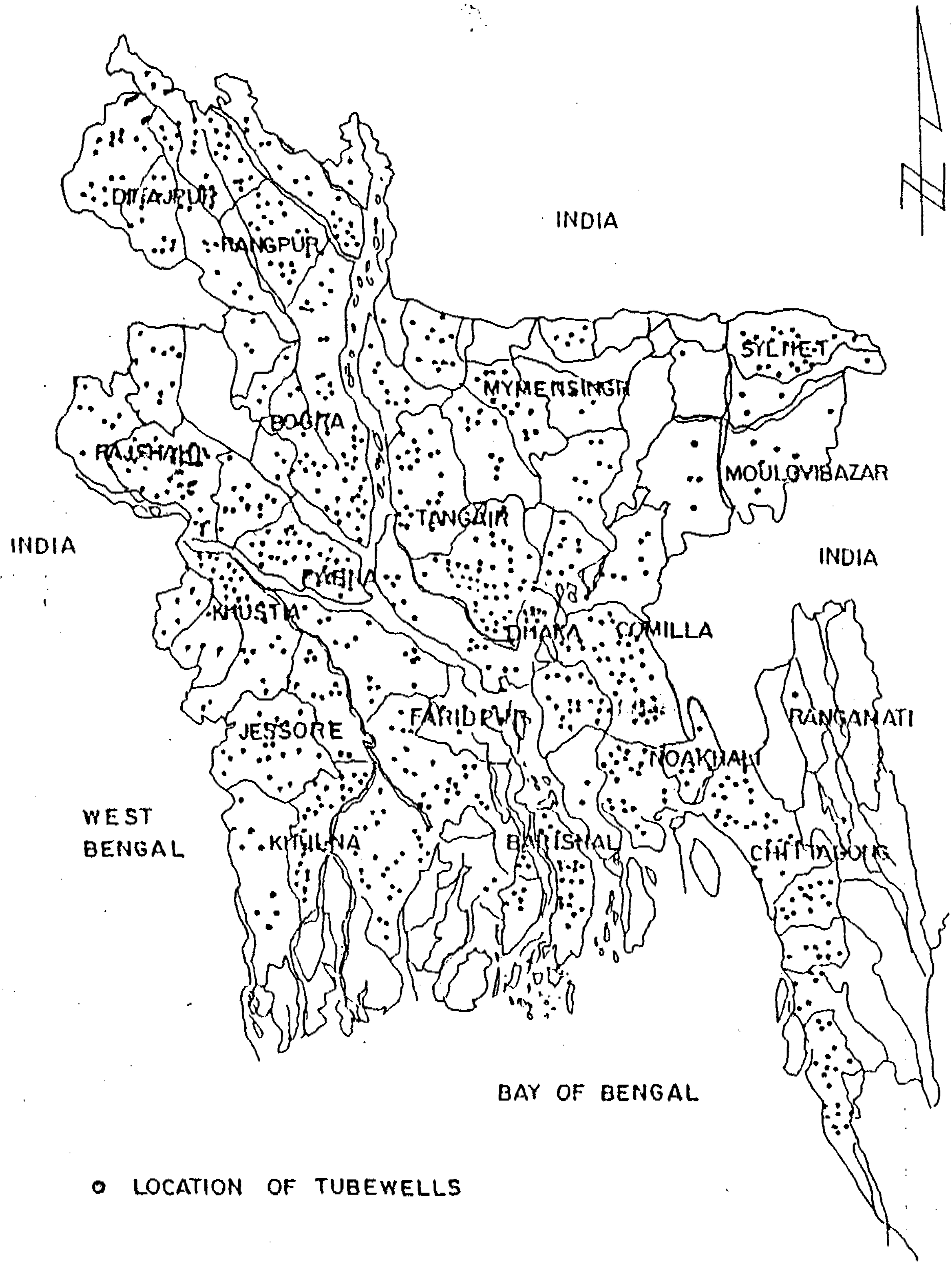


Figure 1 Location of the observed deep tubewells of Bangladesh.

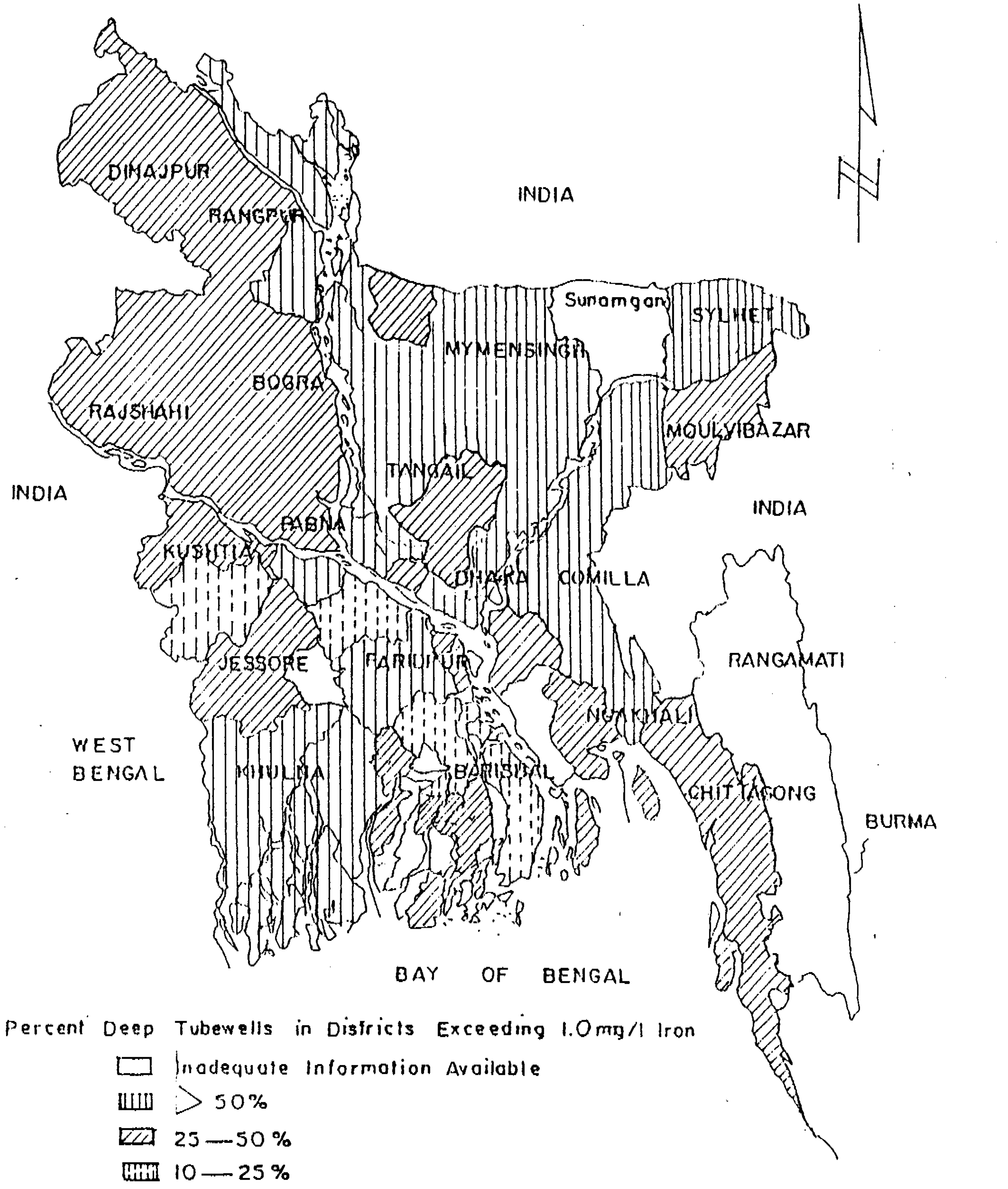


Figure 2 Iron content in deep tubewell[3] water of Bangladesh (Iron > 1.0mg/l).

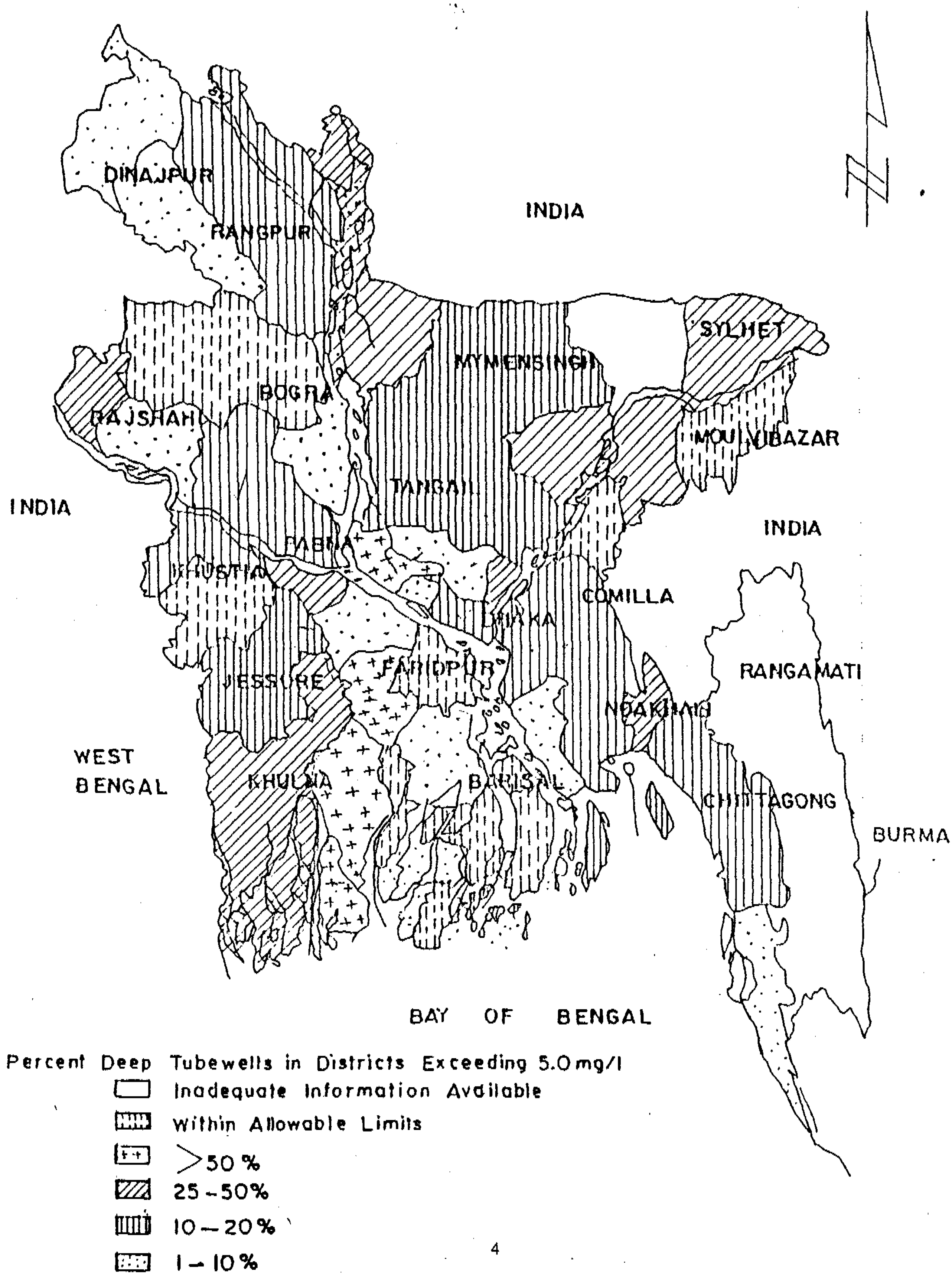


Figure 3 Iron content in deep tubewells water of Bangladesh (Iron > 5.0 mg/l)

II. Iron Removal

Sources of Iron:
Iron exist 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*:**
- The rate of ferrous iron oxidation is of the first order with respect to ferrous iron concentration and the partial pressure of oxygen.
- The 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.
- The 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.

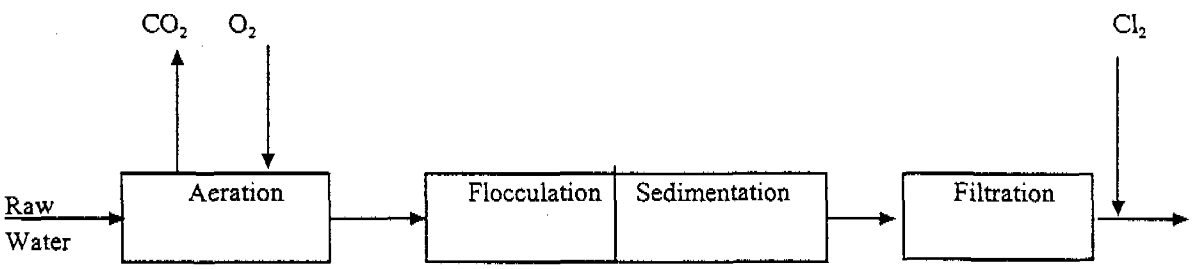
Iron is oxidised, **insoluble**, visible in **ferric form (Fe^{+3})** under the following conditions:
-- In presence of DO, at low CO_2 concentration, at high pH, high alkalinity and in absence of organic materials.

(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.

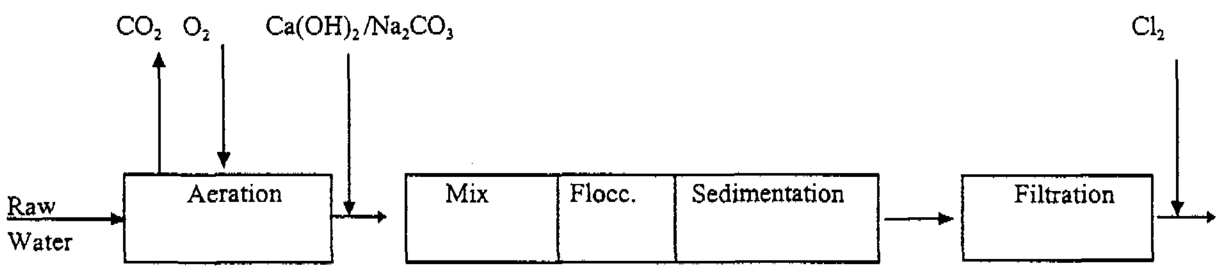
$$4Fe(HCO_3)_2 + O_2 + H_2O \rightarrow 4\ Fe(OH)_{3(s)} + 9CO_2$$

Removal Under Different Environmental Conditions:

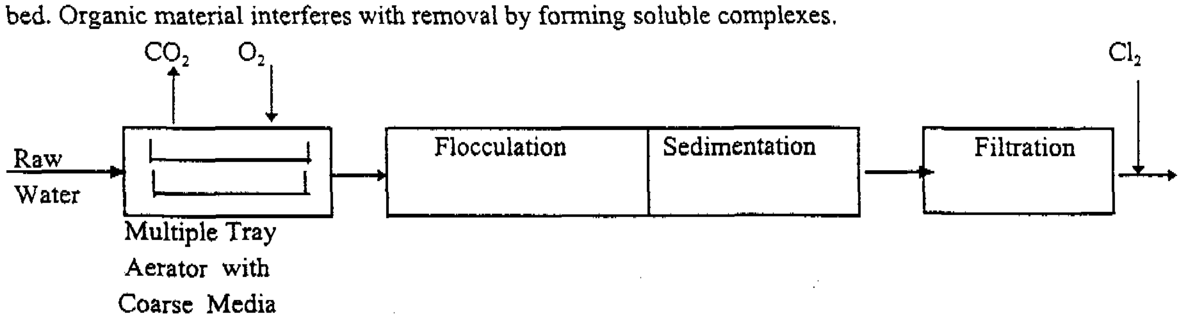
1. Iron alone in ground waters which **contains little or no organic matter with reasonable alkalinity** when aerated CO_2 and H_2S are released raising the pH and oxidised to insoluble iron.



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.

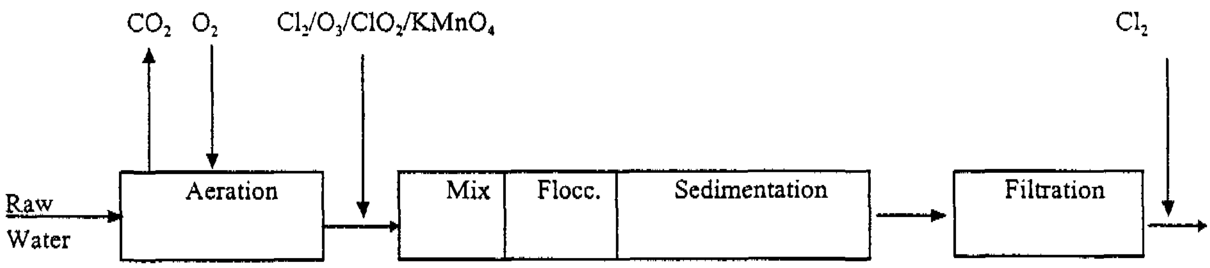


3. If the water **contains organic matter** such as humic or fulvic acid and if **the alkalinity is low,** aeration is sufficiently rapid only if it is catalysed by accumulation of oxidation products (Fe_2O_3) on a porous bed (aeration tower containing trays with coarse media). Iron is removed from solution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

07. Arsenic & Dearsination of Water

1 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.

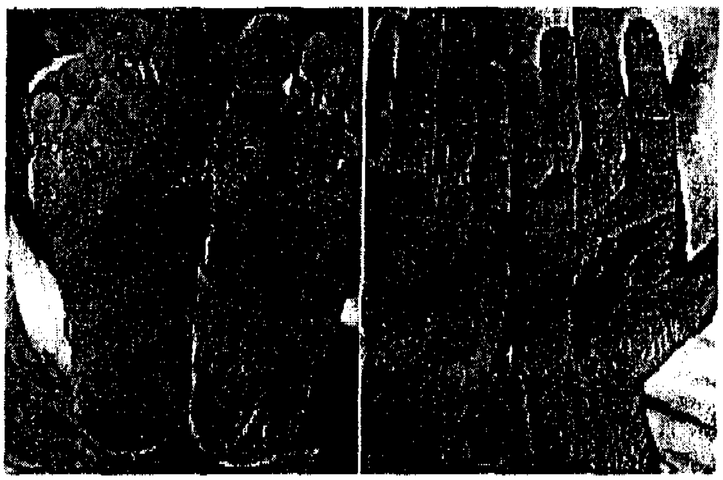


Figure 1 Typical most visible symptoms of Arsenosis or "Blackfeet Disease"

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.

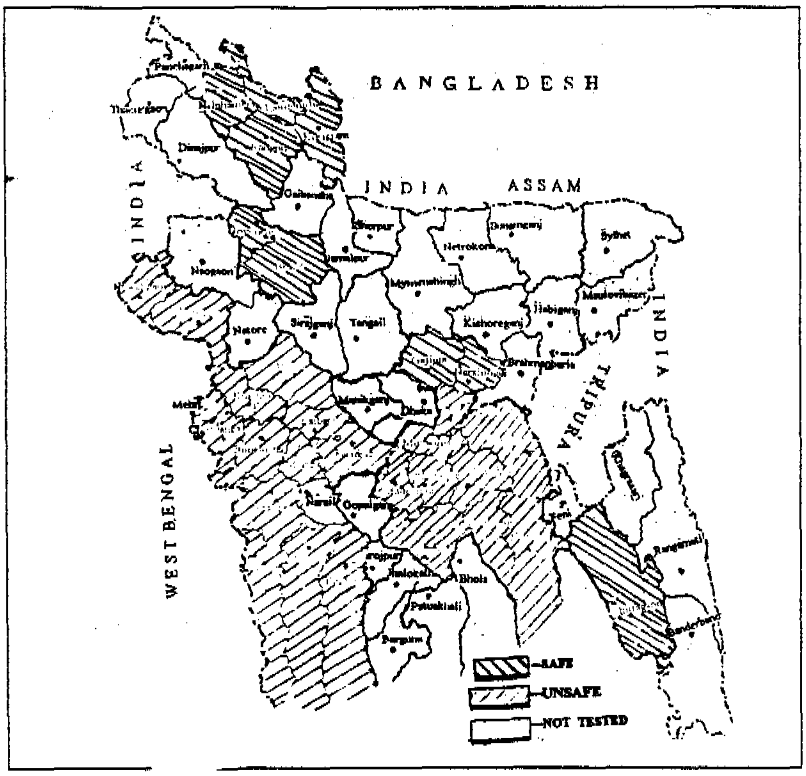


Figure 2 Map of Bangladesh indicating areas where arsenic has been detected at high level in ground water. From Dhaka Community Hospital.

The precise dimension of the arsenic problems are 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.

2 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 As(III)
DMAs(III)	$(CH_3)_2As(III)O^{1-}$	can methylate 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 As(V)
DMAs(V)	$(CH_3)_2As(V)O_2^{1-}$	reduction of As(V) to	
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).

3 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).

4 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:

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

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.
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.

5 Arsenic Removal

5.1 Overview

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.

5.2 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-} + $3H^+$ eq. 6

As oxidation with permanganate:

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

Alum dissolution:

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

Aluminium precipitation (Acidic):

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

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

$H_2AsO_4^-$ $Al(OH)_3$ = Al-As complex + ? eq. 10

pH adjustment:

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

***Figure 3**. Village level Alum/Iron dearsination plant as developed by the All India Institute of Hygiene and Public Health.*

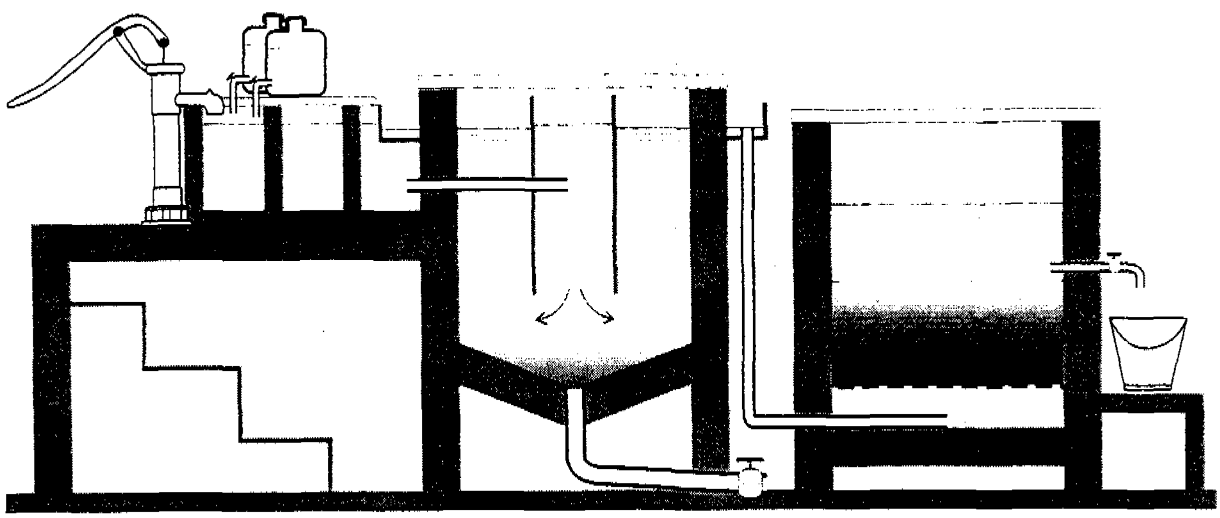


Figure 4. Diagram of the plant illustrated in figure 3. Based on addition of sodium hypochlorite and alum solutions, mixing flocculation, sedimentation and up flow filtration,

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.

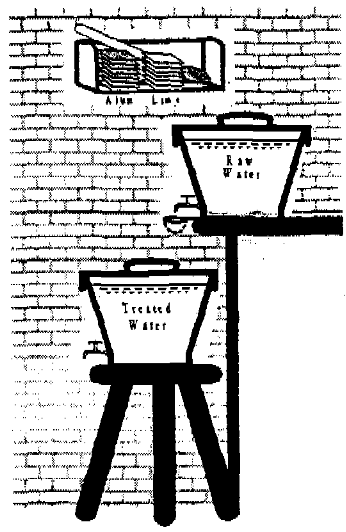


Figure 5 Arrangement of coagulation of water at household level as developed for defluoridation. For dearsination chlorinated lime should be used in order to oxidise As(III) to AS(V). From Dahi et al. (1996)

5.3 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

5.4 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.

5.5 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).

5.6 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):

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

Regeneration:

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

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.

5.7 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.

5.8 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.

6 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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08. 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.

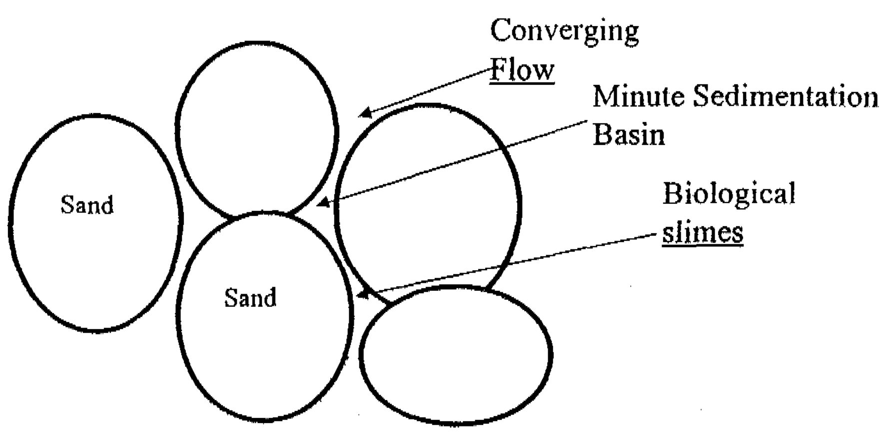
Water Quality Improvement:
(a) Natural Process- Most pathogens are accustomed to live in the temperatures and conditions found in the bodies of humans and animals. They do not survive well outside the body. Storing water for extended periods in open tanks or reservoir prior to treatment can accomplish 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.

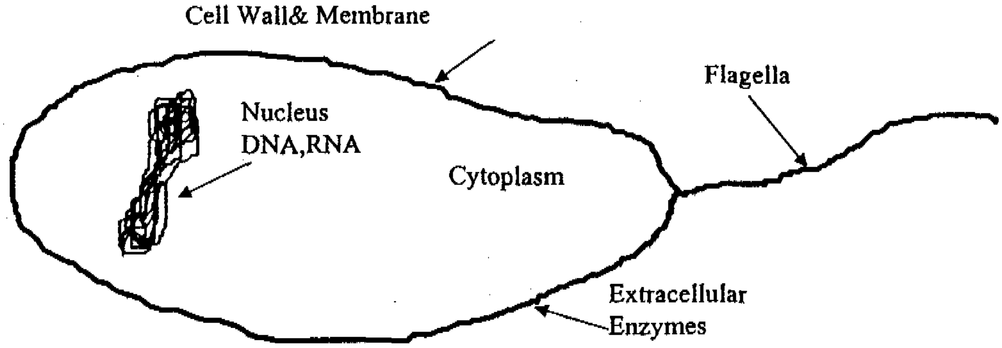
In Rapid sand Filter coagulated floc [$Al(OH)_3$] form a chemical layer on the filter media which is also gelatinous in nature. Bacteria are removed due to adhesion/adsorption on this layer.

(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,

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

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- is the most common means of disinfecting water and usually performed as the final treatment process. The mechanisms 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 viruses inactivation are reported as little as 2 minutes. The disadvantage is that no residual remains in this process of disinfection.

Potassium permanganate- 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- such as silver (0.05 mg/l), copper and mercury exhibit disinfecting action.

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), $C_xH_yO_z$
Inorganic carbon (Autotrophic), CO_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

09. Sanitation Practices in Bangladesh

Existing latrines

Latrine- coverage and type

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 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. A home made latrine comprises of a pit lined with bamboo or an unlined pit covered with a platform of bamboo/wood, and clay. The platform has a defecation hole with a cover. The single pit latrine comprises of a squatting slab with a water seal and a pit. The slab sits on the pit which is usually lined with five concrete rings, the slab is either made of ferro-cement or reinforced concrete. When the pit fill up, a new pit has to be dug and superstructure relocated, or pit has to be emptied. It is simple and sanitary, and used in urban and rural areas. The water seal and the pan are of ferro cement. Now-a-day, plastic pans are available. This pan is cheap as well as durable. The twin pit latrine is the same as a single pit except that it has two offset pits used alternately. When the first pit fills, user switches to the second pit, leaving the first pit contents for 18 to 24 months to complete biological degradation before removal of harmless contents. This type is mainly limited to urban and peri-urban areas.

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 has 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 are 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 neighbours latrine, if available.

Difference in defecation practice

There is difference in defecation practices between males, females and children. There are some significant gender variation 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	5 (2.6)	4 (2.6)	3 (1.5)
Neighbour's Latrine	28 (14.4)	53 (27.2)	5 (2.6)
Roadside Drain	3 (1.5)	1 (0.5)	12 (6.1)
Open Field	99 (46.2)	58 (29.7)	147 (75.4)
River, Water Bodies	24 (12.3)	25 (12.8)	13 (8.7)
Jungle	25 (12.8)	54 (27.7)	13 (8.7)
Public toilet	20 (10.2)	0 (0)	2 (1.0)
Total :	195 (100.0)	195 (100.0)	195 (100.0)

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%). The table below further illustrates this fact.

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

Ways	Frequency (f)	%
Washing in Water body	247	34.6
Washing under Tubewell	23	3.2
Throwing in the Jungle	373	52.1
Throwing in the Yard	72	10.1
Total :	715	100.00

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.

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

Problems in Sanitation

The major problems in pit latrines are:

The action taken by individual households when the pit fills up. Sometimes, the shallow pits fill up too soon for households to get into the habit of using latrines, in addition to the inconvenience of frequent cleaning or change of pits.

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.

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.

Most of the time, Y junction of the double pit latrines does not work properly.

Water seal, the essential part of the sanitary latrine often breaks down. Sometimes, other garbage thrown into the pan blocks the latrine.

10. Aquacultural Utilisation of Waste

- Agri-Aquacultural Definitions
- Aquatic Problems of Low Lands
- Advantages of Aquaculture
- Aquacultural Systems
- Socio-cultural Constraints
- Typical yields
- Typical Design

Definitions of the different Agri-Aquacultural Systems

Agriculture:
The art of cultivating soil, producing crops, and raising livestock, and in varying degrees the preparation of these products for marketing and man's use.

Horticulture:
The art of growing fruits, vegetables, flowers or ornamental plants.

Hydroponics:
The growing of plants in nutritient solutions with or without an inert medium to provide mechanical support.

Aquaculture:
The art of cultivating water bodies, producing fish and other aquatic animals and in varying degrees the preparation of these products for marketing and man's use.

Integrated Farming:
Cultivating soil where multiple crops and livestock, aquaculture and eventually biogas, are interacting, in order to optimise the production, without excessive use of fertilisers and pesticides.

Intensive Farming:
Highly concentrated agriculture, using irrigation, fertilisers, pesticides, sophisticated machinery.

Burn-beating:
Cultivating of bush or forest areas, after burning of original vegetation, until the soil worn-out after few years.

Ecological Farming:
Farming without the use of artificial fertilisers and pesticides.

Sustainable Farming:
Farming where natural environmental resources are conserved in order to ensure the attainment and continued satisfaction of human needs for present and future generations.

Dike Pond System:
Crops, livestock and fish farming, where waste from land is reused in the fish pond and visa versa in order to optimise and diverse the production, eliminate waste and stabilise a low land area at minimum of costs.

Permaculture:
The conscious design and maintenance of agriculturally productive ecosystems which have the integration of people and landscape and the diversity, the stability, resilience of natural

Aquatic Problems of Low Lands

- Floods
- Erosion
- Poor Infrastructure (Roads)
- Rain Water, Waste & Wastewater Disposal
- Environmental Pollution
- Low Productivity

Advantages of Aquaculture at Low Land

- Dispose the waste
- Utilise the fertiliser effect
- Utilise the solar energy at maximum
- Promote health through better nutrition
- Get economically attractive product
- Flood control
- Land management

Aquacultural-Waste Systems

- Un-intended recycling
- Night soil fed fish ponds
- Fish Cage in excreta loaded water
- Sewage fish farming
- Aquatic plant farming
- Integrated farming (DPS)

Table 1. Fish production and yield coditions obtained with and without use of wastewater. Data from Edwards1992

	No Wastewater Chemical Fertilisers		*Wastewater No chemical fertilisers*			*Caw manure Chem. fertil.*
Pond Area	1.4	2.2	0.7	1.0	1.0	2.0
Fish Yield T/ha/8m	4,7	4.7	8.0	8.6	8.1	7.5
Yield factor, Fish/Feed	0.56	0.63	1.1	1.0	1.25	0.9

Socio-cultural Constraints

The Conventional Thinking and Taboos:

- Excreta is anaesthetic
- Excreta is hazardous to health
- Excreta is untouchable for the touchable
- Water sources has to be protected
- Excreta is valuable as energy source
- Excreta is valuable for agricultural use

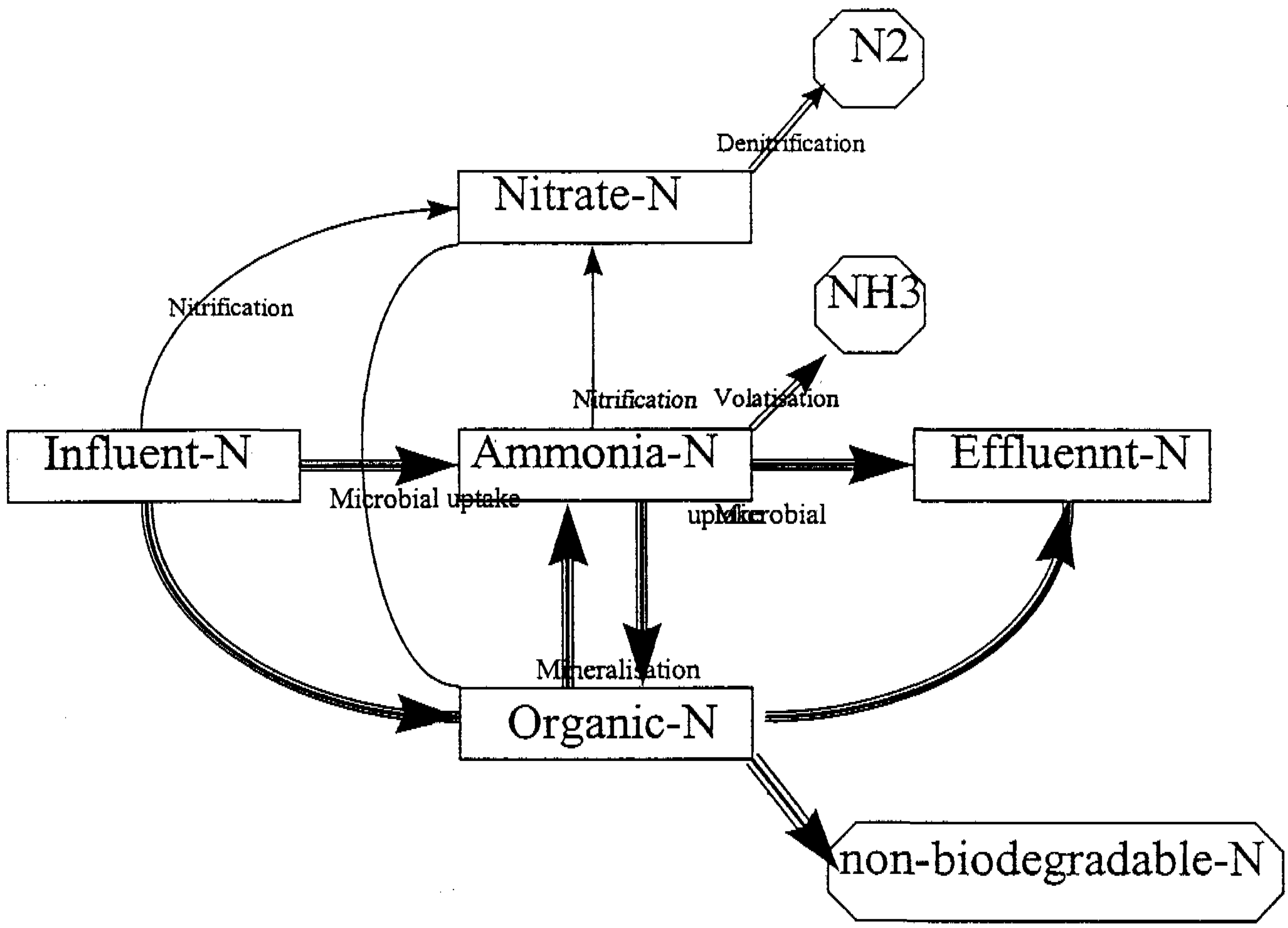
Typical Yields

Product	Tons/ha
Fish	8
Mulberry	26
Sugarcane	75
Banana	11
Elephant Grass	8
Vegetables	34

Typical Design

One Family: 2-3 adults + 2 Children

- Total Dike+Pond Area, m^2: 5000 m^2
- Area Ratio, Pond/Dike: 2
- Pond Depth, m: 2.5 - 3
- Pond Area, 2/3 of Total, m^2: 3300
- Fish input, trophic levels: 6-7
- Pigs equivalent Population, Heads: 10-14



Nitrogen Transformation and Losses in WSP

14. BIO GAS AS A WASTE TREATMENT OPTION

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 in the form of slurry. Biogas is a mixture of methane (usually 55% to 70%) and carbondioxide (usually 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. This paper is aimed to highlight the potential of biogas technology in the Bangladesh context, and to identify the problems and research needs in this field.

Biogas technology

The biogas production technology has been available since the early 1990'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 (Prasad 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 governments of some 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 per cent of the total population of Bangladesh. The daily fertilizer contribution would be equivalent to 2,785 tonnes 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 (X10'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 waste wastes	2.25	0.22	0.06	0.30
Rural Solid Waste				0.39
Total volume	9.25	0.07	0.07	15.75

Mechanism of Biogas Fermentation

Microbes involved in biogas fermentation are generally called biogas microbes. These are three stages in the conversion of organic substances into methane by biogas microbes as follows:

- **Fermentive 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 carbondioxide.
- **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, carbondioxide, etc.
- **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, carbondioxide, formic acid, etc.) into methane and carbon dioxide.

The better the different fermentation processes merge together, the shorter the digestion process. According to the temperature of the digester content, the following types of digestion are distinguished:

- psychrophilic digestion (10°C - 20°C)
- mesophilic digestion (20°C - 35°C
- thermophilic digestion (50°C - 60°C).

The retention time for psychrophilic, mesophilic and thermophilic digestion may be more than 100 days, 20 days and 8 days respectively. Again, the thermophilic digestion is not a general option for a simple plant.

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, had shown a maximum output of biogas at pH 7.5 - 8.0. The test results are given in the following table 2:

Table 2.

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 temperature. The length of retention time of material is also determined by the fermenting temperature. 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°C or more.

- **Carbon-Nitrogen Ratio (C/N)** : 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.

- **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 than 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.

- **Intensity of pressure** : The efficiency of the fermentation process is 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 in this section. These are :

1. Dry - Fermentation
2. Fixed Dome (Chinese)
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.

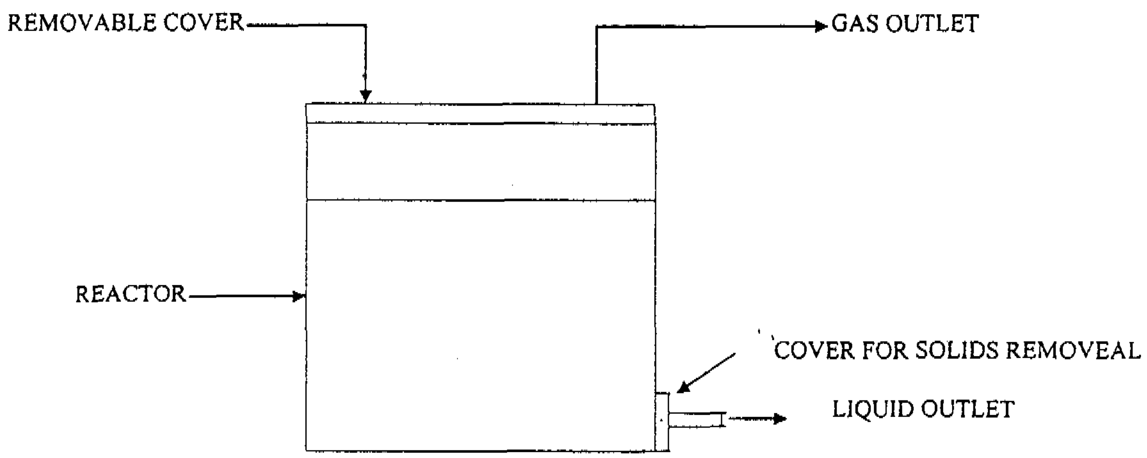


Figure-1 : Batch Digester

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 man hole plug at the top of the digester to facilitate entrance for cleaning, and the gas outlet pipe exists from the man hole cover (Figure -2).

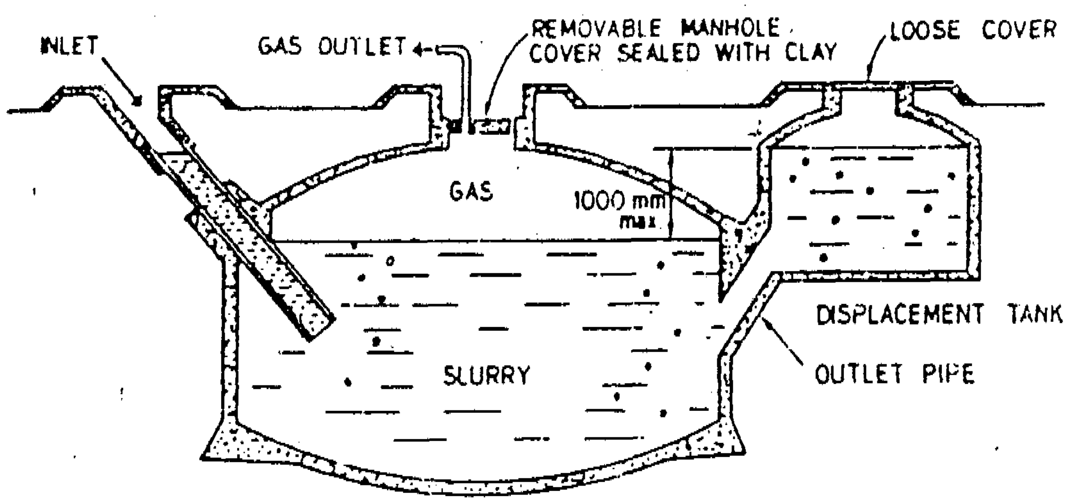


Figure 2 - Fixed dome (Chinese) digester

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 KVIC design consists of a cylindrical reactor with an H/D ratio of between 2.5 and 4.1 (Figure-3). 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 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.

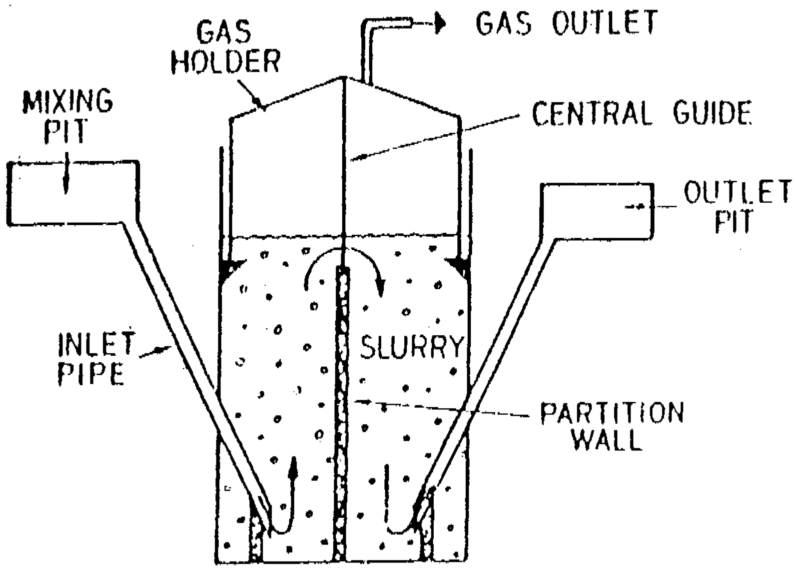


Figure 3 - Floating cover (Indian) digester

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. The feed pipe is arranged such that a maximum water pressure of approximately 40 cm 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).

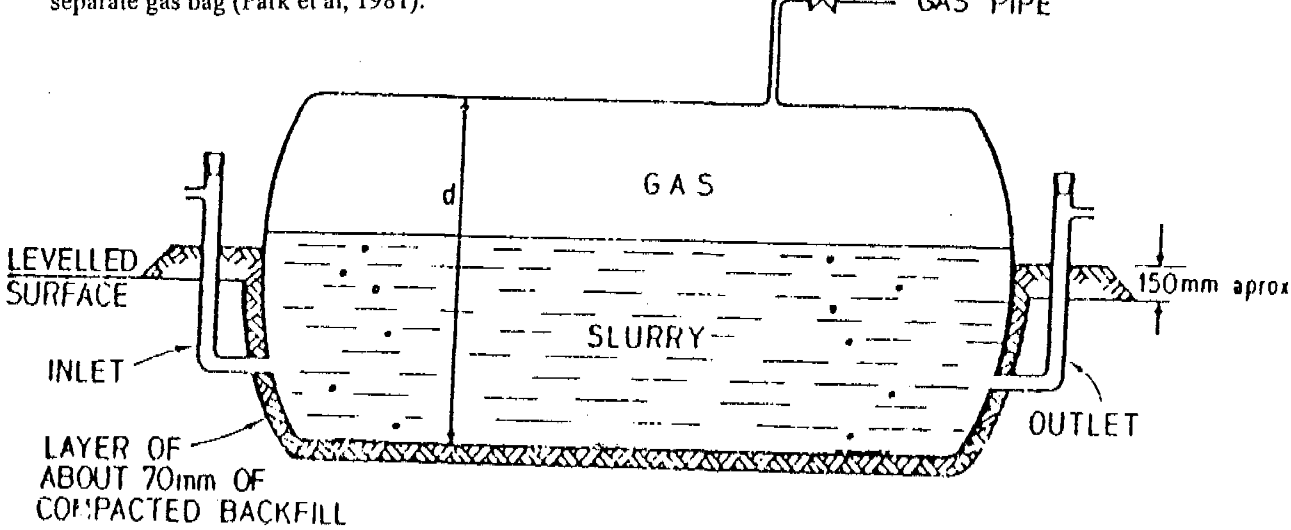


Figure 4 - Bag (Taiwan) digester

Plug Flow:

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). 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.

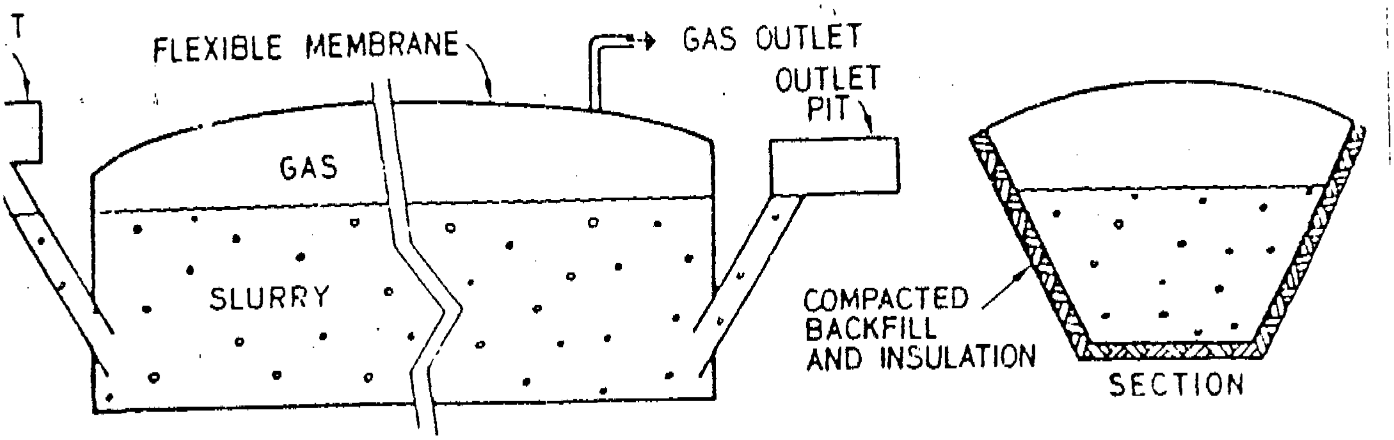


Figure 5 - Plug flow digester

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 bottom of the tank (Figure 6). The liquid flow is alternatively 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 due to the design most of the biomass is retained in the reactor.

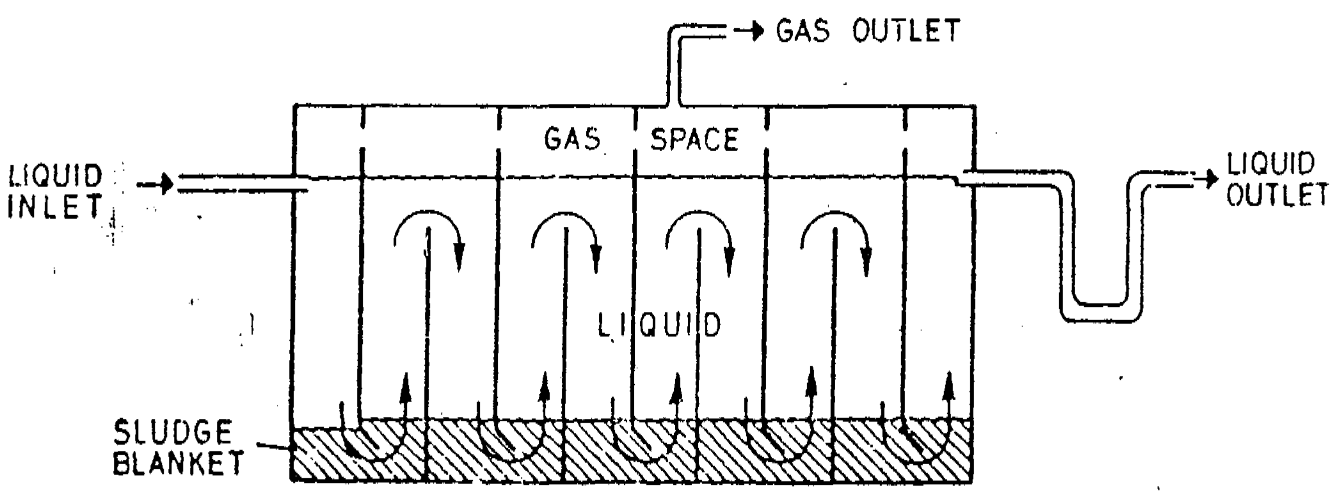


Figure 6 - Anaerobic Baffled Reactor (ABR)

Biogas Fertilizer

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 while 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 fertilizers are higher than those of the compost and the manure in open dump/farm yards (Table-3, APH, 1989).

Table - 3 : 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
Protein 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 major 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 used 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-4 indicates that only 15% of Dhaka city's population is served by a conventional waterborne sewerage system. All other cities mainly have septic tank systems, with some coverage by pour flush pit latrines or bucket latrines.

Table - 4: Urban sanitation coverage in 1990 (in % population coverage), (Source :Task Force,'90)

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. During the digestion process, a significant reduction of BOD occurs. The percentage reduction of BOD in the digestion process is shown in Table-5, from which it is evident that about 70% of BOD, removal occurs within five days of the retention period. Thus, the digestion process improves the quality of digester effluent and minimises water pollution.

Table 2 : 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°C, and from 2 to 3 logs of bacteria removal can be achieved at a temperature of 35°C at twenty days' retention time. Therefore, it can be concluded that a great reduction of 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°C to 70°C 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°C, 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

Experience 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 serves 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 costs about Tk. 1,02,000 (US$ 2,550). The use of this technology minimises indoor air pollution caused by the burning 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.

Problems Associated with Biogas Technology

At present different implementing authorities (Table-6) 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. It is evident from an internal report of the Local Government Engineering Department in 1992 (Table-6) that about 75 per cent 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.

Table-6 : biogas plants constructed by different organisations in Bangladesh

	Number of biogas digester				*Present condition*
Organisation	*Fixed dome*	*Floating dome*	*Bag*	*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

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

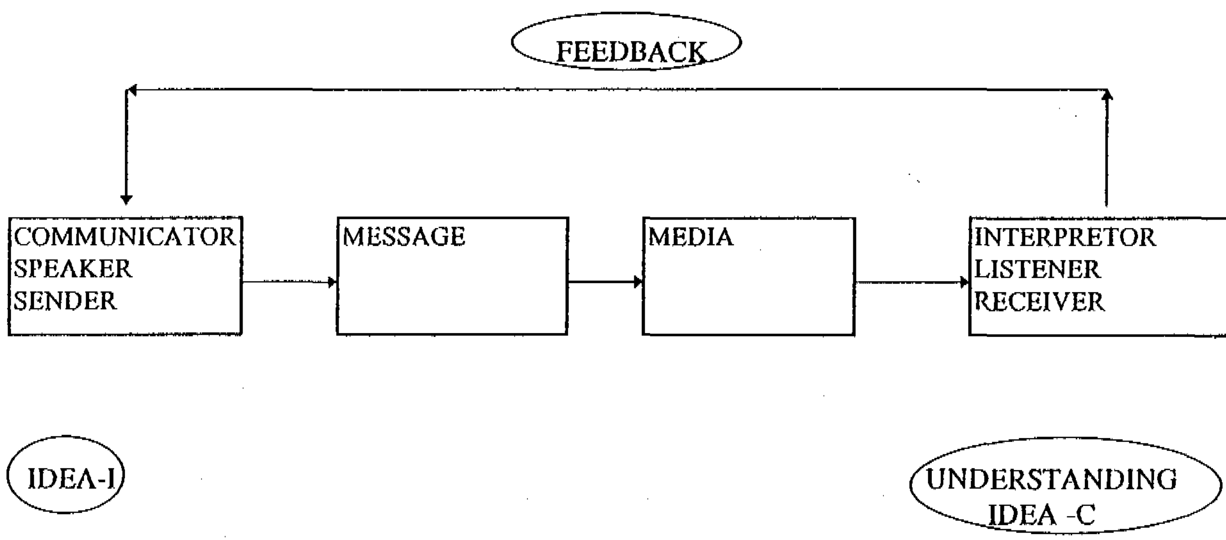
The relevance of biogas technology in Bangladesh lies in the fact that it makes the best possible utilisation of various organic wastes as a renewable and perpetual source of clean energy in the rural and semi-urban areas and provides environmental sanitation. Thus the quality of life in rural and semi-urban 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.

12. COMMUNICATION

Communication is the process of transmitting and receiving information. We can say, it is the process of conveying ideas, knowledge or message from one person or a group of person to other or many persons or vice versa. In human society, communication plays in important part in daily life. We have the advantage of language, spoken words, songs, visual aids, written scripts and so on. Besides, we can also express our feelings by facial expression and gesture of the face, hands etc. It is by communication that an individual wants himself to be understood by others. A deaf mute can communicate by signs and gestures. A normal person can communicate in many ways. It is only a literate person who can take advantage of written communication. Therefore, there are many ways of communicating and interacting. It includes both verbal and non-verbal.

Communication process:

Communication has been defined as the transfer of an idea from one person to another. The idea in the mind of the transmitter, speaker or communicator is referred to as Idea I. The idea, mind of receiver, listener, or interpreter is classified as Idea C. The basic problem of the speaker to get the idea into the mind of the listener in such a way that Idea C will correspond exactly to Idea I that is, the message will have the same meaning to both. When these two ideas correspond, there is an agreement in the communication process. If they do not correspond, there is distortion. This can be illustrated in a cyclic form as follows:



From the diagram we can see that communication is too complex to be viewed simply as a process of sending and receiving message. The speaker has a meaning, he has to choose a medium, and then he has to frame a message. The sender has an idea or an intention which he has to encode into a message. One has to choose the medium. Encoding immediately presents a block or a barrier of Idea I to be equal to Idea C.

Barriers of Communication

Communication is the process of imparting, transmitting or sharing information of one kind or another. But this process is not always smooth. We do not always succeed in transmitting the intended message to the other party because of the existence of various barriers of communication. We become surprised at the non-response or unexpected type of response of the other party. Sometimes, this is because we lack knowledge about ourselves, and at other times, because we know so little about other people. Following may be specified as barriers to communication.

1. The speaker and listener may differ in education, experience and background.
2. One may fail to convey the information the listener needs and can understand.
3. One's stereotypes and beliefs influence what one hears.
4. One's emotional state of mind colours what one hears.
5. Individual conflict.
6. Suspicion about the speakers motivation.
7. Imperfect listening.
8. Failure to evaluate the meaning behind what we hear.

Steps To Improve Communication

1. Plan your communication.
2. Projection.
3. Timing.
4. Believability.
5. Simplicity.
6. Repetition.

Effective Communication

Communication is a very important part of the educational process. While learning aims at changing in level of knowledge, change in attitude and change in behaviour it is implied that the impact of communication also lies in the change that has been effected in the knowledge, attitude and behaviour. Needless to say, communication can be considered effective only if the ideas or the message have been properly received, interpreted and utilised for enhancement of knowledge or change of attitude and behaviour. From the experiences gained from social psychology, there is a close link between knowledge, attitude and behaviour and it is generally believed that the knowledge (information) precedes change of attitude which in turn precedes change of behaviour. So also communication has to step up the knowledge first and this knowledge gained is supposed to motivate further and bring about a change in attitude and behaviour. In any case it is expected that communication will serve its purpose only if the change in knowledge level has been achieved.

Effective communication therefore means to begin with a communication that has not only reached the receiver but has enabled the receiver to have a change in the level of knowledge. For effective communication to take place, the following points are essential.

Communicator:

The communicator should possess the following characteristics.

1. S/he should be knowledgeable and fully conversant with the subject under discussion.
2. S/he should have credibility before the receiver which he gains by his sincerity, honesty and intellectual capability.
3. S/he should have proper attitude towards the receiver and subject matter.
4. S/he should have proper communication skill in selecting and using the channel.
5. Feedback should be ensured.

Message:

The message content should be brief and clear.

1. It should be need-based and timely and appropriate and relevant.
2. It should be supported by factual material to give it proper authenticity.
3. The channel should be manageable by the communicator and should be appropriate.
4. Treatment of the message is also important. Its purpose is to make the message clear, understandable and realistic and specially situated for the channel or media that has been selected. Some of the salient principles in treatment of message for effective communication are as follows:
    - Proper emphasis where required.
    - Repetition for the sake of emphasis.
    - Contrast of ideas and comparisons.
    - Logical sequence.
    - Redundancy for reduction of noise.

Channel or Media:

1. It should be familiar both to the communicator and the receiver.
2. It should be appropriate to the message.
3. It should be available and accessible.

Receiver:

1. Like the communicator, the receiver also should have proper attitude and the desire to receive the communication.
2. The receiver's sensory organs should be intact and in good working condition.

Factors to be considered for effective communication:

1. Language:

Language is the oldest means of interpersonal communication. The sender of the message must communicate through language which must be understandable to the receiver. If the receiver can not understand the language, accent, meaning etc. the whole purpose of communication shall be defeated. Therefore, in order to communicate effectively, the sender must communicate with the receiver with the common language.

2. Ideas:

No two individuals are identical due to their differing attitude, perception; ideas etc. Man is the product of the environment. His/her personality, perception and attitude develops as he became socialized with his/her environment in which he/she grows up. Therefore, while communicating, one should take care of this human individual uniqueness.

3. Experience:

Acceptability of any message to a receiver shall be higher if it matches with the knowledge and experience. Therefore, the sender should transmit his message in a way that conforms to ones belief and experience.

4. Values:

Values is one of the important factors to be considered in course of communication. That is why if we want to send any message or inculcate any idea, we must consider the values, belief etc. of the target group.

5. Hopes and aspirations:

Man wants to live long in good health, peace and prosperity. To achieve this, every human being wants to spend time and resources. If the communication is made in a way to the target group that will fulfil their inherent needs and desires, the message will be readily acceptable.

Means of communication

1. House visit
2. Letter
3. Telephone
4. Meeting
5. Demonstration
6. Role play
7. Slide
8. Newspaper
9. Radio/Television
10. Poster, Bill board

Qualities of a good communicator

i. Knowledge:

- Knowledge about the communication process and techniques
- Knowledge about how to motivate target group
- Knowledge about implementation of development programmes
- Knowledge about environment
- Knowledge about socio-economic condition of the locality.

ii. Attitude

- Friendliness
- Sense of responsibility
- Respect for social values
- Mentality to gain confidence of the target group
- Sympathetic
- Willingness to solve problems from the point of view of target population.
- Respectful to human abilities.

iii. Skill based

- Ability to deliver lecture
- Ability to demonstrate communication aids/materials
- Analytical ability
- Ability to run the meeting
- Skill in developing materials.

Communication of WSS Message

- Carefully go through the WSS issues;
- Develop the message for solving WSS problems;
- Prepare for communication of the message;
- Organise meetings, visit the communities and talk;
- Help to remove discrepancies among male and females.

You will agree that if you follow the communication knowledge, the message on gender issues can easily be sent to all. Thus, we can create gender awareness among both males and females which will ultimately help to make gender balance.

13 Hygiene Education

Introduction

The following text is largely adapted from "Guidelines for Health Promotion and Health Education in Community Water and Sanitation Programs," prepared for the World Bank by the African Regional Health Education Centre of the University of Ibadan, Nigeria.[1]

Hygiene Education

The participants' notes cover the three submodules which deal with hygiene education: The Team Effort, Understanding the Community, and Developing the Program for Change. They discuss the engineer's responsibility as project manager to help the community adopt a strong hygiene education program, a vital part of any water supply and sanitation project.

Establishing Identity in a Community

A water supply and sanitation project is a long-term commitment. For the project to run smoothly throughout, project staff should start correctly by visiting the community several times before any of the construction work is begun.

It is always easier to change technology than it is to change people's behavior and practices. With this thought in mind the project engineer and staff must prepare the community. This involves more than simply telling them that a hygiene education program and new technology will be coming into their village. It requires more than just asking the people to cooperate. The project staff must encourage the community to actively participate in the planning and execution of the project. This is the specific role that a hygiene education team can play as members of project staff.

Hygiene education in a water supply and sanitation project involves the work of two groups of professionals who function as teams. The first is the planning team which includes among its members the project manager/engineer, and many other technical professionals such as health specialists, biologists, and experts in various technologies. The planning team gathers information—through technical and social surveys, from discussions with villagers and other methods—about the community or area where the project will

Case Study—Village Water Systems

Guinea worm is a waterborne disease which is widespread in a rural district in Western Nigeria. It is transmitted directly through contaminated drinking water. It can be controlled and eliminated by installing and using a safe, potable water supply. The staff at a health center, run jointly by the state and a university, decided to help a community in this district after seeing many patients suffering from Guinea worm.

The main personnel involved were a public health engineer and a medical officer. They decided a sanitary well would solve the problem. They identified and chose a pilot settlement based on its size, on the number of sufferers, and on its location. They surveyed the area and found a groundwater source that would guarantee water throughout the year. They also chose the source because it was along one of the paths to the farmlands, thinking this would be convenient to the people.

Money was obtained from the university and a contractor was hired to construct the well. It was a perfect well by all technical standards.

However, on returning to the area some months later, the staff were surprised to find that the well was not being used and the area around the well was overgrown with weeds. The hinges on the cover were rusted tight. When the village leaders were asked about this, they gave a simple explanation.

The people of the village were continuing to use their old water source which had been used for centuries. The people had come to like its taste despite its being contaminated. When the new well was being installed the doctor had tried to explain the dangers of contracting Guinea worm by describing the transmission route of the worm.

But, the people had not understood or believed him. They thought that Guinea worm was a kind of punishment from God for doing bad things, and had nothing to do with where water was drawn.

The doctor had not learned about local perceptions of ill health before preparing his lecture. Certainly, the doctor had not listened to any comments from the community. The new ideas would have been better presented and more easily accepted if given by the teacher or a local leader of the community.

The project staff set about correcting the situation by learning from the people and designing their hygiene education message to better suit the community. They chose a teacher who was happy to deliver the hygiene education message through talks at community meetings and to the children at school. Now, the well has been put back in running order, a handpump has been installed, and a clothes-washing area built. It has become a favorite meeting place for the women of the community. More importantly, Guinea worm has almost disappeared from the community.

The difficulties faced by the project could have been overcome if the community had been involved in the early planning phases, and been able to explain how they perceive health.

The messages this case study provides are clear:

- Appropriate technology is not enough to improve health;
- It is more difficult to change peoples' hygiene behavior than it is to change technology;
- 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 cooperate, these leaders must believe that the project will benefit their people and not conflict with their own interests.

The project engineer and staff must identify who the leaders are and meet with 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:

operate. With this information and the team's wide range of expertise, the team develops a suitable and effective hygiene education program with the community.

When the project actually begins, the second team goes into action. This implementing team is made of field staff. It includes many of the same technical professionals who were on the planning team, although the project engineer may not be directly involved. This team implements the hygiene education program developed with the assistance and support of local people such as teachers, community leaders, midwives, and other groups.

The team effort in hygiene education also extends to any staff members of government ministries and agencies who are involved in related activities. An overall team effort is essential because appropriate technology by itself does not improve community hygiene. It takes the skills of the social experts on the team to understand how the community can improve its hygiene practices and support individuals, especially mothers, in watching for the needed behavioral changes. Then improvements in hygiene and better health can begin. This has proven to be the best way to make hygiene education succeed.

Background Information of the Community

To develop a hygiene education program, staff members must first find out as much as possible about the community before going there. This can be done by talking to people who have visited or worked in the community. Important information would include the following:

- Names and locations of community leaders and other respected persons;
- Customs of addressing people which are considered polite and correct (if staff are all male, can they talk to the women; if staff are all women, can they talk to the men?);
- The correct times to visit without conflicting with important community activities;
- How staff can communicate with women to understand their beliefs and needs and encourage them to participate in the planning and execution of hygiene education.

Community members must be familiar with project staff before cooperation can be expected. During introductory visits staff should try to meet a broad cross section of the people, from the formal leaders to the men or women in the market and on the street, and in a few households. Establishing identity and trust is crucial because people are often suspicious of strangers. They may ask: "Why is this person roaming around our streets? Who gave him or her permission? Can we trust this person?" Such questions should be answered early.

It will take time to establish a good relationship with the community. Some time can be saved by entering the community with a known and respected person. It is a good idea to mix official visits with social visits by attending community functions like festivals or celebrations.

During discussions with people in the community, they will bring up other community needs. Some of these may not apply to hygiene education. But these other needs should not be ignored. The staff member should be willing to put the community in touch with other agencies that can provide assistance. The staff member can often show that there is a connection between hygiene education and other development objectives.

Involving the Community

The following case study illustrates how a simple rural water project fails to improve health because the project staff do not understand the community's perception of health. Therefore, they are unable to develop an effective way to deliver hygiene messages.

- Traditional hierarchy
- Local government
- Religious or cultural organizations
- 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; a successful market-woman or storekeeper;
- 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 schoolteacher who may eventually be a valuable resource in teaching hygiene to the children.

Informal leaders do not have titles or hold offices, so the only way to locate them is by talking to people in the community. Questions like: "Who do people usually turn to for help when they are sick or hurt?" may lead to informal leaders who are interested in health in the community.

The next case study shows the need to understand the overall structure of the community and to take care in identifying leaders. It demonstrates the importance these community members can have in hygiene education.

Case Study—Identifying Leaders

One projects staff member visited a village where his agency hoped to provide a well for the people. He met the village chief who promised to have all the villagers turn out for a meeting the next week to discuss the project.

When the staff member arrived in the village the following week, no one could be found. He was annoyed and started to leave. Just then a man standing alone under a tree caught his attention. He went to greet the man and was told a surprising story.

The man said, "Our chief is well-meaning, but he can never make decisions. No one respects him. They are just kind to him because of his age." The staff member was then introduced to the head of the farmers' union who was the actual leader in the village (although not formally recognized as such). Everyone listened to the head of the farmer's union. He offered to arrange everything for the project meeting and its hygiene education program at the village.

The staff member agreed and as it turned out, on the day he promised, all the villagers turned out to meet the agency staff and the project proceeded.

Planning for Hygiene Education

The promotion of hygiene education will require a specific body in the community through which planning and action can be coordinated. 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 organizations like these, a completely new group might have to be formed. For the long-term benefit of the community, this new organization 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 behavior are to occur.

Finding Organizations in the Community Which Can Help the Hygiene Education Effort

In almost every community there are formal and informal organizations whose aim is to improve conditions in the community. They are valuable human resources and can provide moral support and materials that can aid in the development of water supplies, sanitation, and hygiene education. For example, in many communities in Yorubaland in Nigeria women may not be involved in any so-called "important" activity. On closer examination, however, there may be "market-women associations" where women, in their informal role, have a great deal of influence.

Self-help groups may have obvious titles like the village council. Others are identified by words like "development committee," "improvement society," "progressive union," or "welfare council."

The usefulness of such groups as a mobilizing force in community projects depends on two factors. First, such groups should represent citizens from most, if not all, sections of the community. Second, their aims should include serving the whole community and not just a small group within it.

One should discover the following about each organization:

- What projects they have attempted?
- What reasons there are for the success or failure of the projects attempted?
- Are the members dedicated and hardworking?

Talking with villagers may also tell how good the various organizations are. Listen for comments such as: "They are always doing fundraising, but then the money gets spent on parties and celebrations that benefit no one," or "The town welfare union does good work; anytime people are in need they can expect help."

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 center may be able to teach mothers the proper way to dispose of their babies' excreta. An agricultural extension agency could explain to men the health risks of defecating in open fields. All such agencies should be contacted. The community organization 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 engineer or project manager should take care not to impose new models or organizations on existing structures in the community. In the case of hygiene education, 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 organize a new group and what rules, activities, and structures it should adopt should be left primarily to the community. Imposing new organizations on existing non-formal groups can be detrimental to overall health and hygiene, by weakening local activities that are already functioning. The installation of improved water supply and sanitation facilities provides an opportunity for the engineer to identify and possibly correct some factors that have been obstacles to collective action. Communities can be encouraged to organize themselves to maximize the health benefits from the new technologies. To decide the course of action is not the choice of the engineer or planner alone, but of the whole community.

If a water and sanitation committee has been organized by the community to administer the new facilities, its efforts should be linked to existing health and development activities in the community.

Community Awareness, Needs and Practices

A survey of the community helps project staff understand community needs, behaviors, 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 includes the project engineer, government representatives, and other technical professionals, can develop a program with the community.

Community members will always have answers to questions such as: "What could be done to improve hygiene and sanitary conditions?" Their answers will indicate what they believe is needed in the community. They may feel they need:

- Piped water supply
- Garbage or refuse collection
- Water and latrines at the school
- A clean-up of the site used for open defecation.

They may not have acted before to meet these needs, due to a lack of skills or resources, but the potential for action is there.

Staff members of various agencies will also identify needs. They may cite problems such as:

- High prevalence of gastroenteritis
- No hand-washing after defecation
- Poor nutrition
- Dirty water containers.

Agency staff and community members often see quite different needs for the same community or village. For instance, agency staff and community members will probably agree on the need for latrines to prevent hookworm, if hookworm is a major problem in the village. But if hookworm is only a minor health problem, the villagers may not feel the latrines are such an urgent need.

Improved hygiene will often fit in with the needs expressed by community members. For example, women may want to work in small business or crafts to increase family income, but have no time to do so. Taking care of sick children who suffer from diarrhea is a time-consuming task. One could then suggest that an investment in a clean community water supply would result in fewer sick children, creating more time and energy for economic pursuits. Women can often provide the link needed between water supply and sanitation and other development goals.

Paying Attention to Community Beliefs

Project staff should pay close attention to the habits, beliefs, and taboos of the villagers. 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.

A program intended to provide latrines for all the households in an East African community shows why it is necessary to understand these beliefs and taboos.

14. Women Participation in WSS

According to a UNESCO statement, *"educating a male is equal to educating one person, but educating a female is equivalent to educating an entire family"*.

Women are the prime beneficiaries for any water supply and sanitation project. Women are entrusted with taking care of all the household activities related to water supply and sanitation. Their involvement in proper use of water as well as in health and hygiene related activities is essential.

On an average women work for 14-18 hours a day. Of which, about half of the time is spent to water and sanitation related work like, washing clothes and utensils, bathing herself and children, cleaning excreta, serving food to family, cleaning household etc. In many places of the country, the woman has to collect water from a distant place from her home. It is a very common feature of Bangladesh to see a woman with a water pitcher. Therefore, there is a strong relationship between women, water and sanitation. Now-a-days, any development programme in water supply and sanitation sector admits the role of women and consider the necessity of women participation in WSS activities.

Being the prime target of any water supply and sanitation project, women have to know:

What the sanitation ?

Sanitation is a process through which hygiene can be practised properly to lead a healthy life and keep the body free from diseases. 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 environment clean.

What are the importance of sanitation?

If sanitation is not properly practised:

- person might get sick and spread diseases in the family.
- diseases may spread from family to society.
- family expenses will increase and economic structure of the family will be collapsed.
- diseases related to human excreta (about 50 different types of excreta related diseases are prevailing) will increase and may even lead to death. About 30% of children's death is due to diarrhoea.
- on an average every child is attacked with diarrhoea 4 times a year and about 90% of children of 15 years or below suffer from any type of worm.
- in Bangladesh, people lose about 180 cores of working hours every year because of the lack of proper sanitation.

What is the safe water?

Most of the people of our country do not have sufficient knowledge about safe water. They take clean water as safe water. But this is not correct. The germs can not be seen by eyes and they can survive in clean water. Safe water is free from pathogenic bacteria causing diseases. Normally ground water is free from germs and tubewell water can be considered as safe water. But sometimes, iron, salt and even arsenic are available in ground water.

What are the sources of Water?

Two main sources are:

- surface water (river, pond, lake etc.)

- ground water (tubewell like Tara, no.6 handpump etc.)

How the water gets contaminated?

Surface Water

- water source coming in contact with excreta and urine
- coming contact with rubbish or other rotten materials
- effluents from industries
- floods
- excreta of livestock, poultry etc.

Ground Water

- when collecting water
- when carrying water
- when storing water
- when using water

How does the water borne diseases spread and how can the spreading of water borne diseases be stopped?

Water borne diseases are:
diarrhoea, dysentery, worm, cholera, typhoid, jaundice etc.

If germs in excreta enters the human body it causes diarrhoea / dysentery or other diseases. The eggs of worms can spread through excreta from one person to another. Flies also spread diseases by sitting on excreta, carrying the germs and leaving the same on food. In our country, most people defecates in the open field or in the latrines which are built in such a way that it directly or indirectly mixes with water of rivers or canals. Use of such water is one of the main causes of spreading different diseases.

Control of spreading of water borne diseases is possible by:

- stopping open defecation
- ensuring use of safe water for all purpose
- teaching different ways of purification of water
- enhancing social consciousness

Women are to be taught for use of safe water and sanitary latrines. The expected involvement of women are stated below:

- to understand the relation between personal hygiene and health
- to use sanitary latrines
- to use safe water for all purpose
- to avoid the possibility of contamination of water during collecting, carrying, storing and using
- to make the children habituated to use the sanitary latrines
- to keep the latrine clean
- to take care of the water seal not to break
- to be careful about personal hygiene (washing hand with soap/ash or soil before eating and after defecation)
- to dig a ditch and throw the garbage into it

Women as main water carriers and users they can reduce wastage of water, as care takers of public tap / tubewells they can reduce running cost, clean and maintain the platform of tubewell, as educators of the household members they can improve domestic hygiene and as employed health educators they can promote behavioural change both in public and the family.

15. O& M AND SUSTAINABILITY OF WATER SUPPLY AND SANITATION

Introduction

The main source of drinking water supply in Bangladesh is the underground water. It is being extracted by different kinds of Tube wells and some other technologies. Drinking water supply normally consists of hand tube wells and piped water supply system. HTWs are aimed for the poor people living in the rural areas and fringes. Piped supply system are constructed for both poor and rich people living in the core areas of the urban centres. The characteristics of the two system are different particularly in terms of investment and operation and maintenance costs.

The defecation practices is still traditional and unhygienic. Only 44% people uses some form latrines. 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 in the urban centres.

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 vary widely depending on the type.

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 DPHE under different projects financed by the Government or donors with the understanding that the Pourashava or the users will take over the responsibility of O&M of the system. In no town the Pourashava actually took the responsibility of O&M. But as an utility service the pumps were kept running by DPHE without taking into account the O&M cost recovery. Shallow hand tub wells are already popular in low water table area and being installed and maintained by the local mechanics in the private sector. But Deep HTWs and TARA are still financed by the public sector including maintenance. With that background, emphasis has been given on cost recovery for sustainability of water supply.

For the pourashava water supply the water supply section (PWSS) must be organized in all towns and accounting system to be implemented. At the same time performance of the PWSS 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 of the 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 system:

Sustainability of the 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 the 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 supply 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 which 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 use of sanitary latrines
- Participation of women in operation, maintenance and decision making.

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 in the town.

For sustainability at least some percentage of depreciation cost should be added with the tariff. That will be required for replacement of components and 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:

{PRIVATE }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 above 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:

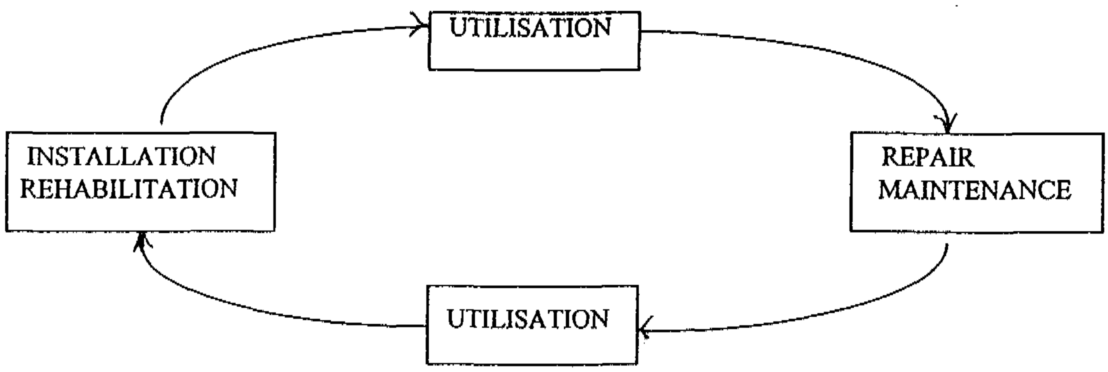
Electricity bill
Salary of staff
Repair and Maintenance
Office expenses

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 amounts 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 realised 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 to the 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 the full involvement of the users in the system. The linkage between the users, the facilities and sustainability is shown below: