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Study Report under the Project
Concerted Action on Elimination/ Reduction of Arsenic in Ground Water, West Bengal, India
(Project: NC/IND/99/967)

(VOLUME I)

Executed by: United Nations Industrial Development Organization

New Delhi
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Concerted Action on Elimination/ Reduction of Arsenic in Ground Water, West Bengal, India

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The Study is dedicated to the memory of those poor women who have lost their dear ones due to inappropriate attention given to environmental concerns.

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FOREWORD

UNIDO is a specialised agency of the United Nations whose primary responsibility is to help developing countries and countries with economies in transition in their fight against marginalization. It promotes productive employment, a competitive economy and a sound environment by mobilising knowledge, skills, information and technology. It focuses its efforts on relieving poverty by fostering economic growth.

Safe drinking water is a basic requirement for health and also for education and learning; agriculture and food production; employment and income generation; enjoyment and culture. Access to safe water plays an important role in issues of social or gender marginalization and thus controls the potential of communities to develop and thrive securely; problems of access lead to conflict and strife at all scales. As water quality has a direct bearing on public health, its non-availability results in economic loss due to increased medical expenses, lost man-days and low productivity.

The UN system has been requested to intensify the national efforts towards reduction of arsenic poisoning related to groundwater supplies and irrigation in India. Because of UNIDO's in-house technical experience in dealing with global environmental issues, the exchange of ideas, research data and results of arsenic containment activities can be fostered between the Government of India, NGO's, UN agencies and multi/bilateral donor agencies and end results accelerated.

The UNIDO service modules are being reformed and the Water quality issue for example work related to Arsenic, Fluoride etc. would fall within the Environmental Management Service Module. This module is key to a great deal of UNIDO's work as it provides links between the International Development Targets of environmental sustainability, economic well being and social development.

To achieve that objective the UNIDO arsenic project aims to operate at a variety of levels to undertake tasks, which promote, amongst others:

- The preparation of development strategies based upon the sensible and safe use of natural resources – including water
- The development and transfer of environmentally friendly technologies to permit cleaner and more efficient production
- The development or re-engineering of processes to reduce harmful emissions or control pollution

These objectives may provide relief from the terrible effects of arsenic poisoning and thereby support the poor community, who is affected the most. It might also offer communities or entrepreneurs the chance to develop business from manufacture, maintenance and so on.

Of course, UNIDO's interests are not restricted to natural contamination. Water pollution emanating from industrial sources such as the leather, pulp and paper, and metallurgical industries, small-scale mining and others has been addressed by UNIDO for many years. The technical measures required for the removal of contaminants are similar for both anthropogenic and geogenic sources. In addition to the technical cooperation, our work involves raising awareness at high levels of the potential hazards, encouraging the formulation of risk assessment on robust scientific foundations, and assisting countries or regions in establishing appropriate policies and strategies to manage and mitigate the risks.

A scientific solution is not the only requirement – it must also be a human one. As a specialist UN agency, we should embrace the diversity, remain objective, impartial, and focused so that the 'best solution' can emerge.

EXECUTIVE SUMMARY

The presence of arsenic, a toxic element, has reached alarming proportions in groundwater sources in the eastern Indian state of West Bengal. Till the 1980s the population was completely unaware that the water used for drinking, cooking and irrigation was laced with arsenic. The community depends heavily on tube wells and hand pumps that tap this contaminated water. In India groundwater has been considered a safe source for human consumption for many years now. As a result tube wells were installed rather indiscriminately without verifying possible geo-hydrological contamination of any kind. The first sporadic cases of arsenic dermatitis were reported two decades back, but it wasn't until many studies and investigations later that they were connected to groundwater contamination and arsenic toxicity was found to be the chief reason behind a whole range of serious ailments affecting the population. Today it has surfaced as a serious health hazard and environmental problem.

The population at risk is reported to be 5.31 million as per the 1991 census. It is about 7.8% of the total population of the state and 15.6% of the arsenic affected districts. Eight districts have been identified with elevated levels of arsenic—Nadia, Murshidabad, Malda, Burdhaman, Hughly, Howrah, North and South 24 Paraganas.

A number of national and international agencies, research groups- both government and private are actively involved in tackling the problem. Workshops, seminars, training programmes and awareness camps have been organised throughout the affected districts. The affected areas have been more or less identified and detailed water quality maps are being charted. Technologies for arsenic removal kits have been brought in and are being run on a trial basis. Efforts are also on to improve the disease surveillance mechanism and provide clinical support to the victims of arsenic poisoning.

It is estimated that there are more than 160,000 tube wells in the villages of the 68 affected Blocks in the arsenic affected districts. Most of these draw water from depths of 15 – 40m, which is the most vulnerable area for arsenic reach soil. If we assume that on an average 25% of the water sources are contaminated with arsenic that leaves almost 40,000 water sources that would need immediate attention. Over the years a lot of schemes have been implemented and relief measures undertaken but the efforts were not concerted and lacked co-ordination. Lack of techno-economic feasibility, infra-structural facilities and social issues coupled with want of a holistic view of the problem were the initial drawbacks that inhibited early corrective measures. Though some of these lacunae still persist, efforts are on to tackle the problem in a more systematic way.

The present project is aimed towards this very goal- to help take "Concerted Action on Elimination/ Reduction of Arsenic in Ground Water". It is a UNDP funded project implemented by UNIDO under Support for Project & Program Development (SPPD). The UN agencies have been requested to coordinate and intensify national efforts towards arsenic mitigation.

The main objective of the project is to assist the Government in bringing together all stake holders for a synthesis of knowledge and taking an integrated view of the arsenic problem by better understanding the issues and potential solutions. The study has undertaken a review of existing policy practices, ongoing interventions, evaluation of arsenic removal treatment technologies, effects of arsenic toxicity on the affected population, presence of arsenic in food chain and options available to mitigate its effects. It has also attempted to analyse training needs at different levels and scope for capacity building and institutional development.

The target beneficiaries of this project will be the Government of India, the State government of West Bengal and the municipal level institutions responsible for arsenic mitigation measures.

Geo hydrological issues
The presence of arsenic in the soil can be attributed primarily to two sources—anthropogenic and geogenic. Arsenic often enters the soil because its derivatives have been used extensively for agricultural purposes as pesticides and herbicides. Other possible routes of entry are burning of coal, careless discharge of industrial effluents and mining activities in the neighbourhood. Though these anthropogenic activities exist, studies in West Bengal show that the arsenic in groundwater is due to leaching of arsenic bearing soil. An attempt has been made to trace its origins.

There are two dominant hypotheses, which explain the cause of arsenic contamination. They are the pyrite oxidation and the oxy-hydroxide reduction hypotheses.
Hydro chemical analysis of water samples by different agencies reveal that the groundwater in the region is mostly alkaline and high in arsenic and iron content while being somewhat low in chloride, nitrate and sulphates. Though studies are needed to determine the exact specification of arsenic- whether it is Arsenite [As(III)] or Arsenate [As(V)], limited studies show that As(V) is predominant.
Sample studies show that both shallow and deep aquifers are generally mild acidic to alkaline in nature. High arsenic (shallow groundwater) is associated with high iron (ferrous), low sulphate, low chloride and low dissolved oxygen.
The Central Ground Water Board has found that it is possible to delineate arsenic free aquifers in some areas provided care is taken not to mix the arsenic rich aquifer with the arsenic free one below it while drilling.

Water Quality and Treatment

Arsenic is widely distributed in the earth's crust and leaches into water through the disintegration of minerals and ores and erosion from natural sources. The redox potential of the aquatic environment determines whether arsenic present will be Arsenite or Arsenate. As(V) is predominant in surface water whereas As(III) is dominant in anaerobic conditions, mainly ground water. However, when groundwater is pumped out and it comes in contact with the atmosphere, some part of Arsenite gets converted into Arsenate.

To adopt the available technologies for arsenic removal it is essential to get a picture of the raw water quality. Samples were taken from several wells in five districts and analyzed by the Central Ground Water Board. The districts are Malda, Murshidabad, Nadia, North 24 Paraganas and South 24 Paraganas. In general, the water was found to be hard and alkaline with excess of dissolved solids. All districts had high iron and manganese concentrations while dissolved oxygen values were found to be very low.

Iron present in groundwater appears to exert a strong influence on the mobilization and transportation of Arsenic in the subsurface. Higher than permissible arsenic concentrations have been found to be closely related with high iron contents but the reverse is not true. In ARPs iron interferes in the removal process. Therefore iron removal becomes necessary as a pre-treatment procedure.

Arsenic removal methods: **There are several treatment methods available for the removal of arsenic in waters for potable use. They include**: -

(a) Chemical precipitation
(b) Adsorption
(c) Membrane processes

Chemical precipitation is the most effective and widely practiced method, particularly in large-scale water treatment plants. Best removals are achieved in case of As(V). Both ferric and aluminium salts are considered to be suitable as precipitating agents. Removal is known to be by co-precipitation and adsorption with freshly precipitated aluminium or ferric hydroxides.

Arsenic can be removed by adsorption on to several types of material which include activated alumina, ion exchange resins, granulated ferric hydroxide, activated carbon, activated bauxite, hematite, laterite, iron or manganese coated sand, iron filings and greensand. In these processes arsenic-rich water passes through a column of media. Arsenic is adsorbed on to the media which when exhausted is regenerated for further use or replaced with fresh media.

In the membrane process a semi-permeable membrane is used to separate materials in accordance with their physical and chemical properties when a pressure differential or electrical potential difference is applied across the membranes. Reverse osmosis and nanofiltration membranes require feed water of high quality. The presence of turbidity, organic matter, iron, manganese and bacteria could foul the membranes irreversibly, and unlike micro or ultrafiltration membranes they cannot be backwashed.

Technology Options

Two kinds of systems have been adopted in the field – community based units and household based units. Adoption of a particular technology largely depends on the cost of the unit, installation costs, the interest of the agency which has developed and adopted the technology, paying capacity of the user especially with respect to household arsenic removal systems and the users' understanding of operation and maintenance aspects.

Though chemical precipitation is an easily adaptable technology in large-scale operations, a smaller version of the plant with Hand Pump attachment has also been developed and installed. But by far, the best alternative so far seems to be the fixed bed operation method using adsorption technique with activated alumina or ferric hydroxide. The reasons being:

- There is no need to add chemicals regularly.
- It can be regenerated once the capacity gets exhausted.
- There is no risk of losing the efficiency of the media due to storage.

Community based units

Seven different types of community-based units in the field were studied. All of them have been installed by the agencies that have designed and developed them. In most cases the responsibility of maintenance still lies with the parent agency. In a number of units the local NGO has taken active interest to install the systems and look after the O & M.

A comparative study suggests that some plants can work in a wide range of arsenic concentration whereas there are a few which can function well in the lower range of arsenic concentration. Since about 75% of sources have an arsenic concentration of below 300 ppb, all the technologies are functional in these ranges provided proper care is taken to run the systems. Water analysis data reveal that about 85% of the sources have arsenic concentration below 500 ppb, which shows there are a few technologies that will require lot of control and monitoring to keep them functional. Other systems like large-scale treatment processes for multiple villages and piped water supply systems have also been reviewed.

Arsenic toxicity & its effect on health

The toxicity of arsenic compounds varies greatly thanks to its complex chemistry. The degree of toxicity depends on the chemical form of the arsenic compounds, route of entry into the human body and the quantity and duration of exposure. Arsenic poisoning can occur by inhaling polluted air high in arsenic content that is released from smelters and mines, drinking water contaminated with it and eating aquatic food which has been affected by arsenic rich sludge and wastes dumped into water bodies.

The two most deadly forms of arsenic—inorganic arsenites and arsenates are present in the groundwater in West Bengal. Arsenites are 60 times more toxic than arsenates but it is believed that for chronic toxicity both these species are equally toxic.

More than five million people are estimated to be at risk from arsenic poisoning and conservative figures suggest that there are over 300,000 patients who are suffering from various stages of arsenicosis.

Environmental arsenic is detrimental to several human organs. Since small doses may have no immediate obvious effects, the appearance of symptoms can be taken to be the result of arsenic accumulation from repeated exposure. The most common signs of long-term, low level arsenic exposure are dermal changes. Initially various types of spotty and blotchy pigmentation occur with diffuse and nodular keratosis. In the later stages oedema of legs, chronic bronchitis, conjunctivitis, peripheral neuropathy and even cancer of skin, lung and bladder could manifest itself.

Chronic arsenic poisoning may have non-specific general effects such as chronic weakness, easy fatigue, lack of motivation, anorexia, weight and hair loss among others.

The Institute of Post Graduate Medical Education and Research, Calcutta in its epidemiological study in the six arsenic affected districts of West Bengal reported among others that chronic arsenic poisoning damaged the liver and made the patients susceptible to respiratory diseases. Very few affected people report to city hospitals for treatment as most of them live in distant rural areas and belong to low socio-economic strata. More than 70% patients reported weakness and lethargy to do any physical labour. Men were found to be more prone to the disease than women.

A major problem in the early detection and treatment is lack of trained medical staff, proper treatment facilities and regular supply of medicines to the patients. Since most of the victims are poor, they find it difficult to continue the prolonged treatment process so essential for recovery. Moreover, treatment facilities are presently available only at selected hospitals in Calcutta and the poor affected villagers have to travel long distances regularly to avail the treatment.

Has Arsenic entered the food chain?

While there is proof of arsenic poisoning through drinking and cooking water, it is a matter of grave concern whether abnormally high levels of arsenic are also entering the crops and plants in the affected area and thereby the food chain; more so, since a substantial amount of groundwater is being tapped for irrigation, especially by small farmers in the region.
However, so far very few studies have been conducted in this field and findings have been inconclusive. Work done elsewhere in the world in countries like Japan have shown a direct correlation between high concentrations of arsenic in soil and low crop yields.

Water is the chief medium in which Indians cook their food, especially in Bengal. Rice, pulses, curries, even tea requires plenty of water. Therefore, any contamination of drinking water poses serious health hazards. The AIIH&PH in a study of food cooked in arsenic contaminated water found that boiling of arsenic rich water reduces its concentration with time but increases concentrations in the distillate. Liquid pulse and potato curry was found to retain most of the arsenic after cooking. However, tea and milk were found to retain most of the arsenic even after boiling.

Socio-economic issues

While several studies have been made on technological and marketing aspects of the arsenic related problem, the socio-economic aspect of arsenic toxicity in West Bengal has been largely sidelined. The community's perception about the existing technologies needs to be understood and found out what efforts are required to make the system more user-friendly.
Large variations exist in the levels of awareness in the arsenic contaminated districts. The awareness levels appear directly proportional to the instances of water testing sites, publicity campaigns and exposure to the media.
Poor perceptions of the health hazards of arsenism exist. Local doctors, paramedical staff and quacks with their half-baked knowledge of the issue have further confused the community. All this and lack of basic education has delayed the acceptance and importance of arsenic mitigation plants. Costly treatments also act as a deterrent to the average daily wage earner.
The community was found to have little or no say in the choice of technology. Since many of these units were installed as pilot studies it was either the local NGO or the manufacturer or the implementing agency like the PHED, which decided on a particular plant. The community's overall reluctance stems from a combination of poor marketing efforts, lack of ownership and low levels of awareness. In several cases people reverted back to tube well water bringing into question the sustainability of the plants.

Cost factors

Under the project seven community based and four Household based ARPs were considered for cost analysis. A comparison was also made with the community based piped water supply systems. The study reveals that, a substantial amount of subsidy is required to implement the programme. Though the community is in a position to share 10% of the capital cost in case of community based ARPs, it will not be possible for the community to bear the full O&M cost, which includes replacement costs. Since low cost technologies are not so reliable a balance has to be drawn between the cost and reliability. Overall cost of almost all the technologies imported from outside the country are on higher side and O&M cost is to be highly subsidized.
Household ARP units, which are comparatively more reliable and need not have day-to-day operation, are costly and need to be subsidized. Alternately, more reliable household ARPs need to be developed for the community, which appears to be eagerly looking for it. Piped water supply systems are quite costly and need to be highly subsidized both for capital as well as O&M cost.

Institutional and training needs

At present the entire water supply system in West Bengal is the government's headache. This goes for the arsenic mitigation efforts too-- right from conducting surveys, water quality tests to installing mitigation plants and maintaining them.
The local communities have to be involved in ownership, installation, maintenance and sharing of costs of the systems. Obviously, the people's lack of involvement translates into lack of concern and sustainability of the technology is threatened.

To institutionalize the system there is a need to adopt a demand responsive approach. **Users have to be given the freedom to choose schemes, control finances and manage projects.** The government must

take a back seat and help only in planning, monitoring and providing financial support. The NGOs will draw volunteers form the local Youth Clubs who are none other than members of the community. This will grant the system tacit sanction of the community.
The Arsenic Mitigation Centre coming up in Calcutta will streamline all arsenic mitigation efforts under one roof and coordinate work by every agency in the field.
Training needs to be imparted in two basic areas—enhancing the community's knowledge base and ensuring long-term sustainability in the use of ARPs. The NGOs have to be trained on the basic issues of arsenic problem, arsenic removal and technology available for it, use of ARPs, identifying symptoms of arsenic toxicity, etc.

Privatisation and marketing issues

The role of private entrepreneurs in the arsenic mitigation program is considerably limited at present. Though several companies are manufacturing arsenic removal plants, most of them are subsidized by the government or linked to development programs. The market is not need driven and no well-established network exists in the affected districts. The reasons for this are:

- Absence of a tried and tested common arsenic removal technology
- High cost of manufacture and subsequent maintenance and operations
- Lack of awareness in the community and therefore low level of acceptance

Private entrepreneurs are yet to visualize the extent of the problem, nor are they sure about the community's demand for the systems. The local people on the other hand are not yet convinced that the technology brought in by the private agencies are indeed foolproof and will serve the purpose. Clearly, there exist distinct links between awareness and acceptance levels of ARPs and the maturity of marketing systems.

The study revealed that there is a huge potential for privatisation that is waiting to be tapped. The constraints are not insurmountable and with a little bit of planning they can be dealt with easily.
Overall an aggressive marketing strategy keeping in view the cost-benefit ratio and the community's direct involvement needs to be adopted for privatisation.

Monitoring And Evaluation

The monitoring and evaluation mechanism presently prevailing in the Rural Water and Sanitation Sector leaves a lot to be desired. The system fails to indicate the following:

- Availability of the quantity of water to the average household
- Adequacy of the system to meet the needs of the community
- The quality of water supplied and level of user satisfaction

The existing monitoring system only reflects the overall physical and financial indicators for the state as a whole but does not help in carrying out any corrective measures at the local level. The community, which has the biggest stake in the sector, has no say in this monitoring system.
The system needs to be demand responsive and motivate the community to participate in the process. Local members have to be trained to operate arsenic removal plants, tackle routine maintenance jobs, collect funds and provide feedback to the implementing agencies. The rural **sanitary marts** outlets in the state have a well-established network in block headquarters and important villages. The outlets in the arsenic prone areas could be used to store ARPs and their spare parts thus providing help at the doorstep.

The community and the project management have to work hand in glove in identifying key problem areas and bottlenecks in the system and follow them up with corrective measures.

1. ARSENIC MITIGATION ISSUES: THE PRESENT SITUATION

1.1 Background

The State of West Bengal lies in the eastern part of India and is spread over a geographical area of 88,752 sq. km. The Tropic of Cancer cuts across this fertile land, which falls between latitudes 21° 30'N and 27° 10'N and longitudes 86° and 90°East. The state is divided into seventeen administrative districts excluding Calcutta, (now called Kolkata) the state capital. The districts are further divided into 341 developmental blocks. A democratically elected self-rule institution called the Panchayat system operates in the rural areas. The Panchayat, consisting of Gram Panchayat at village level, Panchayat Samity at block level and the Zila Panchayat at the district level, is responsible for all rural planning and development.

The annual rainfall in the area is quite high and ranges between a healthy 1,295mm to a heavy 3,945 mm. Overall the climate is tropical, the weather hot and humid most of the year. A number of big rivers and their tributaries criss-cross the state, which has a very high water table in most areas. **Here, like in other places in the country, groundwater has been considered safest for human consumption for many years. More so after increasing incidents of widespread gastro-intestinal disorders made people lose faith in surface water. With advancement of technology more and more tube wells with hand pumps were drilled both privately as well as with government help to meet the needs of the population. As a result, tube wells were installed rather indiscriminately without verifying possible geo-hydrological contamination of any kind.** During the 1980's sporadic cases of people suffering from arsenical dermatitis in the districts of North 24 Parganas, South 24 Parganas, Nadia, Murshidabad and Burdhaman came to light. But it wasn't until many studies and investigations later that they were connected to groundwater contamination and arsenic toxicity was found to be the chief reason behind a whole range of serious ailments affecting the population. Today it has surfaced as a serious health hazard and environmental problem.

1.2 Initial Efforts

Initial epidemiological studies conducted by the Calcutta School of Tropical Medicines (CSTM) and the All India Institute of Hygiene and Public Health (AIIH&PH) in the early 1980's concluded that the presence of arsenic in groundwater posed a very grave public health hazard and the problem needed to be tackled seriously. Soon after, the Government of West Bengal constituted a Steering Committee (1988) comprising of eminent experts from related fields from both the State and Central Government organisations as well as from renowned academic institutions to investigate the matter. The main recommendations of the Committee were:

- Only the third aquifer of ground water should be tapped for drinking
- Water in a new tube well should be carefully tested for arsenic before it is commissioned;
- The yield from the third aquifer should be so regulated that there should not be large-scale vertical leakage of arsenic rich water from upper layers;
- Field trials of arsenic removal techniques involving absorption methods should be made. Vigorous research by competent agencies should be supported;
- A system of periodic monitoring of arsenic content in the tube wells in and around the known arseniferous areas should be developed;
- Agricultural inputs as possible sources of arsenic toxicity in groundwater need to be analysed to rule out the possibilities of contamination.

A number of agencies came forward to study the extent of arsenic poisoning through analysis of samples and epidemiological studies. By 1992, the Government of West Bengal constituted an Expert Committee to look into the following issues:

- To investigate into the causes of arsenic pollution in groundwater;
- To develop technically and commercially viable arsenic elimination plants including modality for disposal of arsenic rich sludge;
- To suggest possible steps for elimination of arsenic from drinking water;
- To recommend such measures as are considered necessary for the removal of arsenic contamination in drinking water derived from groundwater.
- To prepare a detailed map of arsenic infected zones

The expert committee made a number of recommendations that are placed at Annexe I. A number of workshops, seminars, training programmes and awareness camps were organised by state agencies, research organisations and NGOs and conducted in the arsenic prone areas. In 1995, the Government of West Bengal even appointed a Task Force on Arsenic to co-ordinate various activities to mitigate problems arising out of arsenic poisoning.

1.2.1 *Government of India's role*

The Rajiv Gandhi National Drinking Water Mission (RGNDWM), a Government of India body has played a pivotal role in this field. In May 1988, it funded the project to study the nature, degree and cause of arsenic pollution in groundwater. It also provided financial support to the state to implement a number of water supply projects which included replacement of arsenic contaminated spot sources, construction of big diameter deep tube wells and piped water supply systems, setting up of arsenic removal technologies and sanitary protected ring wells. These efforts are expected to benefit around 2 million people in the arsenic affected areas.

RGNDWM, with active support from the state government, external support and research agencies began building a state-of-the-art Arsenic Mitigation Centre in Kolkata in early 1999. This autonomous institution, which is expected to be functional by the end of this year, will have a well-equipped modern research laboratory. It will also be a referral and documentation centre tackling all technical, social and policy issues related to arsenic in future.

1.2.2 *Role of External Support Agencies*

A number of national and international support agencies have been playing significant supportive roles in dealing with the problem. These include import of arsenic removal technologies and their application, assisting in water quality monitoring process and development of mitigation strategy and its implementation.

The WHO played a major role in organising a Regional consultation on Arsenic and standardisation of field test kits. UNICEF along with the State Government is currently implementing a Joint Plan of Action to address Arsenic Contamination of Drinking Water. The objectives of this plan of action amongst others includes identifying tube wells contaminated with arsenic, provide alternate technology, create awareness, R&D activities and improve the disease surveillance mechanism. The India-Canada Environment Facility in collaboration with AIIH&PH, Calcutta is also implementing an arsenic mitigation program in selected villages of the State.

1.3 Permissible Limit of ingestion

According to WHO guidelines, the acceptable value for arsenic concentration in drinking water is 10 µg/l. The Environment Protection Agency (EPA) of the United States of America has proposed that it be reduced to 5 . **However, after taking into consideration the various environmental factors, socio-economic conditions and food habits, many countries including India have recommended a permissible limit of 50 µg/l.** The Indian Standard (IS: 10500:1991) for drinking water also prescribes 50 µg/l as the maximum permissible limit. Though the "Manual on Water Supply and Treatment," May 1999 edition published by Central Public Health and Environmental Engineering Organisation, Ministry of Urban Development, Government of India, recommends 10 µg/l as the 'Acceptable Limit' and 50 µg/l as 'Cause of Rejection' of drinking water, for the present the state agencies are following the acceptable limit of 50 µg/l for all practical purposes.

1.4 Extent of Problem

1.4.1 *Demography*

By May 1993, agencies had identified 149 villages, 6 non-municipal and 3 municipalities spread out in 34 blocks of seven districts that had high arsenic levels in groundwater. The population at risk was 0.96 million. Given the continuous movement of groundwater and peculiar geo-chemical conditions, the problem has worsened with time. By December 1998, the number of arsenic affected habitations increased to 3115, non-municipal areas to 15 and municipalities to 9 in 68 blocks of eight districts. **The population at risk is reported to be 5.31 million as per the 1991 census. The affected population is about 7.8% of the total population of the state and 15.6% of the arsenic affected districts.**

As water quality investigation continues, fresh arsenic affected areas are being discovered. Studies also suggest that more than 0.3 million people have arsenical skin lesions in the affected areas. A district-wise spread of areas affected by arsenic in West Bengal is given below:

Table 1.1 The District-wise spread of arsenic in groundwater – May 1998

District	*Blocks*		*Affected Areas*			*Population at Risk (in million)*
	Total	*Affected*	*Hab.*	*NMA*	*MA*	
Malda	*15*	*5*	*379*	*-*	*-*	*0.54*
Murshidabad	*26*	*15*	*367*	*-*	*-*	*1.17*
Nadia	*17*	*13*	*455*	*7*	*1*	*0.92*
Burdhaman	*31*	*2*	*7*	*-*	*-*	*0.02*
Hugli	*18*	*1*	*15*	*1*	*-*	*0.03*
Haora	*14*	*3*	*6*	*-*	*1*	*0.19*
N 24 Parganas	*22*	*19*	*671*	*2*	*7*	*1.57*
S 24 Parganas	*29*	*10*	*1243*	*-*	*-*	*0.91*
Total	***172***	***68***	***3133***	***15***	***9***	***5.31***

Hab. - Habitations
NMA - Non-Municipal Area
MA - Municipal Area

Studies reveal that the origin of arsenic in West Bengal is geological, which makes it complicated and difficult to control. Lack of techno-economic feasibility, infra-structural facilities and social issues coupled with want of a holistic view of the problem were the initial drawbacks that inhibited early corrective measures. Though some of these lacunae still persist, efforts are on to tackle the problem in a more systematic way.

1.4.2 *Affected water sources*

Water quality tests for groundwater sources (both public and private) in the arsenic affected districts have not been completed so far. This makes it difficult to indicate the exact number of contaminated sources. The UNICEF- Govt. of West Bengal Joint Plan of Action points out that there are around 22,000 public and 128,000 private tube wells in the 68 affected Blocks. Studies carried out by other research agencies suggest that on an average there are about 70,000 water sources per Block. Most of the private tube-wells tap water at depths of 15 – 40m, which is the most vulnerable area for arsenic leached soil. Fortunately, the studies conducted so far show that not all the sources in a village are affected by arsenic. **Since there is no regularity in the distribution of arsenic in groundwater, it is extremely difficult to get a true picture without a census and water quality tests of all sources.**

The Joint Action Plan is currently conducting water quality tests and it is expected that a Block-wise water quality map will soon be available. The tube wells are being colour coded Red and Blue – Red indicates the presence of arsenic above permissible limits and Blue certifies that it is a safe water source for drinking and cooking.

Besides the data available with the Public Health Engineering Department (PHED), Govt. of West Bengal, there are a number of other state agencies and institutions that have collected valuable information on water quality. Unfortunately, most of it has not been properly documented. They lack a common format; sampling and test methods also differ. But using some basic common parameters it might yet be possible to combine the available data from different sources and generate a clearer picture of the affected blocks.

1.5 Major agencies and their roles

Here are some of the key agencies that are playing an active role in the management of arsenic contamination:

- **Public Health Engineering Department (PHED)** – This umbrella department is the main executing agency of the Government of West Bengal, which is responsible for planning, implementation, and maintenance of piped water supply systems and well drilling in the non-alluvial areas of the State. PHED also co-ordinates all activities related to the arsenic programme. Besides, it maintains water quality test laboratories and has generated adequate data in this regard. It has participated in and organised a number of seminars/workshops and initiated awareness activities on arsenic issues in the State.
- **Directorate of Health Services (PH&CD)** -- This State Government agency handles all matters related to public health, medicine and communicable diseases. It plays a very important role in informing, educating and communicating activities related to arsenic in the affected districts thanks to its army of medical and paramedical staff located in district hospitals, blocks and Primary Health Centres (PHC) at the village level. The Joint Director of Health Services (PH &CD) has been

appointed the State Programme Officer for the arsenic issue. The Deputy Chief Medical Officer of Health in the district is the Nodal Officer at the district level.

- **Panchayat and Rural Development Department (P&RDD)** -- The three–tier Panchayat system, which is a democratically elected self-rule mechanism in the district is administered by this department. At the district level it is known as Zila Parishad, at the block level Panchayat Samity and at the village level as Gram Panchayat. This Department also oversees the rural water supply in alluvial areas that is mainly supplied through tube wells with hand pumps.
- **All India Institute of Hygiene & Public Health (AIIH&PH)** -- A Government academic institution, it has been involved in arsenic detection, water quality testing and development of mitigation measures from the very beginning. It has developed both community as well as domestic arsenic removal units and organised a number of seminars, workshops, and training programmes to tackle various aspects of arsenic mitigation. At present it is co-ordinating the implementation of arsenic mitigation projects for about 400 villages through various NGOs under India-Canada Environment Facility programme.
- **Calcutta School of Tropical Medicine (CSTM)** -- This institute has pioneered the detection of arsenicosis in the affected community and is carrying out water quality tests. It has been involved in formulating strategies for handling the clinical aspect of arsenic toxicity.
- **Institute of Post Graduate and Medical Research (IPMR)** -- This institute has carried out epidemiological surveys in arsenic affected areas and is currently involved in the clinical treatment of arsenic affected patients and related research.
- **School of Environmental Studies – Jadavpur University (SOES)** -- This is an academic institution which has developed a substantial data base and carried out a large number of research activities on arsenic pollution in drinking water both in West Bengal and Bangladesh. It has also developed a household-based arsenic removal unit and is actively participating in awareness campaigns to reach out to the rural community.
- **Bengal Engineering College (BEC)** -- This technical institution was instrumental in the development of both community as well as household-based arsenic removal technology using indigenously available material. A number of units are presently in operation in the State. The domestic unit is also being produced and marketed by a private agency.
- **Central Ground Water Board – Eastern Region (CGWB)** -- The agency is playing a major role in conducting surveys and maintaining geo–hydrological records in the state. It has participated actively in all the committees formed on the arsenic issue and has done research work besides helping agencies like PHED with the arsenic mitigation programme. Also, CGWB has tie ups with the National Institute of Hydrogeology (NIH) and the Bhaba Atomic Research Centre for collection of hydro-geological information on arsenic.
- **State Water Investigation Directorate (SWID)** -- This directorate is mainly responsible for investigating into the potential of groundwater resources in the state. SWID is involved in studies for assessing groundwater utilisation for agricultural and other purposes. It has also analysed a good number of water samples and made studies on groundwater hydrology.
- **Department of Environment & West Bengal Pollution Control Board** -- The department is responsible for the planning and assessment of environmental impact on society. So far this department and West Bengal Pollution Control Board have not been directly involved in arsenic mitigation activities.
- **Non-government Organisations** --A number of NGOs have been involved in arsenic management in the State. Prominent among them are the Centre for study of Man and Environment, Pashchimbanga Vigyan Manch, Chandranath Basu Sewa Sangha, The Breakthrough Science Society, School of Fundamental Research and the Rama Krishna Mission Lok Shikha Parishad. All these NGOs are involved in the awareness programme, providing arsenic removal technologies developed by research agencies, water quality testing, training programmes and development of community managed systems.
- **Private Agencies** --Besides the above, a number of private agencies have introduced technologies for arsenic removal. In a majority of cases the technologies have been developed in other countries and tested in that environment. A number of pilot units have been installed in different parts of the arsenic affected districts to test their efficacy. These plants have been installed and are being maintained by the private agencies. PHED is currently trying to assess the arsenic removal capacity of these plants. Some of the major agencies are Pal Trockner, APYRON, OXIDE India Ltd, Water System International and Ion Exchange.

1.6 Progress so far

Several committees constituted by the State government have given a number of recommendations on framing policies and plans to mitigate arsenic in groundwater. PHED is expected to lead the implementation and co-ordination of these efforts.

The first phase of the Action Plan decided to replace 1002 spot sources, construct 23 large diameter tube wells and prepare six piped water supply systems. This has been completed. Schemes for immediate relief, tapping of surface water supply systems and pilot plants for tube well based schemes have been initiated, though the approach has been more towards providing alternate drinking water source and lacks initiatives in encouraging interrelated arsenic mitigation activities.

Though individually there have been a number of successes, **the lack of a holistic approach to the problem and non-utilisation of synergies from different stakeholders has weakened the efforts. Hence the achievements so far have not been as promising as expected.**

1.7 The Present Project and its scope

The "Concerted Action on Elimination/ Reduction of Arsenic in Ground Water" is a UNDP funded project implemented by UNIDO under Support for Project & Program Development (SPPD). The UN Agencies have been requested to coordinate and intensify national efforts towards arsenic mitigation.

The overall objective of this project is to provide support to the government agencies in policy-making and co-ordinating efforts to mitigate the effects of arsenic in groundwater. This will include an overall assessment of the problem including sector issues, review and assessment of available technology for the removal of arsenic from groundwater, the assessment of training needs to make it more community friendly and a broad estimate on the financial requirements at different levels.

The target beneficiaries of this project will be Government of India, the State government of West Bengal and the local level institutions responsible for arsenic mitigation measures. The biggest beneficiaries are expected to be the community who are drinking arsenic contaminated water.

Expected outputs of this study are:

- Participation in establishing an inter-ministerial co-ordination group for the development of long-term strategies for arsenic mitigation.
- Review of existing technologies for arsenic removal and water quality test kits in order to assess the suitability of such methods for arsenic removal; search a for cost effective, reliable, safe method; measures for removal of barriers hindering introduction, effluent disposal techniques; establish the probability of arsenic in food chain and involvement of private sector in the transfer of technology.
- Identification of training needs and capacity building with special reference to community managed initiatives.
- Broad estimate for the financial requirements to plan a comprehensive arsenic mitigation programme.

2. GEO-HYDROLOGICAL ISSUES

2.1 Sedimentation History of West Bengal

The geology of West Bengal reveals that alluvial deposits cover almost three-fourths of the Bengal basin while hard rocks cover the rest. On the west lies the Peninsular Shield with the inter-cratonic Gondwana basin and Rajmahal trap; Shillong plateau lies to the northeast and Naga Lusai belt in the east. The Garo-Rajmahal gap separates the Peninsular Shield from the Shillong Plateau. This gap is the creation of tectonic movements of the earth. The sedimentary fill occurring north of the Garo-Rajmahal gap perhaps represents a part of crustal downwarp formed during Himalayan orogeny.

The southern part of Bengal basin meanwhile is covered by fluviatile Quaternary sediment. The delta plain in this region is mainly formed by alluvial sediments transported by rivers like Damodar, Mayurakshi and Ajoy originating from Chota Nagpur upland in the West and subsequently by the rivers flowing from the Himalayas such as the Ganges, Brahmaputra and their distributaries. Arsenic contamination of groundwater occurs in the recent deltaic sediments which extend eastward in the Bengal basin and beyond into Bangladesh.

The delta region in the northern part of Bengal is characterized by a series of abandoned river channels formed under varying hydrodynamic conditions in a fluvial regime. Abandoned meandering scrolls are the most common form and could be related to flood plain formation in the upper delta region. The sediment of this plain consists of several sequences of clay, sand and silt conglomerate. The delta in the south is made up of tidal mud, distributor levees and inter-distributory marshy complex formed under a fluvial estuarine and marine environment under the influence of a fluctuating sea level in the Tertiary and Quaternary period. This deltaic plain is characterised by the presence of extensive clay blankets that is underlain by silt, sand and gravel.

Thus the depositional history of the sediments in the arsenic affected area can broadly be divided into three divisions:

- The ancient braided stream bars and channels (Moribund type).
- The flood plain or back swamp environment (mature environment).
- The meander belt (active delta).

The Ganga delta with contiguous areas forming the Bengal Basin can be divided into different forms such as deltaic upland, barind, upper delta plain of meander belt, valley margin in fan, marginal plain, lower delta plain of meander belt and delta front. **The higher incidence of arsenic in groundwater is restricted mainly to the upper delta plain with a series of meander belt** (Srivastava & Chakladar, 1999). Depending upon the density of channel network, the composition of sediment changes locally across the delta plains from within a few metres to several hundred meters. This may explain the apparent discontinuity of the arseniferous aquifer.

2.2 Forms of Arsenic in soil

Soil arsenic can be attributed mainly to two sources – anthropogenic and geogenic. Arsenic often enters the soil because its derivatives have been used extensively and indiscriminately as pesticides and herbicides in agriculture. Other possible routes of entry are burning of coal, careless discharge of untreated industrial effluents from metallurgical, ceramic, dye and pesticide manufacturing industry, petroleum refinery, mining activities and smelters in the neighbourhood. Arsenic exists naturally in soils at an average concentration of about 5--6-mg/ kg. This varies from place to place and the highest concentration has been observed in Recent Alluvial clay. The high concentration of arsenic in rocks is due to the ease with which arsenic substitutes for Si, Al or Fe in crystal lattices of silicate minerals. Sedimentary rocks contain higher concentrations of arsenic compared to igneous or metamorphic rocks. Concentrations from coal are (as arsenopyrite conc.1 – 90 mg/kg), coal combustion by products and sewage sludge (3 – 46 mg/kg).

Arsenite (AsIII), the reduced state in inorganic arsenic, is a toxic pollutant in natural environments and is more soluble and mobile than oxidised state of inorganic arsenic, arsenate (AsV). Arsenate can be sorbed into clays, specially kaolinite and montonorillonite. Oxides of Al, Fe and Mn when come in contact with arsenic give rise to various scenarios. Iron oxides adsorb arsenic more strongly than manganese oxides. This ability of amorphous iron oxides to adsorb arsenic is related to their loose and highly hydrated form.

Arsenate is less strongly sorbed than Arsenite. Addition of Arsenite to Manganese dioxide coated sediments may result in its oxidation to Arsenate. If the Manganese dioxide has iron oxide coating large amount of arsenic gets adsorbed. If anions like phosphate are present they can effectively compete with arsenic for adsorption sites, particularly aluminium and iron oxides surfaces.

Arsenic in soil can be a major source of contamination when loose soil particles are carried off as sediments during erosion. Or it can be released in water under anaerobic conditions such as in flooded soils or sediments. A portion of this high arsenic concentration is Arsenite, which is more toxic than Arsenate.

Arsenic retention and release by sediments depends on the chemical properties of the sediments, especially on the amounts of iron and aluminium oxides and hydroxides they contain. Oxidising the sediments could enhance arsenic release to the environment. These inorganic arsenic phases change from mainly oxy-hydroxide and organic phases to a sulphide phase under reducing conditions in the sediments.

Arsenic oxidation from As(III) to As(V) has also been reported to be a biotic process with minor participation of micro organisms. Arsenic is chemically similar to phosphorous. At low levels of phosphate, plants absorb arsenate but with increased concentrations of phosphate, it competes with arsenate for absorption sites and inhibits arsenate absorption.

2.3 Theories of origin

It is absolutely necessary to identify the source of pollution when planning preventive measures. Unless this is identified beyond doubt, it would be difficult to take corrective measures and delineate the polluting sources. This also has bearing on the policy framework for groundwater extraction and utilisation. At present there are two dominant hypotheses, which explain the cause of arsenic contamination. They are:

- Pyrite oxidation Hypothesis.
- Oxy-hydroxide Reduction Hypothesis.

Pyrite oxidation Hypothesis

This hypothesis suggests that arsenic release takes place due to oxidation of pyrite and or arsenopyrite present in aquifers by coming in contact with oxygenated downward moving groundwater, i.e. by deepening of the Vedose zone. This oxygenation is a direct consequence of large-scale extraction of groundwater during the past decades (Mallick and Rajgopal, 1996; Das et al. 1996). But this explanation is not very consistent and leaves a number of questions unanswered. For instance:

- Deepening of vedose zone is possible only in the unconfined aquifers and such aquifers are present only in the upper delta sector.
- Higher arsenic concentrations are found in reducing groundwater.
- The observed low sulphate concentration and high pH are not consistent with oxidation of pyrite.
- Arsenic concentrations frequently increase with depths below the water table.

Oxy-hydroxide Reduction Hypothesis

This hypothesis suggests that arsenic exists in the ferric oxide/ hydroxide coating on the sand and clay particles in the sediments involved and on reduction (from Ferric to Ferrous) the iron oxide dissolves releasing arsenic (Bhattacharya et.al. 1997). In this model the ferrous content in the water will increase along with the increase of arsenic oxyanions in water and the conditions are satisfied in this field. Optical microscopes have confirmed this ferric-oxide/ hydroxide coating and the arsenic contained in it.

Though this hypothesis is highly popular and accepted by many researchers in this field, it needs to be substantiated as to how the reduction takes place and why it did not happen for so many years. Moreover, the area being a deltaic one, to have a clear idea of location, geometry, size and deposition of the aquifers (both arseniferous or otherwise) many more sub-surface studies are needed to substantiate the theory. Borehole core samples of arsenic bearing zones need to be analysed in a systematic way for mineralogical content such as arsenic and other related substances. Core retaining dry drilling will provide access to the material for direct study of the geochemistry and petro-mineralogy of the litho units.

2.4 Hydrogeology

The Bengal basin contains a series of meander belts of which an older composite belt occupies the central part and tends NNE-SSW coinciding with the alluvial valley at the head of the delta. This composite meandering belt is cut on its north-eastern side by four younger meandering belts of River Padma. On its western side there are three successive meandering belts of Bhagirathi River. Sand, silt and clay make up the sedimentary fill in general. The older meandering belts are sandier and are underlain by gravel beds indicating the high-energy streams during their formation. The sediments of the upper delta plain rest directly over the extensive clay beds of the Tertiary period at a depth of about 150 metres with a pronounced unconformity and there is no evidence of the preservation of the older Quaternary deposits. The migration of meander belts with components of channel lag-front bar and levee-back swamp gives rise to festoons of fining upward sequence in a vertical section. Each of the meander streams has such sequence arranged laterally across the composite upper delta plain. This change may take place from within a few to several hundred meters. The apparent discontinuity of the arseniforous aquifer is explained by the complete sealing off of an arseniferous aquifer from a non-arseniferous one due to the cross over from one meander belt to another.

To understand the distribution of arsenic contents both vertically and laterally within sediments of groundwater a study had been conducted by CGWB some time back. They have charted a district wise sub surface lithological character, which is annexed.

In Malda, Murshidabad, Nadia and Burdwan districts groundwater occurs in unconfined/ semi confined condition and the water level varies from 4 to 9m below ground level. In the eastern part of the basin the groundwater fluctuation is within 0-3 m. The normal flow pattern is from north to south with a partiality towards southeast direction. The North and south 24-Parganas districts are also a part of deltaic alluvial plain and are underlain by fluviatile sediments of Quaternary period. It is almost similar to that of Nadia and Murshidabad districts. Groundwater in these districts occurs under unconfined/ semi-confined condition. Depth of the water level for shallow aquifer varies from 3-5m below ground level and for semi-confined aquifer 6-8m. The flow is towards the southeast.

2.5 Hydrochemistry

Analysis of a large number of water samples collected from a variety of sources in the arsenic prone areas by different agencies reveal that groundwater is mostly alkaline and high in arsenic and iron content and somewhat low in chloride, nitrate and sulphates. Since total arsenic is measured in general, we have little idea of specification i.e. whether it is As(III) or As(V). Work done by Geological survey of India on a limited scale (25 samples) shows that As(III) is predominant over As(V); nowhere did As(V) exceed As(III).

2.5.1 Effect of pH and Eh

Arsenic is generally present in groundwater as an oxy-anion i.e. as arsenite (H_3AsO_3) or arsenate (H_3AsO_4) or both. The pH and Eh (redox potential) have a dominant effect on its chemistry. The relation between Eh and concentration of arsenic is linear and arsenic concentration becomes higher as Eh increases.

The effect of pH and redox potential on arsenic mobilisation from contaminated river sediments, mud and soil have been studied by Clement and Faust (1981), Mok and Wai (1990) and Masscheleyn et.al. (1991). In pH ranging from 2 to 11, release of Arsenite and Arsenate follow a pattern of substantial increase with decreasing pH. At lower pH values, metal ions (iron, manganese) get solubilized releasing arsenic. At high pH, the increased hydroxide concentrations displaced the arsenic species from binding sites in a ligand exchange type reaction.

Under oxidizing conditions (0.2 –0.5V), As(V) was found to be the major species with low solubility. A reducing condition (<0.1V) led to mobilisation, which was controlled by the dissolution of hydrous iron oxide. As(V) gets co precipitated with hydrous iron oxide and was released upon their solubilization. The amount of arsenic release was 10-13 fold compared to aerobic conditions with As(III) being the dominant species. The As(III) released under anaerobic conditions was due to the reduction of ferric to ferrous ions, liberating arsenic, which was reduced from As (V) to As (III).

Field data shows that the co-efficient of correlation between arsenic content and data content is somewhat low (0.31). Sulphate content too is low. Pumping tests conducted by CGWB reveals that arsenic content gradually decreased and stabilised within 4 hours of pumping. Water samples collected for Vedose zone by

CGWB indicates Arsenic content is below detectable limit, iron content is very low and phosphate content was less than 0.025 to 1.28mg/l.

CGWB, Calcutta and BARC, Mumbai after analysing a few representative water samples from arsenic prone tube wells in Murshidabad, Nadia and 24-Parganas districts have found that **both shallow and deep aquifers are generally mild acidic to alkaline. High arsenic (in shallow groundwater) is associated with high iron (ferrous), low sulphate, low chloride and low dissolved oxygen**. This indicates that a reduced environment and oxidation of arsenic bearing mineral might not be the mechanism of arsenic release into groundwater (Shivanna et.al. 1999).

In Murshidibad district groundwater from both shallow and deep aquifers are fresh to brackish in nature. Chloride content is low (18 to 96 mg/l) and iron concentration ranges between 0.1 to 7.0mg/l. Water is neutral in nature and pH values range from 6.9 to 7.4. In Nadia district groundwater is neutral to alkaline in nature; pH values range from 6,9 to 8.2. In 24 Parganas, both North and South, ground water is mostly neutral and their pH values are in the range of 6.6 to 7.5. Groundwater quality in the area is fresh.

2.5.2 Distribution of arseniferous aquifers

Based on studies carried out CGWB, Calcutta the distribution of arseniferous aquifers in the eight districts of West Bengal are tabulated below:

S.No	*District*	*Block*	*Depth of TW*	*As. Conc. range*
1.	*Malda*	*English Bazar. Manikchhak, Kaliachhak (I, II, III)*	*20 – 95 m*	*0.05 –1.43 mg/l*
2.	*Murshidibad*	*Raninagar (I, II), Domkal, Nowada, Jalangi, Hariharpara. Beldanga (I). Suti (I, II), Bhagwangola, Berhampur, Raghunathganj (II), Mur-jiaganj, Farakka.*	*20 – 100m*	*0.05 – 1.85 mg/l*
3.	*Nadia*	*Karimpur (I, II), Tehatta (I, II), Kaliganj, Nakashipara, Nabadwip, Hanskhali, Krishnaganj, Haringhata, Chakdaha, Shantipur, Chapra.*	*20 - 80m*	*0.05 – 0.77 mg/l*
4.	*24 Parganas (N)*	*Habra (I, II), Barasat (I, II), Deganga, Basirhat (I, Ii), Swarupnagar, Sandeshkhali II, Baduria, Gaighata, Rajarhat, Amdanga, Bagdah*	*20 - 80m*	*0.05 – 1.18 mg/l*
5.	*24 Parganas (S)*	*Baruipur, Sonarpur, Bhangore (I, II), Budge-Budge II, Bishnupur (I, II), Joynagar I, Mograhat II*	*20 - 100m*	*0.05 – 3.2 mg/l*
6.	*Barddhaman*	*Purbasthali (I, II)*	*20 – 40m*	*0.05 - .24 mg/l.*
7.	*Haora*	*Uluberia II, Shyamnagar II*	*20 - 50m*	*0.05 – 0.35 mg/l*
8.	*Hugli*	*Balagarh*	*20 – 40m*	*0.05 – 0.6 mg/l*

Exploratory drilling conducted by the Central Ground Water Board in the last few years in selected areas of arsenic prone blocks shows that it is possible to delineate arsenic free aquifers in some areas. Work was initiated in 8 blocks in three different districts. In most of the places the arsenic free aquifer has been delineated (100 – 250 meters below ground level) which has a thick layer of intervening clay. However, in some locations, the ground water contains arsenic beyond permissible limits even below the depth of 100m. Therefore, **the drinking water supply has to be delineated cautiously and all care should be taken, so that the arsenic rich groundwater of the upper aquifer does not get mixed up with the arsenic free aquifer below it.** In the northern part of Malda district the thickness of alluvium itself is restricted within 80 – 90m and as such it is difficult to get arsenic free water from deeper levels. In such cases alternate sources/ methods need to be adopted.

Periodic monitoring of arsenic contamination conducted by CGWB in parts of Nadia and North 24 Parganas district show that the **concentration of arsenic is at its peak during the period of April/ May, while its lowest concentration is in the month of August. The study also reveals that arsenic concentration is higher in the region of groundwater mound. The concentration is more where iron concentration is high but the reverse is not true. It has also been observed that with progressive pumping, the**

concentration of arsenic reduces while no such linear equation can be made out in respect of iron concentration.

The pH of groundwater, its chemical nature, movement through sediments and chemical characteristics of the aquifer are among the many determining factors that control the level of arsenic in groundwater.

2.5.3 Isotope studies

A collaborative programme between CGWB and Bhabha Atomic Research Centre, Mumbai was initiated in 1997 to study the dynamics of ground water in arsenic infested areas of Murshidabad, Nadia, South and North 24 Parganas. A number of water samples (ground water at various levels, surface waters and rains) were collected and analysed. The following findings are of interest to this study in the mitigation of arsenic from drinking water.

1. The Carbon-14 data show that the shallow ground water have values in the range of 87 to 109 pmC (percentage of modern Carbon) indicating that they have represented mostly modern recharge. (<50 years).
2. The deep ground water samples from Murshidabad have Carbon –14 value of 78-to 85-pmC giving model ages of <500 years.
3. Low sulphate, high ferrous and low dissolved oxygen contents in ground water indicate a reduced environment. Therefore, the anaerobic conditions leading to reduction of ferric ions seems to be the most plausible mechanism for the release of arsenic into ground waters of West Bengal.
4. High arsenic is confined to old river meander belts. (Eastern part of river Bhagirathi and beyond towards Bangladesh).

2.6 Surface water sources

The State of West Bengal has a generous sprinkling of large water bodies and is criss-crossed by rivers with their tributaries. It also receives very high rainfall with an average of around 2000mm. Unfortunately, there is no mechanism and infrastructure to store this water and utilise it when needed. Besides, most of the rainfall is restricted to a few months of the year thus causing more of destruction by way of flood and soil erosion. **Water quality analysis reports of surface water sources in high arsenic prone areas reveal that arsenic concentration in these cases is mostly below permissible limits**. Hence this alternate source could be utilised for drinking and cooking purposes if properly preserved and kept free from pollution. A tank spread over one acre of land can provide drinking water to about 1000 people throughout the year. (Proceedings: Workshop on Water Resources, 1992) **Studies show that even when depths of both dug well and tube wells, located side by side are almost the same, arsenic concentration is found to be more in tube well water than in well water.** (Dug well Survey Report During Feb.2001- SOES Jadavpur Univ.).

There are big and small water bodies throughout the State. In fact, there are a number of very big lagoons, which can provide household water to a large population in the problem districts. Instead, these lagoons are slowly getting filled up with waste and causing environmental pollution. **It is possible to make some selected surface water bodies functional in each of the problem villages and provide them with small efficient treatment processes to make the water potable.**

For centuries people have been using surface water sources, both large and small, to meet their drinking and cooking water demands. During the dry season the water availability is low and people face a water shortage crisis. After the rains, the available water gets polluted due to waste carried by rains. Common problems that prevail after the monsoons are dysentery, diarrhoea and an occasional bout of cholera. To combat this problem the hand pump mechanism was introduced in the villages. Over the years a lot of research and persistent marketing initiatives made the hand pump a part of every household in urban as well as rural areas. But as **water quality surveillance mechanisms failed to take off, it was very difficult to determine the quality of water being consumed.** Hence the arsenic problem slowly crawled in without notice.

But the surface water and dug well sources cannot be used as such. These are to be properly preserved as sanitary wells, disinfected on a regular basis and personal hygiene methods need to be drastically improved. Only strong advocacy coupled with active community participation can convert these sources into dependable and functional sources.

3. WATER QUALITY AND TREATMENT

Arsenic is prevalent in both inorganic and organic forms in surface as well as groundwater. But in West Bengal it has been more or less established that the source of arsenic in water is geogenic and other elements present alongside it play a prominent role in its reduction and elimination. This makes it essential that we understand the exact forms of the element present in groundwater.
The redox potential of the aquatic environment determines whether arsenic present will be Arsenite (III) or Arsenate (V). As(V) is predominant in surface water whereas As(III) prevails in anaerobic conditions, mainly groundwater. However, when groundwater is pumped out and it comes in contact with the atmosphere some part of the existing arsenite gets converted into arsenate.
The species of arsenite and arsenate present in water depend on the pH value of water. The dominant species under natural water (pH 6-9), for example, are $H_3 AsO_3$, $H_2AsO_3^-$, $HAsO_3^{2-}$ and AsO_3^{3-} for As^{+3} and $H_3 AsO_4$, $H_2AsO_4^-$, $HAsO_4^{2-}$ and AsO_4^{3-} for As^{+5} respectively.

3.1 Raw Water Quality

To adopt the technologies available for arsenic mitigation it is essential to understand the quality of raw water. Hence, samples were taken from several wells in five arsenic affected districts and analysed by the Central Ground Water Board. The full text of the CGWB report is enclosed in the Appendix.

3.1.1 Malda District

Here the groundwater is exceptionally hard and slightly alkaline but does not contain excess of dissolved solids by Indian Standards. The principal ions are calcium and magnesium bicarbonates with alkalinity values up to 560 mg/l as $CaCO_3$, a proportion of which is usually sodium. Conductivity values vary from 580 to 1000 µS/cm, which is acceptable for potable water. Chloride, fluoride and sulphate concentrations are low. Silica concentrations (in reactive form) are quite high ranging from 20 to 30 mg/l and could interfere with certain arsenic removal processes.

Arsenic concentrations in the two samples reported were 0.17 and 0.16 mg/l as As, that is significantly in excess of the Indian Standards of 0.05 mg/l. Iron was also present at very high values in the same samples with concentrations of 3.38 and 6.68 mg/l as Fe. The Indian Standard is 1.0 mg/l. In addition, eight samples were examined for heavy metals. Of this aluminium, cadmium, chromium and copper were present in low concentrations while zinc levels were moderate but not excessive. Lead was present at levels of up to 10 µg/l as Pb, which is less than the Indian Standard. Manganese was also present at excessive concentrations with average and maximum values of 875 and 1248 µg/l as Mn. The Indian Standard value is 0.5 mg/l.
Dissolved oxygen concentrations were consistently low at less than 1.0 mg/l, a common characteristic of groundwater containing iron and manganese.

3.1.2 Murshidabad District

The water here is very hard and slightly alkaline with respect to pH, and contains high but not excessive levels of dissolved solids as indicated by conductivity values that were within the range 565 to 750 µS/cm. The principal ions are calcium and bicarbonate with typical values of 90 mg/l Ca and 280 mg/l $CaCO_3$ respectively. Chloride and sulphate values are consistently low, but silica (reactive) concentrations are moderately high at 18 to 24 mg/l.

Arsenic concentrations ranged from 0.266 to 0.3 mg/l as As in the three samples examined. Iron was present at exceptionally high concentrations--up to 10.2 mg/l. Two samples were examined for heavy metals. Results indicate that aluminium, cadmium, chromium, copper and lead were present in trace amounts, while zinc was present at moderate, but not excessive levels. Manganese was present at 760 µg/l, which is in excess of the Indian Standard.
Dissolved oxygen concentrations were very low at less than 1 mg/l

3.1.3 Nadia District

The groundwater in this region is exceptionally hard and just on the alkaline side of neutrality with respect to pH value. It contains high, although not excessive, concentrations of dissolved solids, as reflected by conductivity values that range from 770 to 1180 µS/cm. The principal ions are calcium and bicarbonate, together with moderate concentrations of magnesium, chlorides and sulphates. Silica is also present at a moderately high level ranging from 23 to 25 mg/l.

Arsenic concentrations varied from 0.082 to 0.96 mg/l as As in the three samples examined. Iron was present at exceptionally high concentrations up to 12.5 mg/l as Fe. Two samples were examined for heavy metals. Results indicate that aluminium, cadmium, chromium, copper, lead and zinc were either undetected or present at very low concentrations. Manganese was, however, present at values up to 870 µg/l as Mn. Dissolved oxygen concentrations were again low at less than 1 mg/l.

3.1.4 North 24 Parganas District

Here again the water is exceptionally hard and slightly alkaline with respect to pH value. It contains high but generally not excessive levels of dissolved solids as indicated by average conductivity values of 840 µS/cm. The maximum reported value of 1830 µS/cm equates to a TDS concentration of about 1200 mg/l. It is within the Indian Standard. The principal ions are calcium and bicarbonate with average values of 115 mg/l as Ca and 370 mg/l as $CaCO_3$ respectively. Chloride concentrations are moderately low while sulphate values rarely exceed 10 mg/l as SO_4. Silica (reactive) is present within the range 20 to 37 mg/l, which is considered to be moderately high.

Arsenic concentrations in tube wells range from 0.05 to 2.34 mg/l and average around 0.49 mg/l. Iron concentrations are very high in ranging from 1.38 mg/l to 15.98 mg/l as Fe (average 7.66 mg/l as Fe).

Approximately 30 samples have been examined for a range of heavy metals, of these cadmium, chromium and copper were only present in trace or undetectable concentrations. Aluminium is consistently present at values in the range 20 to 150 µg/l as Al, with an average of 60 µg/l. Lead was generally undetectable; however, one sample contained 12 µg/l, which is still less than the Indian Standard. Manganese was consistently present in each of the samples examined; with a concentration range from 27 to 1756 µg/l. Dissolved oxygen concentrations were very low at less than 1 mg/l.

3.1.5 South 24 Parganas District

The water is exceptionally hard and slightly alkaline with respect to pH value, and contains high but generally not excessive levels of dissolved solids as indicated by an average conductivity value of 940 µS/cm. Approximately 10% of the well waters have conductivity values slightly in excess of 1500 µS/cm. The increase in dissolved solids is probably due to an increase in saline constituents because of the proximity to the coast. The principal ions are generally calcium and bicarbonate with average values of 106 mg/l as Ca and 395 mg/l as $CaCO_3$ respectively. Chloride concentrations are high in some locations with average and maximum values of 42 and 152 mg/l as Cl. Silica (reactive) concentrations are also quite high with a range from 18 to 32 mg/l as SiO_2.

Arsenic concentrations in tube wells range from 0.01 to 2.9 mg/l (average 0.50 mg/l). Iron concentrations are moderately high in varying from 0.01 to 5.38 mg/l with an average of 1.35 mg/l as Fe.

Cadmium, chromium, copper and lead are present in trace concentrations, while aluminium is generally present at acceptable levels with an average value of 90 µg/l as Al. However, two samples recorded concentrations of 280 µg/l in excess of the Indian Standard of 200 µg/l as Al. Manganese was present in each of the samples with a concentration ranging from 94 to 1156 µg/l as Mn and an average of 556 µg/l. The concentrations exceed the Indian Standard. Dissolved oxygen concentrations were low at less than 1 mg/l.

3.2 Correlation with Iron

The presence of iron alongside arsenic in both soil and water indicate the coexistence of the two elements. The distribution of iron and arsenic in the borehole soil in the highly affected areas show that concentrations of both are higher in upper layers of the soil and decrease with depth. **Iron present in groundwater appears to exert a strong influence in mobilisation and transportation of arsenic in the subsurface.** Although the concentrations of arsenic and iron in groundwater do not always correlate, more than permissible arsenic concentrations have been found to be closely related with substantial iron content. But the inverse is not always true.

In the arsenic removal technologies available in the field, **Ferrous ion (Fe^{2+}) quickly gets oxidized to ferric ion (Fe^{3+}) and forms ferric hydroxide flocks. These flocks get filtered through the media and slowly block them, reducing the flow rate rapidly. This greatly diminishes the efficiency of adsorption.** Hence any arsenic removal technology should seriously consider iron removal technology as its pre-treatment.

All the water samples collected for study contained exceptionally high concentrations of iron, some of which get oxidised when the water is exposed to air. To maximise iron removal water should be properly aerated. A proportion of As (V) would be removed with iron by co-precipitation. The addition of **an oxidant such as chlorine in sufficient concentrations would not only help to oxidise any As (III) present to As (V), but also reduce iron concentrations to very low levels. It would also oxidise any manganese, perhaps in conjunction with the catalytic media filtration. With such concentrations of iron and manganese, a settling or filtration stage, or both, would be necessary to remove the precipitate derived from iron. With a filter alone, it could require very frequent backwashing as the adsorbent would become clogged in a short period.**

3.3 Suitability pointers

All waters are suitable for arsenic removal treatment by chemical precipitation using aluminium sulphate and ferric chloride. In the case of the former, an excess of aluminium sulphate would be necessary to achieve the optimum pH for precipitation.
The pH values of the water samples are within the acceptable operating range for most adsorption processes, particularly with activated alumina or granulated ferric hydroxide. **The presence of silica however, reduces the performance of the activated alumina process if operated at the ambient raw water pH values.** The concentration of phosphates in raw water is not sufficiently high to influence the performance of either of the absorption processes.
The total concentration of dissolved solids in the water is too high for ion exchange processes to operate economically, even though the proportion of sulphates is very low.

3.4 Treatment Objectives

Water containing arsenic should be treated in order to reduce concentrations of the element to values defined in the Indian drinking water quality standards. The Manual on Water Supply and Treatment (Ministry of Urban Development, Government of India 1999) specify two values: 'Acceptable' - 0.01 mg/l (10µg/l) as As, the limit up to which water is generally acceptable to the consumers and 'Cause for rejection' - 0.05 mg/l (50µg/l) as As, the value in excess of that mentioned under 'Acceptable' which renders the water unacceptable, but still may be tolerated in the absence of an alternative better source, but only up to the limits indicated, above which the source will have to be rejected.

Indian standards, like drinking water quality standards of many countries are set on the basis of guidelines defined by the World Health Organisation (WHO). These values have become more stringent with time due to a better understanding of the toxicological effects of various chemicals and substances and developments in analytical methods that permit the accurate determination of much lower concentrations. For example, values for arsenic have varied from 0.2 mg/l (200µg/l) as As in 1958 (WHO; 1958); 0.05 mg/l (50µg/l) as As in 1984 (WHO; 1984) and 0.01 mg/l (10µg/l) as As in 1993 (WHO; 1993). The value given in 1993 'Guideline Values for Drinking Water' is only a provisional value.

The WHO Guideline value for arsenic in drinking water is based on the 'provisional maximum tolerable daily intake' of inorganic arsenic assuming that 20% of it is from drinking water. This varies from country to country and even from region to region within a country depending on the climate, dietary habits of the local population and socio-economic factors. Therefore, when applying WHO Guideline Values to local situations, these issues should be given ample consideration. **Studies should be undertaken to establish the maximum tolerable arsenic concentration in drinking water that is acceptable to the population in West Bengal.** Until such values are established, the immediate objective is to treat the water to an arsenic concentration below 50 µg/l as As, which is presently accepted by state agencies.

Besides India there are about 20 other countries where arsenic is found in drinking water concentrations in excess of about 50µg/l. In some developed countries it has recently become a matter of grave concern because of the very low values specified in updated national drinking water quality standards. Standards set by countries with a serious arsenic problem, various foreign regulatory bodies and some international agencies are given below for comparison.

Table 3.1: Standards for arsenic in drinking water

Country/regulatory body/ International agency	Concentration as As/remarks
India (CPHEEO, MoUD)	0.01 mg/l (acceptable) 0.05 mg/l (cause for rejection)
Bangladesh	0.05 mg/l
Japan	0.01 mg/l
Finland	0.01 mg/l
Chile	0.05 mg/l (0.01 mg/l is being considered) (Kercher, 1999)
China (National Standard GB5749-85)	50 µg/l
Taiwan	50 µg/l
Argentina (Argentine Food Codex)	0.05 mg/l (maximum authorised concentration (Madiec, 2000)
Mexico	0.05 mg/l (maximum contaminant level) (Simeonova, 2000)
UK (Water Supply (Water Quality) Regulations, 1983)	50 µg/l 10 µg/l (compliance scheduled for end of 2003)
Germany (DIN, 1996)	10 µg/l (Jekel, 2000)
US Environmental Protection Agency, (US EPA; 1975)	50 µg/l (maximum contaminant level) (Comments requested at 3 - 20 µg/l by 2006)
Council of European Communities (CEC; 1998)	50 µg/l 10 µg/l (compliance scheduled for end of 2003)
WHO (1993) guidelines	0.01 mg/l (provisional)
Australia (National Health and Medical Council; 1996)	0.007 mg/l
New Zealand (Ministry of Health; 2000)	0.01 mg/l

3.5 Arsenic Removal Methods

As mentioned earlier ease of arsenic removal depends on its form in water. As(III), which is much more prevalent in groundwater, is difficult to remove because it exists predominantly in the non-ionic form as H_3AsO_3, $H_2AsO_3^-$, $HAsO^{2-}_3$. Whereas with As(V) which is the dominant form in surface water, removal is relatively easy as it exists as the monovalent $H_2AsO_4^-$ ion or bivalent $H_2AsO_4^{2-}$ ion. Therefore, the oxidation of As(III) to As(V) improves the effectiveness of arsenic removal.

There are several treatment methods available for the removal of arsenic in waters for potable use. They include: -

- Chemical precipitation;
- Adsorption;
- Membrane; and
- Biological processes.

Since As(V) is the easier of the two forms to remove, whenever As(III) is present an oxidation stage usually precedes most of the recognised treatment processes.

Oxidising Agents

The kinetics of As(III) oxidation by aeration or other similar oxygen addition processes is very slow and could take several weeks under normal conditions. Strong alkaline and acid conditions, presence of copper salts, carbon and high temperature help in increasing the rate of reaction. The rate of reaction also increases rapidly by the presence of iron and manganese oxides and hydroxides, which has been observed in the subterranean removal of arsenic. The oxidising agents most effective in the oxidation of As(III) to As(V) are chlorine, sodium or calcium hypochlorite, chlorine dioxide, potassium permanganate, ozone and hydrogen peroxide in the presence of ferrous ions, the so-called Fenton's reagent. Hydrogen peroxide forms hydroxyl free radicals in the presence of ferrous ions, which is known to promote the oxidation reaction.

The use of chlorine or hypochlorites for oxidation could result in the formation of trihalomethanes (THM) from reactions with natural organic matter, which are known to be harmful. Chloramines do not oxidise As(III). Therefore when ammonia is present in water, breakpoint chlorination should precede the process in order to remove ammonia and ensure free chlorine presence for the oxidation stage.

Chlorine dioxide is produced on site by the reaction between sodium chlorite and chlorine, or hydrochloric acid or aluminium sulphate. The reaction also produces chlorates and chlorites by disproportion, by-products which are considered harmful. Chlorine dioxide does not react with natural organic matter to form THM. It could also be used when ammonia is present, as it does not react with ammonia.

Potassium permanganate is an effective oxidant, but it forms a brown, muddy precipitate of manganese dioxide, which has to be removed by filtration. Care should be taken to control the dose accurately as over-dosing adds a pink colour to the water. Ozone is not preferred solely for arsenic oxidation because of its high capital and operating costs.

The weight of oxidant required per unit weight of As(III) depends on the presence of Fe (II) and organic matter as they too demand an oxidant. By using potassium permanganate to oxidise As(III), satisfactory results have been achieved with 1.26 mg potassium permanganate for 1 mg of As(III). The reaction was rapid and oxidation was independent of pH in the range 6 to 8.

Laboratory studies have concluded that **chlorine, potassium permanganate and ozone were very effective in oxidising As(III) to As(V) in the pH range 6.3 to 8.3 in the presence of dissolved iron and manganese.** Chlorine dioxide was not very effective. In-situ produced chloramines oxidised only 40% of As(III). The studies conducted elsewhere also demonstrate that the presence of sulphide retarded the oxidation process using chlorine, permanganate or ozone, although greater than 95% oxidation was still possible. Total organic carbon had no effect on chlorine and permanganate oxidation. Ozone oxidation was delayed due to the reaction with total organic carbon.

3.5.1 Chemical precipitation process

Chemical precipitation is the most effective and widely practised method for removing arsenic, particularly in large-scale water treatment plants.

Best removals are achieved for As(V). Both ferric and aluminium salts are considered to be suitable. Removal is by co-precipitation and adsorption with freshly precipitated aluminium or ferric hydroxides. **Iron salts perform better than aluminium in arsenic removal. This is so because all of the Fe added precipitates as hydroxide whereas not the entire Al dosed forms aluminium hydroxide**. This difference is due to the effect of pH on the precipitation reaction. The capacity of iron (III) and aluminium (III) hydroxides to remove arsenic could be reduced by other ions, in particular phosphates in the water. In such cases a higher dosage of aluminium or iron salt would be necessary to achieve equivalent removal efficiencies.

The normal pH range for aluminium hydroxide precipitation is within 6.5 to 7.5. Outside this pH band aluminium hydroxide dissolves to form soluble aluminates (pH>7.5) and other soluble salts such as chlorides and sulphates (pH <6.5). **Ferric hydroxide is less sensitive to pH changes and precipitation reaction could be carried out over a wider pH range (pH 4 to 10).** Ideally 'jar tests' should be carried out to optimise treatment chemistry (i.e. aluminium or iron salt dose and pH) to ensure low soluble aluminium or iron residues in water.

In a full scale plant the influence of the increase in dose for arsenic removal was clearly demonstrated. It showed average arsenic removals of 82, 89, 86, 94 and 96% using ferric chloride doses of 3, 4, 5, 6.5 and 10 mg/l respectively, while aluminium sulphate doses of 6, 10 and 20 mg/l produced removal efficiencies of 23, 24 and 69% respectively. In the same plant turbidity removal averaged 93.9% in the ferric chloride test and 97.1% in the aluminium sulphate test (Scott et al; 1995). Many workers have reported increase in As(V) removal by increasing the coagulant dose. **In general greater than 90% As(V) removal can be achieved by aluminium salts at pH values <7 and by ferric salts at pH values <8.5** (AWWA; 1988).

High removal efficiencies are reported in laboratory tests when ferric chloride is used with hydrated lime; in a full-scale plant comprising clarification and granular activated carbon, adsorption removal efficiencies of 97 to 98% were obtained.

In ground waters As(III) usually co-exists with iron in its reduced form Fe (II). Arsenic is removed along with iron by mechanisms of adsorption and co-precipitation. Soluble As(V) removal during oxidation of Fe (II) is very significant. At a full-scale treatment plant, oxidation of Fe (II) at concentrations greater than 1.5 mg/l resulted in 80 to 95 per cent removal of As(V). Removal efficiencies for As(V) by aluminium and ferric salts and As(III) by ferric salts are considered to be independent of the initial arsenic concentration (Hering; 1997). Of the ferric salts, both ferric sulphate and ferric chloride have been successful. Ferric Chloride, though highly corrosive is more commonly used because being a by-product of the steel industry it is cheaper than ferric sulphate. Also because hydrogen ions formed in the hydrolysis reaction regulate the coagulation pH better.

Of the aluminium salts, work to date has concentrated primarily on aluminium sulphate. Removal efficiencies using polymerised aluminium salts such as polyaluminium chloride, polyaluminium silicate sulphate or polyaluminium chlorohydrate have not been thoroughly investigated. They could offer better prospects because of their wider operating pH band.

As(V) is also effectively removed by lime softening depending on the operating pH (Sorg and Logsdon; 1978). During softening at about pH 9.0 (to remove calcium hardness only), As(V) removal was only up to 10%. At pH values in the range 10 to 11 when the total softening process to remove both calcium and magnesium hardness is affected, As(V) was reduced from values in the range 100 to 300 µg/l to 1 to 5 µg/l in laboratory tests and pilot plants (Sorg; 1993); in a full scale treatment works the reduction varied in the range 60 and 95%.

Overall, the process for arsenic removal by chemical precipitation comprises the following stages as outlined in Table 3.2: -

Table 3.2: Different stages in Arsenic removal process

Process	***Function***
Oxidation (where necessary)	*Converts As(III) to As(V)*
pH adjustment	*Facilitates Fe (III) or Al (III) hydroxide formation*
Addition of Fe (III) or Al (III) salt	*Adsorption and co-precipitation*
Sedimentation (where necessary)	*Removal of precipitates and other suspended solids*
Filtration	*Removal of precipitates and other suspended solids*

Arsenic removal depends on the efficiency of the individual process stages. Sub-processes such as mixing of chemicals in water and the control of pH within optimum ranges (in particular for Al (III) salts), also assume importance. Mixing efficiency in oxidising, pH correction and precipitation of chemicals in the receiving water are crucial to the removal process. Good mixing also helps reduce the cost of chemicals. A good control parameter for optimum pH is the concentration of soluble aluminium or iron residuals present in the water before or after the solid-liquid separation stages. This should ideally be of the order of 0.02 mg/l as Al or 0.05 mg/l as Fe. After precipitation, the efficiency of the downstream solid-liquid separation processes, which could include direct filtration or clarification followed by filtration, becomes important in the removal of arsenic.

The use of the optimum coagulation pH is essential to minimise soluble residual aluminium or iron concentrations and maximise aluminium or ferric hydroxide precipitation. Efficient suspended solids separation is essential to reduce the breakthrough of arsenic containing floc. Experience at operational plants shows that there is a greater risk of arsenic breakthrough with aluminium salts than with ferric salts due to high aluminium solubility and flock stability

In groundwater treatment the flock formed in the absence of turbidity would primarily be a chemical flock, which is fragile. This is more difficult to remove efficiently by conventional solid-liquid separation processes, normally limited to a media filtration stage. In these cases more efficient membrane filtration of the microfiltration or ultrafiltration type should be considered (see Membrane Processes). For small-scale treatment cartridge filters could also be used.

3.5.2 Adsorption process

Arsenic can be removed by adsorption on to several types of material which include activated alumina, ion exchange resins, granulated ferric hydroxide, activated carbon, activated bauxite, hematite, laterite, iron or manganese coated sand, iron filings and greensand. In this water containing arsenic passes through a column of the media. Arsenic is adsorbed on to the media and when the media is exhausted as indicated by rising concentration of arsenic in the effluent, it is regenerated for further use or replaced with fresh media. Adsorption processes are primarily applied to groundwater because they contain low turbidity that could otherwise clog the bed. When they are applied to surface waters or turbid groundwater, pre-treatment, which should include filtration should precede the process.

Activated alumina

Activated alumina is aluminium oxide prepared by thermal dehydration of aluminium hydroxide (e.g. gibbsite, bayerite, etc). The most common type of activated alumina used in adsorption processes is the γ(gamma)-alumina, which is prepared by dehydration at 450°C. Its zero-point discharge pH at 8.2 is higher than for most mineral oxides. Therefore, it has good adsorption properties towards several anions in water around pH 7.0.

Activated alumina is a very effective agent for removing arsenic; As(V) more than As(III) (Gupta; 1978). Some manufacturers have achieved very high removal of As(III) by using iron coated activated alumina. Therefore, a pre-oxidation stage may not be necessary in these cases. Major factors that influence the removal of arsenic are pH and competing ions in the following decreasing order of selectivity in the pH range 5.5 to 8.5 (Clifford; 1991):

$$OH^- > H_2AsO_4^- > H_3SiO_4^- > F^- > SO_4^{2-} > HCO_3^- > Cl^- > NO_3$$

The other competing ion not included in the above sequence is phosphate (PO_4^{3-}), which is considered to be as selective as $H_2AsO_4^-$ and F^-. Activated alumina is used to remove both phosphate and fluoride in water. Of the competing anions, silicates are the most influential in reducing the adsorption capacity of both As(V) and As(III). Silicates prefer to adsorb on activated alumina with maximum effect at pH 9. At pH values of 6 to 6.5 used in arsenic removal, interference from silicates is not appreciable. Sulphate and bicarbonate ions cause marginal reduction in As(III) and As(V) adsorption at pH values less than 7. The presence of phosphate ions at concentrations greater than 5 mg/l as P is known to cause an appreciable reduction in As(III) adsorption at pH greater than 6 and in As(V) at pH greater than 7 (Azizan; 1999). Chloride and nitrate concentrations are usually too low to have any influence on arsenic adsorption on activated alumina. The presence of calcium ions is known to enhance the adsorption of As(III) at pH values greater than 6 and of As(V) at pH values greater than 8 (Azizan; 1999). Activated alumina, unlike ion exchange does not show marked chromatographic peaking.

When an activated alumina bed is exhausted it is regenerated to restore its adsorption capacity. The regeneration process usually consists of desorption of arsenic with sodium hydroxide in downflow mode, followed by a downflow water rinse and then an upflow acid wash to neutralise excess sodium hydroxide and to achieve protonation by converting alumina to the chloride form, and finally a water rinse.
When the feed water contains suspended solids due to turbidity or oxidised iron, a water backwash usually precedes the regeneration cycle. The regeneration process is known to recover over 85% of the adsorptive capacity of virgin activated alumina with no further appreciable reductions in subsequent regenerations.
There are two types of activated alumina. The standard type is manufactured in many countries including India. Indian material is currently used in a design developed by Bengal Engineering College. Apyron uses US material in West Bengal. Alcan Chemicals also manufacture a similar product in the UK. The adsorptive capacity of the standard product typically varies between 15 to 17g As/kg adsorbent.

Activated alumina is primarily used in the treatment of groundwater. When water contains high turbidity or iron concentrations, pre-oxidation and filtration stages are desirable to remove turbidity or ferric hydroxide precipitate; alternatively activated alumina adsorbers need to be backwashed regularly to minimise rapid head loss development, particularly when using finer media.

Ion exchange resins

Arsenic is removed effectively by strong-base anion exchange resins of the chloride form. As with activated alumina As(V) which is present as monovalent $H_2AsO_4^-$ and divalent $H_2AsO_4^{2-}$ in the pH range 6 to 9 is removed by ion exchange resins; removal of As(III) occurs only at a pH greater than 9.2 when monovalent arsenite ion $H_2AsO_3^-$ predominates. At neutral pH, As(III) is present as H_3AsO_3 (arsenous acid) which is non-ionic and is poorly adsorbed.
In this process arsenic is exchanged for chloride and therefore the competition by other anions present e.g. sulphates, bicarbonates, nitrates in the water is extensive. The selectivity of major ions for adsorption in the decreasing order is as follows (Clifford; 1991):

$$SO_4^{2-} > HAsO_4^{2-} > CO_3^{2-} > NO_3^- > Cl^- > H_2AsO_4^- > HCO_3^- >> H_3AsO_3$$

The process is therefore considered to be uneconomical for waters containing total dissolved solids greater than 500 mg/l or sulphates greater than 25 mg/l (Clifford; 1991), although it may be practical

for sulphate levels up to 120 mg/l. Ion exchange produces nearly 100% As(V) removal. The presence of sulphates however reduces adsorption capacity significantly. Ion exchange therefore tends to produce significantly lower volumes of treated water between regenerations than activated alumina.

Once exhausted the resin is backwashed and regenerated with a concentrated solution of sodium chloride followed by a water rinse to displace the regenerant. In the regeneration process the adsorbed As(V) ions are replaced by chloride ions. The minimum sodium chloride concentration is about 5% $^{w}/_{v}$ (50 g/l).

The ion exchange process requires pre-treatment to remove turbidity and precipitated iron as they foul the resin and clog the columns resulting in a rapid development of head loss. Resins are also susceptible to residual chlorine, organic carbon and bacterial contamination. Chlorine, if used for oxidation of Fe(II), should be removed by sodium bisulphite or similar product ahead of the ion exchange column.

Granular ferric hydroxide

Granulated ferric hydroxide is an adsorbent developed specially for arsenic removal. It has a larger capacity for arsenic compared to activated alumina in the same way as it has been demonstrated in the precipitation reactions where ferric salts remove arsenic better than aluminium salts. It is reported that arsenic is adsorbed on amorphous ferric hydroxide about 3 to 10 times more efficiently than on activated alumina (Pierce and Moore; 1982).

The material is apparently produced at present by three manufacturers, one in Germany (GEH Wasserchemie GmbH & Co), one in Canada (ADI Group, Inc) and the other in Finland (Kemira).

The adsorption process is pH dependent, its capacity decreasing with increasing pH. The optimum operating pH range is 5.5 to 8 (Pal; 2000). Unlike activated alumina, anions, except orthophosphate do not interfere with the adsorption process. Turbidity in water is effectively removed in the adsorber but results in the rapid development of head loss because of the small particle size of the media used. Any iron present as ferric hydroxide would also be similarly removed. It is suggested that in order to minimise excessive mechanical loads the adsorber should be backwashed frequently. Using a pre-filter when turbidity and iron values in raw water are high would be helpful. When iron is present in the ferrous form, oxidation using chlorine, potassium permanganate or ozone, followed by filtration through a filter containing a catalytic manganese dioxide media is usually used. The ferric hydroxide precipitate formed is removed in the filter. Oxidised iron could remove up to 70% of arsenic by co-precipitation and adsorption, depending on the concentration of iron in raw water.

The adsorber is normally operated at volumetric surface loading rates in the range 15 to 20 $m^3/hr\ m^2$. The empty bed contact time is usually 3 to 6 minutes depending on the inlet and outlet arsenic concentrations, required bed-life, exhaustion and cost. Once exhausted, the media cannot be readily and economically regenerated and is therefore discarded.

Activated carbon

Granular activated carbon (GAC) is known to remove arsenic to some degree depending on the pH of raw water. As(V) is best removed at low pH values (typically 4 to 5) when arsenic is negatively charged and GAC is positively charged (Gupta and Chen; 1978). As(III) is removed at pH values above 9.2 when it is negatively charged. Tests carried out by The All India Institute of Hygiene and Public Health using GAC showed that although GAC could be used to remove arsenic, it is not economically viable due to the large quantity required. Adsorption and the rate of removal of As(V) could be improved significantly in the presence of ferrous ions. Tests on a small water filtering system comprising oxidation by chlorine, chemical precipitation by ferric chloride at an Fe:As ratio of 4:1 at pH 7 showed 90% arsenic precipitation. GAC is regenerated by stripping the adsorbed arsenic with a strong acid or base and further treating it with a ferrous salt (Huang and Fu; 1984).

Jadavpur University, Calcutta, used activated charcoal in combination with a ferric salt and an oxidising agent to prepare a tablet that would remove arsenic in 'point-of-use' applications. Apparently, when the tablet is added to arsenic containing groundwater, it turns black due to the breakdown of the tablet. The contents, when filtered through a special candle filter made from fly ash, clay and charcoal, gave significant arsenic removal. It is not evident whether activated charcoal plays a role in the removal of arsenic since the ferric salt primarily removes it.

Other iron based materials

Iron oxide or manganese oxide coated sand or manganese greensand removes arsenic by adsorption. It has been shown that manganese greensand outperforms iron oxide coated sand in As(III) removal

(Viraraghavan et al; 1999). For optimum performance the former required an Fe: As ratio of 20:1; As(III) concentration was reduced from 100 µg/l to 25 µg/l.

The feasibility of using **haematite** (an iron ore containing Fe_2O_3) has been studied for As(III) removal. A 96% removal was reported with an influent concentration of 1.0 mg/l at pH 7.0 and 20°C (Singh et al; 1988. The haematite used had a particle density of 3.89 kg/l and size 0.88 to 1.0mm. A manganese zeolite column to remove any arsenic slippage followed the hematite column. The water tested contained 0.62 to 0.875 mg/l arsenic, about 0.5 mg/l iron and up to 0.4 mg/l manganese.

A two stage adsorption/filtration system consisting of a coarse sand and iron chip filter followed by a wood charcoal and fine sand filter has been successfully tested in Bangladesh (Khan et al; 2000). It is claimed that As(III) was almost completely removed from an initial concentration of 0.8 mg/l and the total arsenic concentration was reduced from about 1.0 mg/l to less than 0.01 mg/l.
Laterite soil (composed mainly of hydrated iron and aluminium oxides and hydroxides) has been used in a filter column together with Fe_2O_3/MnO_2 in an adsorption/filtration process developed by Jahangirnagar University (British Geological Society; 1999). A granular filter medium developed from a mixture of laterite soil/Fe_2O_3/MnO_2 was used. The mixture was treated in a furnace with temperature of 1400°C and the resulting bricks were broken down to suitable size granules and chemically treated to maximise its arsenic removal properties for a feed water containing 1.8 mg/l arsenic at 250 ml/min. The column has a daily capacity of 30 litres and theoretical life to exhaustion of 2 years, after which the media is thrown away. It claims to remove both As(III) and As(V).

3.5.3 Membrane process

In this a semi-permeable membrane is used to separate materials in accordance with their physical and chemical properties while a pressure differential or electrical potential difference is applied across the membranes. Pressure driven processes are broadly classified according to the membrane pore size and size of particles removed. Reverse osmosis and nano-filtration, which is also known as low pressure reverse osmosis, employ the osmosis principle to separate ions.

Chemical precipitation with iron or aluminium salts followed by microfiltration or ultrafiltration can remove arsenic more efficiently. Primary design parameters are membrane flux, trans-membrane pressure and backwash and chemical cleaning frequencies. Membrane flux for micro and ultrafiltration systems ranges between 80 to 200 $l/h.m^2$ and trans-membrane pressure varies in the range 0.1 to 1.0 bar, depending on the type of membrane and feed water quality. Once a particle layer has formed on the membrane surface, it must be cleaned by backwash with water. In practice, depending on the feed water quality, backwash frequency ranges from 30 minutes to 3 hours and the duration ranges between 3 seconds to 3 minutes. Feed water recovery varies between 85 and 98% depending on the water quality.

Membranes are commonly made of polyethersulphones, cellulose acetate, polypropylene, or polyvinylidine difluoride. Of these, all but polypropylene have a high chlorine tolerance and all are suitable for operating at pH values normally found in raw water.

Nanofiltration and reverse osmosis achieve arsenic removal by ionic separation. In nanofiltration, rejection of monovalent ions (Na^+, K^+, Cl^-) is poor (40 to 70%), whereas rejection of multivalent ions (Ca^{2+}, Mg^{2+}, SO_4^{2-}) or ionic compounds is comparatively high (85 to 95%). Reverse osmosis rejects all dissolved salts at an efficiency of 90 to 98%. The removal of As(V) by reverse osmosis is almost proportional to the efficiency of sodium chloride removal (Kang et al; 2000). Early work has shown reverse osmosis membranes of cellulose acetate or aromatic polyamide thin-film composite construction reject As(V) more efficiently (90 to 99%) than they reject As(III) (46 to 75%).

Reverse osmosis and nanofiltration membranes require feed water of high quality. The presence of turbidity, organic matter, iron, manganese and bacteria could foul the membranes irreversibly, and unlike micro or ultrafiltration membranes they cannot be backwashed. Iron and manganese, when present, should either be totally removed upstream of the membranes or maintained in their reduced states by keeping the feed water anaerobic until the water has passed through the membranes. Organic matter should be removed by granular activated carbon adsorption.

3.5.4 Microbiological process

Arsenic could be removed by co-precipitation or be adsorbed on to ferric oxide produced by biological oxidation of ferrous ions in groundwater. Bacteria which can bring about the oxidation are *Gallionella ferruginea, Leptothix sp., Crenothrix polyspora* and *Sphaeratilus natans*. If the bacteria are absent from groundwater they could be introduced from a suitable source. Rapid gravity or pressure sand filters could be used as biological reactors.

Pilot plant work by Lehimas et al demonstrated that the critical parameter for arsenic removal is the initial iron concentration. For waters containing 8 to 12 mg/l Fe, a 90% As(III) removal was achieved at an initial concentration of 400 µg/l. In addition, iron was totally removed. With low iron concentrations (1 to 2 mg/l Fe) the removal was poor with 36 to 44% removal.

Bacteria that can be used to oxidise As(III) to As(V) in the presence of oxygen and alkalinity have been isolated in Australian mine waters by Macy and Dixon. One type of bacteria grows only in the presence of a small concentration of organic carbon. In laboratory tests using fluidised bed reactors over 99% of As(III) with an initial concentration of 3.0mg/l was converted to As(V), which was then removed by adsorption on to ferric hydroxide or ferromagnetic beads coated with ferric hydroxide (Macy and Dixon; 1998).

3.6 Precautions while sampling

At the concentrations found in surface and groundwater arsenic compounds are colourless, odourless and tasteless and are not easily detectable by simple chemical techniques. However, a number of instrumental methods, which permit the detection of arsenic at concentrations down to 1 µg/l or less, are available. Such equipment is expensive and only available in laboratories of repute.

Arsenic (V) may be co-precipitated with iron (Fe^{2+}) when groundwater comes into contact with air while sampling. It is therefore important that the appropriate precautions are taken when samples are collected, particularly if the analysis is not to be carried out within a few hours of sampling. The use of a number of preservatives has been investigated for use with samples intended for the analysis of arsenic in water. These include hydrochloric, nitric, sulphuric and ascorbic acids. A number of other compounds or ions can interfere with the determination of arsenic; these include hydrogen sulphide, chloride, phosphate, nitrate, sulphate or iron.

3.6.1 Analytical Technique applied for Arsenic Determination

Several methods are available that can be relied upon to give total arsenic concentration irrespective of the nature of the chemical compounds containing arsenic. These are spectrophotometry, inductively coupled plasma, neutron activation analysis, x-ray fluorescence spectroscopy, hydride generation and flameless atomic absorption spectrometry, polarography etc. General discussions on the various methods have been enclosed in Ratnayaka's Report in Volume II. CGWB, Eastern Region, carried out the analytical work as part of the study. Full text of their findings is enclosed in Volume II of the report. For determination of arsenic in water CGWB has used two methods. These are:

1. By Spectrophotometer – Silver diethyl dithio carbomate: Arsenic determination was done using Gutzeit generator. In the water sample concentrated hydrochloric acid, potassium iodide and stanous chloride were added successively for reduction of arsenic to trivalent state. Zinc was added after 15 minutes to this and arsine gas thus generated was passed through silver diethy dithiocarbamate – pyridine solution for half an hour. The absorbance of the red colour was measured at 535nm using a spectrophotometer.
2. By Atomic Absorption Spectrophotometer – Hydride generation: Inorganic Arsenic was reduced to trivalent state and then subjected to arsine generation using hydrochloric acid and sodium borohydride measured by Atomic Absorption Spectrophotometer.

For determining concentration of other chemicals in water samples, CGWB in general applied Standard Methods. Volume II of the Study Report also encloses a detailed description about the Field Test Kits available in the region. A Comparative Statement of different Field Kits is enclosed. Though Field Test kits are in use in many parts, the results are not always comparable with the laboratory-tested methods. But these are quick methods and could be considered when a large number of water sources are under scrutiny.

3.7 Technology Options

Various experts believe that the best solution to the arsenic problem lies in providing alternate sources of arsenic free water by tapping surface water sources. This however, is quite a costly and time consuming proposition and needs a network of operation and maintenance management. Since it will take years, if not decades, to provide all the arsenic affected villages with safe surface water sources, treatment of groundwater is being considered as a short-term relief measure to the problem.

Two different types of systems have been adopted in the field – community based units and household units. Little attempt has been made to determine whether a particular technology is suited to that area or not.

Though in general, treatment processes have been provided where the quality of groundwater is not suitable for drinking due to arsenic contamination, adoption of a particular technology largely depends on:

- The cost of the unit including its installation charges
- The interest of the agency that has developed and adopted the technology.
- Paying capacity of the user with respect to household arsenic removal systems.
- Comprehension of the users about the operation and maintenance of the units.

Most of the removal processes are better suited for removal of As(V) from groundwater. Therefore the effective removal of arsenic as a whole may need complete conversion from As(III) to As(V). This will need an oxidising agent otherwise the process becomes very slow. Though chemical precipitation is an easily adaptable technology in large-scale operations a smaller version with Hand Pump attachment has also been developed and installed. By far, Fixed bed operation using adsorption technique seems to be most prospective technology because of the following reasons:

- There is no need to add chemicals regularly.
- It can be regenerated once the capacity gets exhausted.
- There is no risk of losing the efficiency of the media due to storage.

While selecting the media for any adsorption technique, criteria to be kept in view are:

- Cost of the media.
- Ease or difficulty in operation.
- Cost of operation.
- Useful service life per cycle between regeneration.
- Potential of reuse.
- Regeneration procedure
- Number of useful cycles.
- Possibilities of desorption of adsorbed arsenic.

Water quality data collected from different arsenic affected areas indicate that on an average about 75% of the groundwater sources contain arsenic less than 300 µg/l and 85% of sources have less than 500 µg/l. Hence the adopted technology should atleast be able to take care of the minimum concentration of 500 µg/l, if not more.

3.7.1 Community Based Units

It was possible to study seven different types of community-based units in the field. All these units have been installed by agencies, which have designed and developed them. In most cases the maintenance responsibility still lies with the concerned agency. In a number of units the local NGO has taken active interest to install the systems and facilitate its maintenance. However, the research agency, which has developed the systems, has helped the NGO in the installation and O&M. Short description of each of the technologies reviewed are given below:

<u>1. AMAL</u>

Process:

The AMAL Arsenic Removal Units- Hand pump Attached has been developed and installed by Bengal Engineering College. Ten community-based units are in operation and some more are to be installed soon. Activated alumina used is manufactured in India and hence easily available. About 100L of the medium is housed within a stainless steel column and operated in the down-flow mode. As the groundwater in the area contains very high concentration of iron, the oxidised iron flocks get collected in the activated alumina medium and need to be regularly backwashed. The backwash is not disposed of directly into open drains, but made to pass through a course sand bed that arrests the iron flocks and the flow-through is disposed of. After exhaustion, the medium is regenerated and restored by treatment with 1N caustic soda and 0.5 N Hydrochloric acid. The regeneration is done at the site.

Performance:

Though more than ten community based have been installed so far, due to logistic constraints performance and socio-economic data has been collected from only four working units. The Bengal Engineering College has installed these units with financial support from Water for People, Denver, and USA. The performances of the units with respect to arsenic removal have been found to be good. In all the cases the treatment units were able to bring it to below permissible limits. BE college had handed over the units to either CBOs or NGOs for O&M. This has allowed some cost recovery from the beneficiaries. Demands for such units are quite high.

AMAL

Technology -- Bengal Engineering College, Sivpur, Howrah.
Process -- Adsorption by Activated Alumina AS-37 manufactured by Oxide India, India.
Operating Procedure -- Handpump with lifting arrangement attached to the inlet pipe.
Passes through a stainless steel perforated splash plate.
Water then passes trough activated alumina media followed by graded gravel.
Chemical Addition – None other than AA (AS-37, which has chemical treatment).
Operating range – pH 5.5 to 8.5
Flow Rate – 10 l/min.
Contact time – 5 minutes.
Medium volume-- 100 l.
Capacity – 15,00,000 l. before regeneration.
Capital Cost – Rs. 50,000.
Backwash – Regular backwash to remove deposited iron flocks required to keep the system at functional level. Backwash water contains arsenic hence needs proper disposal arrangement.
Regeneration/ Restoration – The medium can be regenerated/ restored at least two to three times depending on the initial concentration of arsenic in raw water. NaOH and HCl are used for this process. Disposal of spent alkali and acid along with high concentration of arsenic needs special care.
Staff Requirement – Trained manpower available locally can run and backwash the system. Skilled manpower required for regeneration.

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2. APYRON

Process:

Apyron Technologies Inc., USA, is the developer and owner of this proprietory treatment system. The system uses Apyron's Aqua Bind ™ that is reported to be able to remove most of the prevalent forms of arsenic in groundwater. They have so far installed three community-based units in India and some more are likely to be installed very soon.

Performance:

Two community based units installed by Apyron were reviewed for performance and socio-economic factors. Locations for both the units were decided in consultation with PHED. The results show that the units are able to function satisfactorily over a long range of arsenic content and bring it within permissible limits. Though the plants have been operating for many months, maintenance of the units still lie with Apyron. It appears that so far no serious attempt has been made to involve the community for the management of the systems. Operation and maintenance charges are being borne by the private agency too.

APYRON

Technology – Apyron Technologies Inc, Atlanta, Georgia- 30340
Process -- Oxidation and Adsorption by Activated Alumina Aqua-Bind ™.
Operating Procedure -- Handpump with lifting arrangement attached to the inlet pipe.
Water passes through oxidizing tablets.
Water passes through three chambers-media 1 for iron removal, media 2 for arsenic removal and media 3 for polishing.
Chemical Addition – Oxidizing agent and three different mediums.
Operating range – pH 6 to 8
Flow Rate – 8 -14 l/min.
Contact time – 2-3 minutes.
Capacity – 180, 000 l. at 500µg/l arsenic conc.
Capital Cost – Rs. 83, 000.
Backwash – Regular backwash once a week to remove deposited iron flocks required to keep the system at functional level. Backwash water contains arsenic which needs proper disposal.
Regeneration/ Restoration – Not applicable. Medium to be disposed off by safe landfill.
Staff Requirement – Trained manpower available locally can run and backwash the system. For recharging skilled manpower required.

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3. AIIH&PH

Process:

AIIH&PH has installed a number of community based Arsenic Removal Plants (ARP) based on the method of oxidation followed by co-precipitation. The system could be termed as conventional water treatment plant in a mini scale. An attempt is being made to use locally available chemicals such as bleaching powder for oxidation and alum for co-precipitation. Since iron content in groundwater is quite high, regular backwashing of the system keeps it functional. Backwash water, which has high arsenic content needs to be collected in the sludge for further safe disposal.

Performance:
A number of community based units designed and developed by AIIH&PH have been installed and are functioning in different parts of arsenic affected areas of the State. Most of them have been installed in collaboration with a prominent NGO. Officials of AIIH&PH have facilitated the installation and running of the system. Under this study three units were reviewed. Though the unit is able to reduce arsenic content below detectable limits, the results obtained are not always satisfactory mainly due to external factors. Community members have been trained to add chemicals. Apart from human error the quality of chemicals has not been always of standard grade.

AIIH&PH

Technology -- All India Institute of Hygiene and Public Health, Calcutta.
Process -- Oxidation followed by co-precipitation.
Mixing Zone –Baffle type.
Flocculation Zone – Circular.
Sedimentation Zone – Circular
Filtration system -- Upflow
Operating Procedure -- Handpump with lifting arrangement attached to the chemical mixing chamber. Then it passes through a series of chambers functioning for coagulation, flocculation and sedimentation. Finally the water passes through the graded gravel bed filtration chamber.
Chemical Addition – Bleaching powder and alum
Operating range -- Normal available ground water.
Filtration rate – 1000 l/hour/ m^2 (Maximum).
Capacity – 12,000 liters/day
Capital Cost – Rs. 30, 000.
Backwash – Regular backwash to remove deposited iron flocks required to keep the system at functional level. Backwash water contains arsenic hence needs proper disposal arrangement.
Staff Requirement – Trained manpower available locally can run and backwash the system. For changing gravel, disposal of backwash water and sludge skilled manpower required.

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4. PAL TROCKNER

Process:
Pal Trockner (P) Ltd with technical collaboration of M/s Harbauer GmbH, Germany installed a number of fixed bed systems using granular activated ferric hydroxide (Adsorp As®) with high specific surfaces. The main application of Adsorp As® is the adsorption removal of arsenate, arsenite and phosphate from natural water.

Performance:
A large number of these units are presently functioning and under installation in the arsenic affected districts of the State. Under the present review, three units were selected. All results were found to be good. The units are capable of working over a large range of arsenic concentration. Since the first group of plants were installed keeping in view the need for evaluation of the units and with collaboration of PHED, the locations were not always suitable for community use. The community is able to carry out daily operation and backwash. Beneficiary contribution was not noticeable in any of these units. The private agency is still maintaining the system from time to time when required.

PAL TROCKNER

Technology – Pal Trockner in collaboration with M/s Harbauer GmbH, Germany
Process -- Oxidation and Adsorption by Ferric Hydroxide Adsorb As®
Operating Procedure -- Handpump with lifting arrangement attached to the inlet pipe.
Passes through oxidizing agent and filter bed
Water passes trough granular ferric hydroxide medium.
Chemical Addition – Oxidizing agent- Manganese dioxide grannular ferric hydroxide.
Operating range -- 5.5 to 8 pH.
Flow Rate – 10 -12 l/min.
Contact time – 3-4 minutes.
Capacity – 900, 000 l.
Capital Cost – Rs. 86, 000.

Backwash – Regular backwash, once in a week to remove deposited iron flocks required to keep the system at functional level. Backwash water contains arsenic hence needs proper disposal arrangement.
Regeneration/ Restoration – Not applicable. Medium to be disposed off by safe landfill.
Staff Requirement – Trained manpower available locally can run and backwash the system. For recharging skilled manpower required.

5.PHED

Process:
Public Health Engineering Department, a Goverment of West Bengal agency co-ordinating and implementing drinking water supply programme in the State has been developing a number of methodoligies for providing safe water sources to the community. These include:

- Providing piped water supply systems by tapping either surface water sources or pumping water from the deeper aquifer.
- Providing large scale treatment processes for drinking water sources tapping arsenic contaminated groundwater.
- Providing small scale community based arsenic removal units based on multimedia.

One such unit, mentioned at point three has been installed at Jhaudia village in Jalangi Block of Murshidabad district. Installed since August 1999, this serves about 50 families in the village. An attempt has been made to use cheaper material for the process.

Performance:
Though a number of such multimedia units are reported to be functional in different parts of the arsenic affected area, only one plant located in Murshidabad District was reviewed for analytical and socio-economic study. The results show that the arsenic content in treated water is much below the permissible limit. Apart from waste management, community management of the system needs to be considered for large scale implementation of these plants.

PHED – Multimedia Unit

Technology -- Public Health Engineering Department, Govt. of West Bengal.
Process -- Oxidation, co-precipitation and filtration.
Chamber I – Naturally occuring Pyrolusite, MnO_2.
Chamber II – Hematite, Fe_2O_3 along with Gravel and Jhama.
Chamber III – MnO_2, Feldsper along with gravel and Jhama
Chamber IV—Activated alumina
Operating Procedure -- Handpump with lifting arrangement attached to the chamber I. Then it passes through a series of three chambers functioning for co-precipitation and finally filtration.
Chemical Addition – mentioned above.
Operating range -- Normal available ground water.
Flow rate – 15 –18 l/ m.
Rate of filtration – 1,000 liters/hour
Capital Cost – Rs. 45, 000. (including departmental charges)
Backwash – Regular backwash to remove deposited iron flocks required to keep the system at functional level. Backwash water contains arsenic hence needs proper disposal arrangement.
Staff Requirement – Trained manpower available locally can run and backwash the system. For changing gravel, media, disposal of backwash water and sludge skilled manpower required.

6. Ion Exchange

Process:
Ion Exchange (India) had designed and installed ARP units based on treatment processes which include catalytic oxidation of iron and arsenic through granular media and adsorption of arsenate anion on a strong base anion exchange resin. Depending upon arsenic content and use, the resin needs regeneration once a month. For this Ion Exchange feels that a central regeneration facility needs to be established by the company. But this is feasible only if a large number (perhaps around 2000 units) are in operation within a reasonable distance at one place.

Performance:
An Ion Exchange plant is functioning at Dasdia village, Haringhata Block, Murshidabad district since November 2000. Since it started functioning late analytical work could not be carried out. However, socio-economic review was conducted. The community appears to be involved in the working and is using it. The plant, however, needs continuous monitoring and support for stabilisation of the system. The agency, however, has to send skilled technician for monthly regeneration of the system.

ION EXCHANGE

Technology – Ion Exchange (India) Ltd.
Process -- Oxidation and Adsorption by anion exchange resin
Operating Procedure -- Handpump with lifting arrangement attached to the inlet pipe.
Passes through oxidizing agent in a FRP cylinder
Water passes trough ion exchange resin.
Chemical Addition – Oxidizing agent and resin.
Operating range -- 6 to 8 pH.
Flow Rate – 4-5 l/min.
Contact time – 3-4 minutes.
Capacity – 30, 000 l at 1000 ppd. Then the media is to be regenarated.
Capital Cost – Rs. 72, 000.
Regeneration/ Restoration – This is required to be done on regular basis by the agency.
Staff Requirement – For recharging skilled manpower required.

7. Water System International

Process:
Water System International has developed and installed one ARP using technology, which involves oxidation, followed by adsorption by resin. There are four cylinders, the first one is for oxidation followed by two chambers having resin and the fourth chamber contains polishing material. One unit is currently functional and we are told that more are to be installed soon.

Performance:
The installed unit was reviewed for performance as well as for socio-economic factors. It was reported to be able to reduce arsenic content below permissible limits in most cases. Mostly the representatives of the agency handle the plant and the process of community management is yet to be developed. The regeneration work is to be handled by skilled manpower of WSI.

WATER SYSTEM INTERNATIONAL

Technology – Water System International
Process -- Oxidation, Adsorption by anion exchange resin followed by polishing material
Operating Procedure -- Handpump with lifting arrangement attached to the inlet pipe.
Passes through oxidizing agent in a cylindrical body.
Water passes through two chambers of ion exchange resin.
This is followed by polishing material
Chemical Addition – Oxidizing agent, resin and polishing agent.
Operating range -- Normal pH range
Flow Rate – 10 l/min.
Contact time – 3-4 minutes.
Capacity – 300, 000 l
Capital Cost – Rs.87, 000.
Regeneration/ Restoration – This is required to be done on regular basis by the agency.
Staff Requirement – For recharging skilled manpower required

Other Community Based Systems:
PHED has been providing safe water sources in the arsenic affected areas by tapping surface water sources or by providing conventional treatment processes in the existing groundwater sources. Some large piped water supply systems covering a number of villages are already under implementation. In some cases deep aquifers, with arsenic concentration within permissible limits have been installed to provide piped water supply system to individual or multiple villages. Two water supply systems – one for a Municipal area and another for multiple villages was considered for review.

1. **Sujapur piped water supply scheme** was commissioned with groundwater source to supply water to a population of 27,000 in six villages in 1987. Later it was observed that the water contained arsenic beyond permissible limits. By February 1996 arsenic removal plants were installed. The treatment processes involved are:

    - Chemical oxidation using chlorine.
    - Coagulation by rapid mixing using ferric chloride.
    - Sedimentation.
    - Filtration through existing pressure filter.

Reports suggest that the systems have successfully treated the water and brought down the arsenic content to below permissible limits. The only problem is amicable disposal of the arsenic rich sludge. However, other noticeable problems related to multiple village water supply system are: inequitable distribution of water leading to low availability in the end villages, wastage of treated water in the villages near the source, water availability in the limited time, total dependence on supply of electric power, maintenance of pipeline system, etc.

2. For water supply project in the Gobardanga Municipal area, PHED has adopted conventional treatment methods but with some modifications. The processes involved are:
   - Chemical oxidation using chlorine.
   - Coagulation by alum.
   - Sedimentation.
   - Potassium permanganate coated sand filtration through pressure filter.

   In actual practice, Potassium permanganate is added along with chlorine in the form of bleaching powder solution and the results are found to be within permissible limits. The average per capita maintenance cost due to these treatment processes are quite high, more so because of a limited distribution system and wastage of treated water.

3. PHED has installed a number of piped water supply systems in the arsenic prone areas to meet the drinking water needs. In most of the cases deep tubewell sources are being used without any provision for arsenic removal. More than eight such water supply schemes covering 15 villages have been commissioned very recently. The schemes cover one to four villages. The average per capita cost of the scheme comes to Rs.1200 and average per village maintenance cost comes to about Rs. 1.67 lakhs, which is quite high. Apart from this the piped water supply systems suffer from other problems such as non-availability of water in the end villages, poor maintenance of the piped system, dependence on power supply, etc.

4. There are a number of small surface water sources, which could be economically utilised for meeting household needs. The Roughing Filter along with Slow Sand filter could be used. This hand pump operated system is disinfected with bleaching powder. Since surface water sources are mostly free of arsenic this system is safe for drinking and cooking. However, efforts need to be made to see that the source remains well protected from external pollution. The community should take the main responsibility to protect the source and operate and maintain the system. The estimated cost of this plant is around Rs.65,000 provided the source of water is available without any cost. The per capita O&M cost is also low and well affordable by the households. The major drawback is getting a well protect perennial small surface water source.

5. Rainwater, which is free of arsenic pollution, is another source that could be collected and stored for drinking and cooking purposes by individual households. Though this is a high rainfall area, major precipitation is restricted to a few months of the year. Hence storage capacity has to be adequate atleast for 100-120 days so that the drinking and cooking water needs are available throughout the year. In general, this could be done by roof top collection by individual families so that maintenance is easy. Though maintenance cost will be quite minimal, high per capita cost will not allow most of the poor families to go for it. Even by having ferro-cement tanks the average reservoir cost comes to about Rs. 3000 per family. With arrangements for rain water collection average per capita investment is about Rs.1000.

Comparative Study of functioning of Community based ARPs

Though details about seven community based units have been incorporated, for analytical work related to water quality the comparison has been drawn between six plants. This is because the plant installed by Ion Exchange started functioning after field data collection had been completed.

From results obtained it is apparent that some of the plants can work in a wide range of arsenic concentration whereas there are a few which can function well in the lower range of arsenic concentration. In any case, since about 75% of sources have arsenic concentration below 300 µg/l, all the technologies are functional in this range, provided proper care is being taken to run the systems. Water analysis data also show that about 85% of the sources have arsenic concentration below 500 µg/l, which implies there are a few technologies that will require lot of control and monitoring to keep them functional. Moreover, since these plants are expected to be community based one has to keep in view the likes and dislikes of the community.

However, there are limitations of the study. These are:

- There are hardly one/two working plants installed by different agencies, which have functioned for some months.
- Location of the plants had been decided mutually between the agency and coordinating department.
- Quality of water changes from place to place and might affect the arsenic concentration and its status, which is directly related to the efficiency of the system.
- Not enough samples could be obtained for lack of time and physical constraints

In fact, for best results water quality testing for each of the plants need to be carried out at monthly intervals on a year round basis. This will indicate seasonal variation of the raw water quality, treatment capacity/ status of the plants on a year round basis and utilisation of the treatment units. Another basic problem about these plants is that there is no proper documentation of what procedures have been carried out on these units from time to time. The study team was unable to obtain any record of water flow (even if in some cases the flow meter was installed this was non functional at different points of time), the backwash log book if any, any change in media, etc. in a majority of the treatment units. All these would have helped in better evaluation of the existing units and in planning for the future.

Table 3.3: - Community based ARPs—Arsenic in µg/l

AGENCY.	*UNITS*	*TESTS*	*RAW WATER*			*TREATED WATER*		
			RANGE	*MEAN*	*SD*	*RANGE*	*MEAN*	*SD*
PAL TROCKNER	*3*	*9*	*165 – 1120*	*520*	*376*	*5 – 136*	*19*	*44*
AIIH&PH	*3*	*9*	*5 – 780*	*328*	*256*	*5 – 352*	*133*	*160*
WSI	*1*	*3*	*126 – 310*	*224*	*90*	*5 -- 160*	*57*	*89*
APYRON	*2*	*6*	*290 – 2340*	*1098*	*750*	*5 – 45*	*19*	*17*
AMAL	*4*	*12*	*50 – 610*	*254*	*185*	*5 – 72*	*26*	*27*
PHED	*3*	*9*	*82 – 960*	*270*	*210*	*5-- 35*	*14*	*10*

3.7.2 Household Based Arsenic Removal Units

People living in the arsenic prone areas are mostly dependant on community based water supply systems. Though some of them possess tube wells with hand pumps of their own, due to high arsenic concentration they are sceptical of using them for drinking and cooking. Others use them as they don't have access to any alternate safe water source. We found that people are on the look out for alternate water arrangements – deep tubewell, community based ARPs or household based treatment plants. Of course, household based units mainly cater to the rich as at present they are quite beyond the means of a poor family. If these units are made available within a reasonable distance, costs kept between Rs. 250-300 and a foolproof backup system established there is no reason why the community will not accept them and pay for its maintenance.

Four household-based units adopted in the field were reviewed for analytical work and socio-economic factors. Three of them are based on the technologies already discussed in the case of community-based units. These are:

- AMAL Household units using activated alumina.
- Pal Trockner Household unit using ferric hydroxide.
- AIIH&PH unit using bleaching powder and alum.
- SOES unit using filter candles and chemical tablets.

1. AMAL Household units

This is a conventional domestic candle filter unit where the candle has been replaced by activated alumina of As 37 grade manufactured by Oxide India Pvt. Ltd. It is fitted with a stainless steel disc with a suitable aperture to control the rate of flow of water from the upper chamber. The capacity of this chamber is about 5 litres. The units are available in two capacities – 20 l and 24 l. Both stainless steel and polypropylene versions are available with the selected agents of the manufacturer. There are more than 500 units in operation in the State. These units have been sold without any subsidy from any agency.

AMAL Household Unit

Technology – Oxide (India).Catalysts Pvt. Ltd. Durgapur, West Bengal
Process -- Adsorption by activated alumina As 37 grade
Operating Procedure -- Raw water is poured in the top chamber. This passes through the media. Treated water gets collected in the lower chamber to be taken out for use.
Chemical Addition – No other chemical except activated alumina of As 37 grade.
Operating range -- Normal pH range
Flow Rate – 5 l/hr.
Contact time – 3-4 minutes.
Quantity of medium – 3 kg.
Capacity – 7000 – 8000 l in first cycle. In the second cycle this further increases.
Capital Cost – Polypropylene 20L – Rs.1650 Stainless Steel 20L – Rs.2200; 24L- 2400.
Regeneration/ Restoration – This is required to be done on regular basis by the agency.
Staff Requirement – Household can handle day to day unit. Regular backwash to be done. For recharging skilled manpower required.

Performance of AMAL Household Unit:
The mere fact that individual households have purchased more than five hundred units without any subsidy and they are in use shows that people are looking for some technology that will be readily available within accessible distance. Oxide India has set up a network of dealers at different towns in the State. They are also doing marketing to a limited extent. The results obtained from analytical work shows that the units are functioning smoothly. The network arrangement for once a month water quality testing of arsenic concentration in treated water and regeneration activity needs to be made foolproof so that people can afford them. The drawback of the unit is its high cost. Only upper middle class people can afford them. Some soft loan scheme could be introduced to make the unit more affordable.

2. Pal Trockner Household Units
Pal Trockner uses the same principle as its community based unit to reduce arsenic at the household level. The household units, with two different models, are christened "Nilkantha". About 50 such units are currently in use. The agency so far has not appointed any dealer or agent for marketing the product. Since there is no regeneration involved, the media has to be totally replaced once it is exhausted. Generally, this is to be done once a year.

Pal Trockner Household Unit

Technology – Pal Trockner (P) Ltd. Calcutta in collaboration with M/s. Harbauer GmbH, Germany.
Process -- Oxidation followed by adsorption by Adsorp As® (ferric hydroxide).
Operating Procedure -- Raw water is poured in the chamber. This passes through the media. Treated water gets collected in the lower chamber to be taken out for use.
Chemical Addition – Oxidizing agent mixed with medium.
Operating range -- Normal pH range
Flow Rate – 15 l/hr.
Contact time – 2/3 minutes.
Quantity of medium – about 1 kg.
Capacity – 10,000L
Capital Cost – Janata model – Rs. 3500. Shoven model – Rs.4 500.
Regeneration/ Restoration – This is not required. The medium to be replaced by the agency.
Staff Requirement – Household can handle the system on day to day. Backwash to be done on regular basis by household.

Performance of Pal Trockner unit:
The analytical results for the functioning of the units show that the system is working very well. This unit also works in a long range of arsenic concentration in drinking water. Since there is neither a network of dealers nor strong marketing approach from the agency, the units are not easily available to the community. Another drawback is the high cost of the unit. Only a very small percentage of households could procure it for their daily use.

3. SOES Household Unit:
This is a low cost household-based unit designed and developed by the School of Environmental Studies, Jadavpur University, Calcutta. The system consists of two earthen jars, one fitted with a candle made of fly ash, clay and charcoal and a chemical tablet containing ferric salt, an oxidising agent and activated charcoal. Both the filter and chemical tablets have been patented by SOES under the aegis of Government

of India. More than 150 units have been manufactured and made available to the poor household by SOES. Even chemical tablets are produced and made available to the beneficiaries by SOES on a regular basis.

SOES Household Unit

Technology – School of Environment Studies, Jadavpur University, Calcutta.
Process -- Oxidation followed by co-precipitation and filtration.
Operating Procedure – The chemical tablet is added to raw water and stirred. It is allowed to settle for an hour and the supernatant is poured in the top chamber. This passes through the candle filter. Treated water gets collected in the lower chamber to be taken out for use.
Chemical Addition – Oxidizing agent, ferric salt, activated carbon, fly ash, clay and charcoal.
Operating range -- Normal pH range
Flow Rate – 2/3 l/hr.
Capacity – 20L/day
Capital Cost – Rs.600.
Regeneration/ Restoration – This is not required.
Staff Requirement – Household can handle the unit on day to day basis. Backwash to be done on regular basis by household. Sludge to be disposed off through soak pit after mixing with cow dung.

Performance of SOES unit:
The performance of the unit depends on the way it is being handled by individual households by way of upkeep of the chemicals. Besides, users have to handle the mixing of chemical tablet and backwash of filter, which increase possibilities of human error. Hence the results obtained are not always positive. The results also show that at higher range of arsenic concentration the treated water is not always below permissible limit. Another problem is colouring of water due to carbon presence because of occasional mal-function of the filter. The backwash water, which contains arsenic, is disposed off by mixing with cow-dung and by discharging it in the soak pit.

4. AIIH&PH Household Unit:
The All India Institute of Hygiene and Public Health, Calcutta has developed domestic filters based on oxidation and co-precipitation technology. The unit uses either a modified candle filter or sand gravel filter. The candle filter is a Tripura type filter that uses rice husk along with sand. Bleaching powder and alum is used as chemical for treatment. Ram Krishna Mission Lok Shiksha Parishad, an NGO, has distributed about 150 such units amongst the villagers in North 24 Parganas district. The cost of each unit is around Rs. 200.

AIIH&PH Household Unit
Technology – All India Institute of Hygiene & Public Health, Calcutta.
Process -- Oxidation followed by co-precipitation and filtration.
Operating Procedure – The bleaching powder and alum are added to raw water and stirred. It is allowed to settle for half an hour and the supernatant is poured in the top chamber. This passes through the Tripura filter. Treated water gets collected in the lower chamber to be taken out for use.
Chemical Addition – Bleaching powder and alum.
Operating range -- Normal pH range
Flow Rate – 2/3 l/hr.
Capacity – 30L/day
Capital Cost – Rs.200.
Regeneration/ Restoration – This is not required.
Staff Requirement – Household can handle the unit on day to day basis. Backwash of filter to be done on regular basis by household. The sludge with high arsenic concentration to be disposed off in the toilet pit.

Performance of AIIH&PH unit:
The performance of these units greatly depend on the human factor and the quality of chemicals available in the local market. Since the chemical addition is on a day-to-day basis it is very difficult to maintain the dose. Besides, with change in water quality it is impossible for the units to handle changed arsenic concentration. If excess chemical is added it affects the taste of water. The strength of bleaching powder changes with exposure and time affecting the efficiency of the system. For these reasons the units are operational at a lower range of arsenic concentration.

Comparative Study of functioning of various Household based ARPs

Of the four household-based units that have been reviewed, the units marketed by Pal Trockner seem to be most efficient in arsenic removal. This, however, is very costly and only high-income groups of the society can afford it. Pal Trockner is yet to set up a dealers' network to make their units available on demand. The AMAL Household unit shows promise because of its competitive cost and arsenic removal efficiency and is functioning reasonably well in most of the areas. Both the SOES and AIIH&PH units are cost effective but efficiency of arsenic removal is subjected to human error and quality of chemical in use.. This restricts their application to low range of arsenic concentration, preferably within 300 µg/l. A comparative study of various units is tabulated below:

Table 3.4:- Household based ARPs –A comparitive study of efficacy (Arsenic conc. In µg/l)

AGENCY	UNITS	TESTS	RAW WATER			TREATED WATER		
			RANGE	MEAN	SD	RANGE	MEAN	SD
PAL TROCKNER	10	29	10 – 2950	520	776	5 – 140	12	27
AIIH&PH	10	30	15 – 184	86	40	5 – 78	24	30
AMAL	10	29	16 – 410	230	123	5 – 102	18	70
SOES	10	28	50 – 1050	235	244	5 – 200	42	62

3.8 Disposal of Sludge and Backwash Water

All the community and domestic technologies adopted need to be backwashed on a regular basis. Iron, which is usually present along with arsenic, forms flocks and gets deposited on the medium. These flocks also arrest some arsenic alongside. On prolonged use the medium gets blocked and the flow of water decreases. Unless the medium is backwashed regularly, the system slowly becomes non-functional. This backwash water, which is mostly obtained from the first chamber of the treatment units, has a high concentration of arsenic. **In majority of the cases this is thrown out into the open drain or used for watering kitchen gardens. So, inadvertently, the arsenic being so painstakingly removed is finding its way back into the environment at higher concentrations and creating additional health hazards.** Some of the results obtained for different technologies are tabulated below:

Table 3.5: - Arsenic Concentration in Backwash water from Community units (in µg/l):

AGENCY	LOCATION	RAW WATER	BACK WASH WATER
PAL TROCKNER	SERPUR- S 24 PARGANAS	340	1110
AIIHPH	SARDARPARA – S 24 PARGANAS	520	2520
AMAL	BETAI - NADIA	720	1890
APYRON	ADAHATA –N 24 PARGANAS	2340	1360
WSI	JOYPUR – N 24 PARGANAS	310	184
PHED	GOBARDANGA –N 24 PARGANAS	870	784

Table 3.6: - Arsenic concentration in backwash water from household units (in µg/l):

AGENCY	LOCATION	RAW WATER	BACKWASH WATER
PAL TROCKNER	CHANDOKHAL S 24 PARGANAS	140	150
PAL TROCKNER	DHABDHABI-S 24 PARGANAS	410	131
AMAL	D. LAXMIPUR - MALDA	131	1400
AMAL	D. LAXMIPUR - MALDA	204	2040
SOES	BERACHAMPA – N 24 PARGANAS	117	2230

Since there are no records of backwash being done, in places where the concentration of arsenic is found to be low we assume that it is done at a longer interval. But units in which the effluent contains very high concentration of arsenic as well as iron, backwash is obviously being done on a day to day basis.

The community units designed by AIIH&PH, Pal Trockner and AMAL have designed devices to collect/ treat the backwash waters and make them arsenic free to the maximum extent possible. But the problem persists in a majority of cases.

Sludge, spent regenerant and exhausted mediums all have very high concentration of arsenic and need special attention for their disposal. All the agencies have suggested various solutions to dispose off these effluents, but not many studies are available to see whether this highly toxic effluent/sludge is not creating environmental hazards elsewhere. Also, it is beyond the scope of this review to get into such details. However, a few suggestions are being discussed below:

- Both SOES and AIIH&PH have suggested disposal of the sludge obtained from household units into the soak pits where bio-methylation by microbes will help in the final disposal of arsenic. Research work carried out by AIIH&PH show that biomethylation can reduce arsenic in ARP sludge by as much as 80%. (Arsenic Sludge Treatment and Disposal by Ranjan Chakraborty, Prof. A Majumdar and Dr. G Banerjee, December 2000)
- In case of AMAL plant the alkali and acid solution used for regeneration-restoration contains a high concentration of arsenic and iron hydroxide flocks are allowed to settle. The decanted matter with low concentration of arsenic is discharged in open. The settled matter is to be mixed with cement in concrete blocks and is expected to get fixed there.
- APYRON has indicated that the arsenic contaminated spent media has been found to be non-hazardous waste as per US Environment Protection Agency standards and could be disposed along with sanitary waste in a landfill.
- Pal Trockner points out that the spent granular ferric hydroxide with high arsenic content is non-toxic and non-hazardous and can be used for manufacture of bricks (5% iron oxide is added with clay and gives brick a bright colour). The brick is baked at a temperature of 900-1200°C to avoid any leaching.

3.9 Strengths and Weaknesses of different Technologies

Based on the undertaken review, an attempt has been made to list out strengths and weaknesses of different technologies operating in the field. Apart from analytical work, the socio-economic factors were also considered. The details are tabulated below:

AGENCY	*STRENGTH*	*WEAKNESS*
Community Units		
AMAL	*1. Medium locally available. 2. Easy handling by community. 3. Per capita investment is nominal- Rs. 200-225. 4. O&M cost is within affordable limit of community. 5. Regeneration cost is low.*	*1. Frequent backwash. 2. Regeneration to be done by agency. 3. Best suited for As. Conc. Below 1000 µg/l. (90% of source). 4. Disposal of arsenic rich waste needs to be addressed. 5. Al content in treated water increases.*
APYRON	*1. Works satisfactorily in a long range. (checked up to 3000 µg/l). 2. Small size of the unit. 3. Once a week backwash.*	*1. High per capita cost – about Rs. 350. 2. Very high recharging cost. 3. O&M cost to be subsidized. 4. Recharging to be done by agency. 5. Al contents in treated water increases. 6. Medium to be imported. 7. High As content in Backwash*
AIIH&PH	*1. Chemicals locally available. 2. Per capita investment low – Rs.100-125. 3. O&M cost affordable by community. 4. Community can handle the technology.*	*1. Availability of quality chemicals to be ensured. 2. Day to day chemical addition is a hassle and quantity doubtful- human error. 3. Sludge disposal difficult. 4. Best suited for low range up to 300 µg/l. (75% Of sources). 5. Treatment unit subject to mishandling.*
Pal Trockner	*1. Works satisfactorily in a long range. (checked up to 3000 µg/l).*	*1. High per capita cost – about Rs.350. 2. High recharging cost.*

	2. Small size of the unit. 3. Community can handle it in day-to-day basis.	3. O&M cost to be subsidized. 4. Recharging to be done by agency. 5. Medium to be imported. 6. High as content in backwash.
ION Exchange	1. Small size of the unit. 2. Community can handle the unit on day-to-day basis. 3. Per capita investment around Rs.250 (nominal)	1. Monthly recharging to be done by the agency. Viable only when large number of units is installed. 2. O&M cost to be subsidized. 3. High turbidity may affect the treatment process. 4. More effective in medium range up to 1000 ppd (90% of sources)
PHED (Multimedia)	1. Low per capita cost Rs.200. 2. Uses locally available material. 3. Works well in medium range of operation – 500 µg/l. (85% of sources)	1. Very high O&M cost. 2. Recharging to be done by agency. 3. Open unit likely to be mishandled. 4. Size of structure- big.
Water System International	1. Small size unit.	1. Regular recharging to be done by agency. 2. High per capita cost. 3. Very high recharging cost. 4. O&M cost to be subsidized. 5. High turbidity may affect the treatment process. 6. High As content in backwash. 7. Al contents in treated water increases.
PHED – piped water	1. Long-term solution. 2. Water quality tested on regular basis. 3. Trained manpower to handle.	1. Very high per capita cost – Rs.1200 and above. 2. Very high O&M cost. 3. O&M cost to be subsidized. 4. Al contents in treated water increases. 5. More suitable for medium range up to 500 µg/l. 6. Backwash high As content.
HOUSEHOLD Unit		
AMAL	1. Very simple operation. 2. Low O&M cost. 3. Available in the market.	1. High capital cost – Rs.1650. 2. Regeneration to be done by the agency. 3. Backwash has high As content. 4. Al content in treated water increases. 5. Works better in range up to 500 µg/l.
AIIH&PH	1. Low cost – easily affordable by community. 2. Low O&M cost. 3. Chemical locally available.	1. Difficult to procure quality chemicals. 2. Treatment process subject to human error. 3. Works better in a low range up to 300 µg/l. 4. Requires regular WQ check. 5. Al in treated water increases.
Pal Trockner	1. Works effectively in a wide range – up to 3000 µg/l (checked) 2. Very simple operation.	1. Very high cost. 2. Iron removal is high.
SOES	1. Very low capital cost. 2. Low O&M cost.	1. Upkeep of chemicals subject to human error. 2. Works better in a low range up to 300 µg/l. 3. Al in treated water increases. 4. Backwash has high As content

4. ARSENIC TOXICITY: EFFECTS ON HEALTH

4.1 Introduction

Arsenic exists in nature usually in the form of arsenic compounds. Because of its complex chemistry the toxicity of these compounds varies greatly. The degree of toxicity depends on the chemical form, the route of entry into the human body and the dose and duration of exposure. Large quantities of arsenic compounds are released into the environment as a result of unrestrained human industrial and agricultural activities. Arsenic laden emissions from smelters, coal fired power plants and herbicide sprays pollute the air; mine tailings runoff, smelter wastes and natural mineralization pollute water and subsequently sea food. This results in excessive arsenic intake by the human body far beyond permissible limits, causing health hazards and eventually leading to arsenic poisoning.

4.2 Toxic forms of Arsenic

The element has four valence states: -3, 0, +3 and +5. Arsines and methylarsines, which are characteristics of arsenic in the –3 oxidation state are generally unstable in air. Elemental arsenic (As^0) is formed by reduction of arsenic oxides. As(III) and As(V) are found in the environment as compounds of different minerals. The various forms of arsenic, in descending order from most to least toxic, are

Arsines > arsenites (inorganic, trivalent) > arsenoxides (organic, trivalent) > arsenates (inorganic, pentavalent) >arsenium compounds > metallic arsenic.

Arsenites are 60 times more toxic than arsenates but it is believed that for chronic toxicity both these species are equally toxic (SOES, 1999).

Since 1983 a large number of people have been found to be suffering from arsenicosis in six districts of West Bengal. At present groundwater in more than 68 blocks in eight districts have been reported to contain excessive arsenic. **More than five million people are estimated to be at risk from arsenic poisoning and conservative figures suggest that there are over 300,000 patients who are suffering from various stages of arsenicosis**. Both arsenites (inorganic As(III) and arsenates inorganic As(V)) are present in the groundwater in this region.

4.3 Arsenicosis & its stages

Chronic exposure to low concentrations of arsenic is of prime importance for the present study because people in this region consume water that has arsenic concentrations beyond 50 µg/l. Though arsenic toxicity produces myriad problems in the human body, the most common signs of long-term, low level arsenic exposure are dermal changes. Important clinical manifestations of chronic arsenicosis may be:

1. Early manifestations: Dermal manifestations, melanosis (diffuse pigmentation), spotty pigmentation and depigmentation, blotchy pigmentation and depigmentation, diffuse keratosis and nodular keratosis.
2. Non-carcinomateous manifestations: Chronic bronchitis, conjunctivitis, hepatopathy, peripheral neuropathy, peripheral vascular disease, edema of legs, weakness, anemia.
3. Advanced manifestations: Cancer of skin, lung and urinary bladder, Browen's disease.

Diffuse nodular keratosis is mostly observed in the soles of the palm and foot and is often surmounted by small, corn like elevated nodules of up to 10mm in diameter. Black foot disease and endemic peripheral vascular disorder is also associated with arsenic poisoning. Sub acute and chronic oral exposures generally affect the same organs and systems as those affected by acute exposures. These include gastro-intestinal tract, circulatory system, skin, liver, kidney, nervous system and heart. Chronic arsenic poisoning may have non-specific general effects such as chronic weakness, easy fatigue, lack of motivation, anorexia, weight and hair loss among others.

4.4 Biomarkers

The number of years of exposure is a common basis in the estimation of relative exposure dose in arsenic toxicity caused by inhalation and ingestion. Normal blood arsenic values generally range from 1 - 40µg/l. while current arsenic exposures elevate these levels at least 10 fold (Vahter, 1988). Urinary arsenic level is the frequently used biomarker in diagnosis. Almost 60-70 percent of the daily-ingested inorganic arsenic is excreted through urine. Though absorbed arsenic is excreted mainly via the kidneys, other routes such as skin, human milk and faeces remove a small amount. About 76 percent of the organic arsenic ingested with flounder is excreted in the urine within 8 days (SOES, 1999). In a 24-hr. urine specimen presence of up to 20µg of inorganic arsenic or 50µg of total arsenic are considered within normal limits. Once exposure ceases, it may take 7-10 days to return to the normal levels.

4.5 Physiological effects

Environmental arsenic is detrimental to several human organs. Since small doses may have no immediate obvious effects, the appearance of symptoms can be taken to be the result of arsenic accumulation from repeated exposure. The particular nature of the chronic symptoms seen in an individual from continued or repeated small doses of arsenic depends on the susceptibility of the particular organ of that person. Hence we find that some individuals are more affected than others by arsenic though they may have been exposed to similar environmental conditions. **Symptoms may be wide ranging-- from being non-specific chronic fatigue to severely damaged body organs as evident in the following paragraphs.**

- *Gastrointestinal Effects*: Chronic low-dose arsenic ingestion may not give rise to any symptomatic gastrointestinal irritation or may produce mild oesophagitis, gastritis or colitis with respective upper and lower abdominal discomfort. Anorexia, malabsorption and weight loss may be present.
- *Respiratory Effects*: This occurs when arsenic laden dust is inhaled mostly during exposures to industrial processes or mining. There is often rhinitis, pharyngitis, laryngitis and tracheobronchitis, which cause symptoms like stuffy nose, hoarseness, sore throat and chronic cough. Arsenic can even induce or aggravate asthma in susceptible individuals. Drinking of arsenic contaminated water can cause chronic cough, bronchitis or pulmonary fibrosis.
- *Dermatological Effects*: Skin is the major organ of arsenic accumulation. Chronic exposures to arsenic will produce a variety of distinguishing marks on the skin due to arsenic toxicity. These are keratosis, hyperkeratosis of palms and soles. Spotty pigmentation and depigmentation also occur.
- *Haematological Effects*: Chronic exposures to arsenic affect the haematopoietic system. Normochromic and normocytic anaemia is quite common.
- *Hepatic Effects*: Since the liver tends to accumulate arsenic with repeated exposures, hepatic involvement is quite common. Chronic arsenic induced hepatic changes include cirrhosis, portal hypertension without cirrhosis, fatty degeneration and primary hepatic neoplasia. Patients may first report bleeding oesophageal varices, ascites, jaundice or simply an enlarged tender liver.
- *Cardiovascular Effects*: Both the heart and peripheral arterial tree commonly show effects of arsenic toxicity. Ischaemic heart disease, peripheral vascular disease (Black foot disease), Raynaud's phenomenon, hypertension are some of the cardiovascular manifestation of chronic arsenic poisoning.
- *Neurologic Effects*: Arsenic poisoning can damage the peripheral and central nervous system. Severely affected patients can partially recover after exposure stops but some permanent damage will be done. Paresthesias and hypethesias usually appear first followed in some cases by weakness or even paralysis starting in distal lower or upper extremities.
- *Reproductive Effects*: Inorganic arsenic is reported to be readily crossing the placental barrier and affects foetal development but organic arsenic does not seem to do so easily and is stored in the placenta itself. (Squibb and Fowler, 1983)
- *Carcinogenic Effects*: Arsenical skin cancers commonly occurred in the presence of other dermotologic manifestation of arsenicism. Excessive arsenic in drinking water tends to concentrate in the skin, where there are visible direct toxic effects with chromosomal changes and increased rate of skin cancers. Increased incidence of bladder and lung cancer have also been reported.

4.6 Epidemiology

In the 1950s and early 1960s people depended on surface water and shallow wells to meet their drinking and other household water needs. With development of reliable hand pumps, a strong advocacy for safe ground water source and elaborate supply chain, the hand pump system became more acceptable. Privately owned pumps were quite common in rural Bengal. Though tapping the groundwater system was introduced in a big scale, the water quality surveillance mechanism was not in place to monitor the possible chemical contamination of groundwater. This resulted in people consuming the arsenic laced water on a large scale unaware of the contamination. By 1983, a large number of patients began reporting to hospitals in Calcutta with a host of unexplained symptoms that went undiagnosed by local doctors. Initially even doctors there had difficulty in diagnosing the disease but later on the School of Tropical Medicine, Calcutta isolated it as arsenicosis and concluded that the cause was drinking arsenic contaminated water.

Spurred by these findings, a number of Institutions started research activities in this field. The Institute of Post Graduate Medical Education and Research, Calcutta in their epidemiological study in the six arsenic affected districts of West Bengal reported the following:

1) Very high incidence of liver involvement and respiratory disease has been observed in the patients. Enlargement of liver has been found in case of more than 76.9% cases. More than 57% of patients were found to be suffering from respiratory diseases.
2) More than 70% patients reported weakness and lethargy to do any physical labour.

3) There were a few patients who did not have keratosis and hepatomegaly when the arsenic level in the water taken by them was more than 500 –1000 μg/l, while there were those who did not have any lung or neurological symptoms even when it was more than 1000 μg/l.
4) There is no correlation between the quantity of arsenic taken through water and the level of arsenic found in hair, nails and liver tissue.
5) Symptomatic treatment and drinking of arsenic free water produced some improvement in most of the patients with regard to gastrointestinal symptoms, weakness, pigmentation and degree of keratosis.
6) Very few affected people report to city hospitals for treatment as most of them live in distant rural areas and belong to low socio-economic strata.
7) Men are more sensitive and prone to suffer from the disease compared to women (10.7 per 100 male and 8.7 per 100 female).
8) High protein diet helps in eliminating inorganic arsenic. Poor people whose protein intake is less are likely to suffer more. Protein from animal sources or vegetable sources like pulses, wheat, soyabean lentils, etc are equally effective.
9) Chelation therapy for chronic arsenic toxicity is thought to be the specific therapy for relief of symptomatic clinical manifestation and reduction of arsenic stores in the body system. Skin thickening of sole and palm can be treated by application of keratolytic ointment (containing salicylic acid). Anti oxidants like retinol, vitamin C, vitamin E may play a role in the management of the problem.
10) Awareness of local medical practitioners is vitally important, as they are to be involved in clinical identification, medical care and follow up of patients with arsenic lesions.

Another study of patients suffering from arsenic contamination has concluded that a large number of people presented varying degrees of other symptoms apart from skin pigmentation, which is quite common.

Thickness of skin of palm and sole	65.5%
Weakness	70.5%
Gastro-intestinal symptoms	58.6%
Respiratory related problems	57.08%
Nervous system	50.6%
Restrictive lung disease	53.0%
Combined obstructive and restrictive lung disease	41.0%
Enlargement of liver	76.9%
Splenomegaly	31.4%

A major problem in the early detection and treatment of arsenicosis in the remote villages of West Bengal is lack of trained medical staff, proper treatment facilities and regular supply of medicines to the patients. Since most people suffering from the disease (more than 70%) are poor, they find it difficult to continue the prolonged treatment process so essential for recovery. Moreover, treatment facilities are presently available only at selected hospitals in Kolkata and the poor affected villagers have to travel long distances regularly to avail the treatment. This again eats into the villagers' meagre savings.

4.7 Strategy for prevention and control

The preventive measures in tackling arsenic toxicity basically depend on early diagnosis and case management, detection of arsenic in water and supply of arsenic free water. Though the state agencies have already initiated a number of measures, a short list of strategies have been listed to take care of future actions, if any:

i) Early detection and management of affected populations by surveys;
ii) Development of appropriate alternative water supply options;
iii) Delineation of affected areas for early detection and prevention of further exposure;
iv) Development of educational and communication materials to make people aware of the problems associated with arsenic contamination of water used for drinking and cooking;
v) Initiate training programmes for health personnel at district, blocks and grass root levels (including private practitioners) and also for NGOs working in the related field of the affected areas. The training should include detection, treatment and follow up action of the patients.
vi) Establish outpatient departments in Block level hospitals in the affected areas and provide adequate trained manpower to meet the needs of the community.
vii) Strengthen co-ordination between the departments of Health, Public Health Engineering, Panchayat and the Rural Development Department of the State Government so that the Arsenic mitigation programme could be planned and implemented successfully.

5. ARSENIC IN FOOD CHAIN

5.1 Introduction

The source of arsenic in groundwater in West Bengal is primarily geogenic even though anthropogenic sources do exist. Besides being used for drinking and household purposes, groundwater is also used in agriculture in this region. To usher in the "Green Revolution" in the country the extraction of subsurface water for irrigation purposes increased substantially over the past few decades. Inevitably, it lead to the arsenic contaminated aquifer being tapped. Thus season after season crops have been growing on this arsenic rich water. Though the bioaccumulation of arsenic in soil is a slow process, it can still cause toxic effects by accumulating in plants and thereby entering the animal and human food chain. However, the total amount of arsenic in soil and its chemical forms has an important influence on plant growth, animal and human health.

Unfortunately, there are not enough research activities conducted on Indian soil to substantiate the entry of arsenic into the food chain. Some work done by Bidhan Chandra Krishi Vidyalaya, Kalyani, District Nadia, West Bengal is yet to be published. A few studies done by other research agencies has not yielded conclusive results. But from work done in others parts of the world it could very well be said that there is a considerable possibility of arsenic entering the food chain through agricultural products in the area.

5.2 Concentrations in Soil

Arsenic is found in the soil at an average concentration of 5-6mg/kg, where there is no contamination. But this varies from place to place. As we have seen earlier arsenic is released into groundwater through various chemical processes. There are a quarter of a million bore wells of various sizes and capacity in the affected districts of West Bengal. Though some of them are being used for drinking and household purposes and pump a smaller quantity, the bore wells that cater to minor irrigation draw out large quantities.

There is no sufficient data available to show exactly how much of arsenic is being pumped out on a daily basis. Preliminary studies conducted by local agencies show that **on an average around 200 mg of arsenic is emerging out with groundwater through each of the minor irrigation tube wells when working for a continuous period of 8 hours.** This has been observed in Raninagar Block, Murshidabad District. (SOES Research Paper, 1999). Another study conducted by the same institution in a single Rural Water Supply scheme in Malda shows that there is an annual withdrawal of 147kg of arsenic from groundwater.

5.3 Forms of Arsenic in Soil

Inorganic arsenic present in the soil can be converted into organic form by soil microorganisms. Researchers have reported that fungi, yeast and bacteria in soils can convert arsenic to methylated forms as well as gaseous arsine. Arsenic is a transitional element or metalloid commonly forming complexes with metals, but it reacts readily to form covalent bonds with carbon, hydrogen and oxygen. Arsenic is abundantly available in nature in combined state mostly as minerals of sulphides, oxides as arsenites and arsenates. The forms of arsenic present in soils depend on the type and amounts of sorbing components of the soil, the pH and the redox potential. The percentage of water-soluble arsenic is proportional to arsenic added to the soil and inversely proportional to the iron and aluminium content. It has also been observed that solubility of arsenic in soil increases with decrease in Eh and pH (Micheal and Russell, 1976). Studies have shown that the relationship between soil arsenic and growth of plants depends on the form and availability of arsenic in soil. The toxicity of arsenic varies with its form and valence, its toxic order being AsH_3 > As(III) > As(V) > organic As.

Chemical forms of arsenic and their transformations in soils are shown in **Figure 5.1**. It indicates that oxidation, reduction, desolation, precipitation and volatilisation of arsenic reactions are a common occurrence in nature.

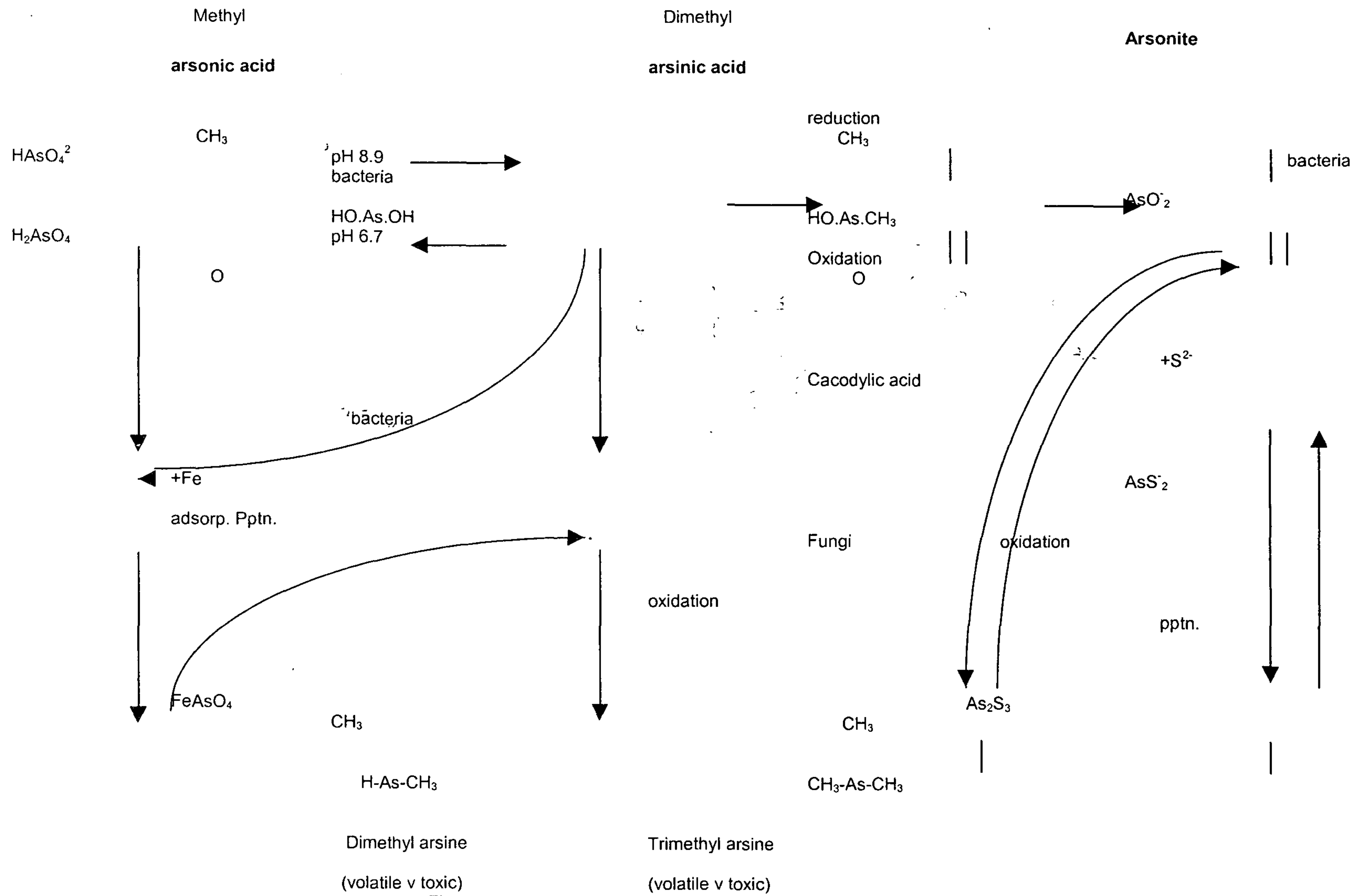


Figure 5.1: Chemical forms of arsenic and their transformations in soils

5.4 Effect on Growth of Plants

In India not many detailed studies have been carried out to ascertain the inter relation between arsenic in soil and growth of plants. The few that have, have not been published. A study in this regard is beyond the scope of this project. But from various studies conducted in Japan and other countries it has been observed that there is no simple relationship between the total arsenic in soil and its rice yield. However Kiyosue and Yano (1975) have found that soluble arsenic in soils extracted by 1N HCl, 0.5 N HCl or 2.5% acetic acid after seven days of incubation showed high correlation with rice yield. In another study it has been observed that the concentration of arsenic in paddy soil extracted by 1N HCl is linearly correlated with rice yield (Masujima, 1978).

5.4.1 Positive correlation

Rice growth seems to depend on the amount of arsenite present in soil. Arsines damage the roots of rice plant, resulting in the inhibition of nutrient uptake. Tensho (1973) observed that arsenate got reduced to more toxic arsenite in submerged conditions. This arsenite was more soluble in soils and readily absorbed by paddy plants. The contents of arsenic in the roots, stems, leaves and ears of the rice plant has got a positive correlation with the extractable arsenic in soil (Koyama et.al. 1976). The distribution of arsenic in plants mostly is in the descending order –i.e. it is maximum in the roots and the lowest in the leaf and edible parts (Liu et.al. 1985). This is an important issue because there are a large number of vegetables whose roots are also consumed by the community.

5.4.2 Decreased crop yield

To understand the effect of arsenic on agricultural products let us assume the mean values of arsenic concentration in soil (top 15cm) to be 6 mg/kg. This will correspond to about 12 kg of arsenic per hectare to a depth of 15 cm. The average water requirements for rice are 8650 m^3 of water per hectare. If we consider an arsenic concentration of about 0.2mg/l (average reported in the region) this will contain about 1.7 kg of arsenic per hectare in one crop cycle. Considering the top 15cm of soil for crop plantation, each cycle will increase the amount of arsenic by about 14 % (initial concentration of 6 mg/kg). This means within a 7-crop period the arsenic concentration will get doubled unless naturally occurring arsenic reduction mechanism plays a role. However, studies elsewhere have shown depressed crop yields were recorded at about 25 – 85 mg As/kg of fresh weight.

At soil arsenic concentrations of 3 to 28 mg/l of water-soluble arsenic and 25 – 85 mg/kg of total arsenic, most of the plants show significant drop in crop yield. This decrease in production has been observed in case of peas, rice, soybeans, alfalfa, barley etc. Study also shows beets accumulate arsenic more readily at increased temperatures but addition of phosphate fertilisers reduces the intake (Merry et.al, 1986).

5.4.3 Soil type

It has also been observed that the toxicity of arsenic in various soils decreased in order from sandy soil to alluvial soil to black soil to red clay. In general, arsenic availability to plants is highest in coarse–textured soils having little colloidal material and little ion exchange capacity and lowest in fine textured soils, high in clay, organic material, iron, calcium and phosphate (NRCC, 1978).

Many studies have observed that a variety of vegetables readily adsorb arsenic and retain it. This in turn might affect the food chain. Hence it is essential to analyse the critical content of arsenic in soil so that its ratio could be controlled in order to save the vegetables and crops. However lot of research work needs to be done to ascertain the soil condition, vegetable and crop intake of arsenic from soil and water requirements of the vegetation.

5.5 Agricultural product analysis

As part of the study food grains, vegetables and fruit samples were collected from various fields being irrigated by arsenic contaminated water. The food articles were cleaned with water and digested to determine the arsenic concentration in the left out dry mass. Though certain amount of arsenic might have escaped during heating, the enclosed list shows the amount recovered. (Annexure)

From this it can be observed that **certain amount of arsenic is already available in food articles, but detailed study will be necessary to work out the arsenic poisoning limitations in each of the food items in both dry and raw conditions; the normal intake of these food articles in combination with other foods; the present level of arsenic in food articles in non-arsenic irrigated areas and amount of arsenic in the soil in relation to raw water quality.** Hence this has to be a long drawn out study looking into the inter-relation between groundwater–soil-food articles-animal/human chain and arsenic in groundwater.

5.6 Food cooked in Contaminated water

Water is one of the main ingredients being used for cooking of food in Indian households especially in Bengal. Boiling of rice, preparation of pulses and curries like potato, making tea, etc. use water drawn from the drinking water source. Studies carried out by Dept. of Biochemistry & Nutrition, All India Institute of Hygiene and Public Health, Kolkata has found out a number of interesting results with respect to cooking of different food articles in arsenic contaminated tubewell water. The findings are listed below:

- Boiling of arsenic rich water reduces its concentration and this has direct relation with time. For instance, boiling for 5 minutes will reduce the arsenic concentration by 20% and for 25 minutes the concentration will reduce by 65%. At the same time volume of water will reduce by 15% and 55% respectively.
- Concentration of arsenic in distillate increases with boiling time – increase of 34.4% with 10 minutes boiling and increase of 60.45 % when boiled for 25 minutes.
- Liquid pulse (Dal – common preparation in any Bengali household) retains about 91.2% of arsenic when cooked ih arsenic rich water.
- Potato curry retains about 92% of arsenic when cooked in water with arsenic.
- If excess water is taken out of the boiled rice about 66.6% of arsenic gets retained. However if cooked water is not drained out arsenic retention is around 93.3%.
- About 56% of arsenic gets retained in tea liquor if boiled with arsenic rich water.
- Diluted milk (ratio 2:1) retains about 87% of arsenic.

The study shows that when food cooked in arsenic water is consumed, 57% of the arsenic intake is from food whereas drinking water contributes about 43%. Hence families using arsenic contaminated water for cooking are inadvertently exposed to arsenic poisoning of food articles.

5.7 Future Action

Irrigating crop with arsenic rich water will increase arsenic concentration in the soil. This in turn is likely to increase concentration in the edible portion of the food product. The plant–soil relationship is quite complex and requires detailed study with respect to forms of arsenic, soil characteristics, the type of plant and other environmental conditions. It is desirable to see whether arsenic concentration in crops has increased to levels that might affect human health and crop production. A limited study conducted under this project has not witnessed any appreciable change in crop production; therefore a long drawn out study needs to be initiated to establish the role of arsenic in the food chain.

6. SOCIO-ECONOMIC ISSUES

6.1 Overview

Studies carried out by different agencies have found the presence of arsenic in as many as 70 blocks across nine districts of the state. While the presence is extensive, there is little in the way of clinical treatment for arsenicosis. Therefore, provision of arsenic free water becomes the only logical way of addressing the problem.

Various efforts of the government, along with external support agencies, private organizations and research institutes, have been aimed at addressing arsenic contamination. These efforts have included awareness generation, water quality tests and the introduction of arsenic removal technologies. Each of these activities is in a different stage of achievement, varying across different regions. Most of the technologies are at the nascent stage of research and development, and while many studies have focused on the technical aspects, few have carried out socio-economic and marketing assessments, necessary for commercializing the technologies.

6.2 Aims & Objectives

It is in the context of the above that a study was undertaken to:

- Take an integrated view of the arsenic problem by better understanding socio-economic issues and their potential solution;
- Gauge the community's perception about the existing technologies and what efforts are required to make the system more user friendly;
- Study the community's understanding of arsenic toxicity and its perception of the problem.

The study used both exploratory and investigative methods. Target segments interviewed included:

- Users of Arsenic Removal Plants (ARP) – both community and domestic;
- Panchayat members and representatives of state agencies involved in the program;
- Personnel of company/ institution involved in developing/ marketing ARPs;
- Dealer personnel marketing ARPs;
- Maintenance personnel of community based plants;
- Community opinion leaders;
- Training institutions;
- NGOs involved in the arsenic mitigation process.

Attempts were made to cover every kind of technology installed, although in areas where only a limited number of plants of a particular technology have been installed, the choice of location was constrained. A concentration of ARPs of most of the technologies in one district, North 24 parganas, resulted in a degree of bias towards this district in the sample. A total of seven technologies were analyzed over five districts.

6.3 Social Factors

The social aspect of arsenic contamination in groundwater and its containment revolved around two main issues: general awareness of the community on arsenic contamination and social aspects relating to arsenic removal technology. More specifically, the four areas examined were (1) awareness levels; (2) health concerns; (3) technology options; (4) operations and maintenance.

6.3.1 Awareness

Considerable variations exist in the levels of awareness on the arsenic problem across the affected areas. **The awareness is either through the incidence of arsenicosis in a specific village or arsenic related activities undertaken by governmental and non-governmental agencies**. Thus, in areas where water testing or arsenic awareness campaigns have been set up, awareness on the issue has been relatively higher. These have typically been carried out by an NGO or by a government agency such as the PHED. Exposure to television, newspaper or other mass media has also contributed to familiarizing the problem, though in a somewhat limited way.

In most areas, where there is some awareness, arsenic is seen as a 'poison' present in tube well water. A proper understanding of its properties, its implications and strategies to address it, is lacking even in areas where awareness campaigns have been initiated through NGOs. Therefore, the correlation between arsenic and various medical symptoms experienced by people in arsenic affected areas is at best a local perception, and does not seem to have been verified by local doctors, in a holistic manner. Perhaps because of limited awareness, people prefer arsenic free water from deep tube wells to the treatment units. Since the test reports of the treatment plants are not regularly available, people are skeptical about the plant's efficacy. A major irritant is the involvement of multiple agencies claiming their product to be the best. As no coordinating agency is available presently to certify the efficacy of the treatment processes the community views the system with suspicion.

Since food cooked in arsenic water is equally lethal, the enormity of arsenic toxicity and its repercussions to the human system is not getting to the community.

Lack of basic education seems to be another factor that is hampering the early acceptance of the systems and understanding the seriousness of the problem. It is only in select cases, particularly with educated and economically well off users of domestic filters, that the understanding of arsenic and its problem is tangible.

6.3.2 Health Concerns

The reported symptoms of arsenic toxicity include skin problems such as black spots on different parts of the body, roughness of the skin and growth of warts; hyperacidity; respiratory problems; digestion problems and general weakness. According to the families of the patients, these symptoms usually take three to five years to set in.

The extent of awareness on the physical bearings of arsenic contamination was directly co-related with the prevalence of arsenicosis in the area. However, as mentioned earlier, these are primarily local perceptions. While doctors may have linked some ailments like skin eruptions to arsenic poisoning, it is unclear whether all of the symptoms identified by the local people were in fact a consequence of arsenic contamination. There does not seem to have been any concerted campaign highlighting the range of adverse health impacts of arsenic. Such a campaign would be especially relevant in the case of pregnant women and nursing mothers.

A major problem in rural areas is that **even doctors and paramedical staff are quite unaware of the methods of screening people and identifying symptoms caused by arsenic poisoning in early stages. To make matters worse, quacks tend to mislead people and make them lose valuable time (as early detection helps in quicker recovery).**

In some extreme cases of arsenic contamination, death has been reported from different regions. Surprisingly however, in some areas such as Adahata in North 24 Parganas, where the concentration of arsenic appeared to be amongst the highest, villagers were not aware of any arsenic induced death. Field surveys failed to clarify whether deaths were related to arsenic toxicity or not. This suggests a lack of clarity on the co-relation of symptoms with the disease.

Significantly, since arsenicosis is not perceived to be a contagious disease, there seems to be low social ostracization resulting from it. There do exist concerns on the cosmetic aspects of the disease, because skin problems make the patients appear dirty or ugly. This is particularly pronounced in the case of women, who fear problems in marriage as a consequence of the adverse changes in looks. Similarly other studies have indicated that in some extreme cases the married women suffering from the disease have been turned out of their in-laws' house.

People suffering from arsenicosis generally feel lethargic and physically weak. Since a majority of the people are daily wage earners and agricultural labourers, it affects their income. This in turn affects their purchasing power making it a vicious cycle. **It has been found that the toxic effect of arsenicosis is slowed down appreciably with high carbohydrate and protein diets.** Since the poor can hardly manage to purchase their food, dietary deficiency make them more susceptible towards the disease.

Getting proper treatment at the village level is difficult. Trained medical professionals are not always available and people have to travel all the way to Calcutta for diagnosis and treatment. This costs a lot of money and drains out most of the poor man's savings. Besides, the treatment process being long and costly people tend to avoid them altogether.

While there exists some awareness of adverse effects on human health, **the adverse impact, if any, on livestock or agriculture is negligible**. Even if there are any, the local people have not felt them so far. In discussions, most villagers do not seem to have made any connection between the two. Research studies conducted elsewhere show that animals are not as sensitive to arsenic as humans owing to differences in gastrointestinal absorption. In the Project area, despite probing, very little information was found on the presence of arsenic in the food chain. The message warning people about cooking with arsenic contaminated water has evidently not been very effective.

6.3.3 Technology Options

Limited awareness

Community awareness on the choice of available technology for arsenic removal is negligible. In fact, a particular technology being used in a particular site is invariably the choice of the NGO operating in that area, the PHED or Public Health Engineering Department or the manufacturer of the kit/ plant rather than an informed decision made by the local population. An ARP is rarely set up because of demand from the local community except in cases where people have contributed towards the capital cost of the plant. The local people had little knowledge of the reasons for selection of a particular technology – whether it was based on aspects of costs, maintenance, known brand or any other.

The reason for this community disinterest is a combination of lack of serious effort from NGOs and state agencies and the negligible marketing efforts by the manufacturers. Instances where manufacturers and dealers have publicized their products through fairs, exhibitions, demonstrations, etc, the awareness has been distinctly greater. This has been proved in the case of some domestic filters that target individual buyers. Since the community plants are largely supplied through development programs or NGOs publicity to the local community has therefore been minimal.

Sustainability

In the case of **community-based plants**, the very first issue that raises concerns is the choice of location of the plants. Where the local community and the panchayat have been involved, decisions regarding the location have benefited a large number of the community. In other places, the choice of location has been questionable and affected the extent of usage. It was found in the latter, that people continued using the contaminated tube well water.

In several cases studies revealed that people reverted back to tube well water, after a while, bringing into question the sustainability of the plants. This is specially so in the case of cooking, because apparently foods like rice do not cook well in arsenic treated water using a particular technology. Other reasons for not using treated water are irregular water supply, inadequate flow of water, malfunction of the plant and the presence of impurities such as worms. It was observed that whenever the community is involved in the maintenance and management of the plants, the acceptance and regular operations is considerably smoother than when they are not.

Deterring cost factor

Issues relating to domestic ARPs are somewhat different. For one, the cost factor deters a large segment of the population from using the technology. Even with substantial subsidy from the promoting organisation, acceptance levels have been low. There is therefore a strong need to develop a low cost option for greater acceptance.

The acceptance of the domestic ARP was found to be significantly more than the community one. Its relatively easier maintenance, lower cost, and the absence of intra group conflict could in part contribute to this preference.

6.4 Capital cost sharing

Sector Reform proposals advocated by the Government of India envisages a minimum of 10% capital cost contribution and 100% O&M contribution from the beneficiaries. It has been observed that for optimum use one community unit will be sufficient for 50 families (about 250 individuals). Based on the average paying capacity, a one-time contribution of Rs. 100--Rs. 150 per family should be sufficient if the costs of the community plant along with the accessories are kept within Rs. 50,000. Similarly, monthly O&M cost for the community unit needs to be kept within Rs.600 to make the system sustainable.

In case of household arsenic removal technologies the current costs range between Rs. 2000 to Rs. 3500. Though a cheaper ARP costing a mere Rs. 200 has been introduced, it has technical loopholes that prevent its large-scale introduction. However, locals agree that for widespread acceptance of the household units the costs should be restricted to around Rs. 500 or subsidy measures introduced. O&M cost of these units should not be more than Rs. 10-20 per month.

*Under the demonstration Project "**Community based Sustainable Potable Drinking Water Supply in West Bengal**" implemented by the Rama Krishna Mission Lokshiksha Parishad, an NGO and supported by RGNDWM, beneficiaries had contributed amounts as high as 30% of the capital costs. The capital cost contribution from the villagers ranged between Rs.10 to Rs.5,000 with 42.5% contributing between Rs.10–Rs.100,, 43.5% contributing Rs.100-Rs.300 and 10% contributing between Rs.300-Rs.500. This one time contribution was collected in two-three installments. The beneficiaries themselves decided which family would contribute how much, but every family had to contribute according to their pay capacity. Everyone received equal share of the treated water source irrespective of their share of contribution.*

6.5 User satisfaction

While it is yet to be medically proven, users of ARP treated water do perceive a turnaround in ailments such as hyperacidity, indigestion, constipation, skin problems and overall body weakness. Interestingly, while on the one hand there is a perceived benefit, there also exists a strong need to gain assurance that the treated water is actually arsenic free. This implies that frequent water tests need to be carried out. The community also needs to be reassured of the safety of the chemicals being used and that there aren't any long-term side effects incurred from them.

Using treated water also has economic implications. It has been found that the working capability of the community is greatly hampered by the arsenic problem. The loss of person-days, medical cost, travel and transportation costs for the treatment in Calcutta also poses a substantial economic burden to the family.

6.6 Operations & Maintenance

For regular maintenance of the community plants, the manufacturing company appoints a person to address day-to-day operational issues. The process of operating and maintaining the plants is not viewed as being particularly complicated and could, with adequate training, be handed over to the local community. However, there is currently reluctance when it involves adding of chemicals to the plant on a daily basis. It is felt that being assured of the quality of the chemicals is a problem and there are no checks on the amount of chemical added. In most cases, maintenance continues to be the responsibility of the manufacturer or the implementing agency. Clearly, there is a need to conduct training on maintenance aspects and hand over such aspects to the community for greater ownership and sustainability of the products. In this context, a manual for operation and maintenance of the plants, which could be used by the community, would be extremely useful.

1. Company's role

Currently the company bears the maintenance as well as installation costs in most cases; in some cases they are borne by an ongoing programme or through development grants. Where local community has been involved in managing and running the plant through the formation of committees, user contributions are collected for the operations and maintenance expenses, which then become the responsibility of the committee formed. Perhaps the reluctance to hand over the responsibility of maintenance to the community stems from the technology being at the nascent introductory stage. Even in localities where there are no local contributions for regular maintenance, the community is not completely averse to the idea of contributing.

2. Simple maintenance

Maintenance of the domestic ARPs has been found to be quite simple. In most cases the housewife looks after the filter, which needs to be backwashed periodically. The wastewater is thrown into open drains, which suggests that as in the case of community plants, the issue of waste disposal remains to be addressed effectively. The chemicals required for dosing are currently supplied by the NGO. The community is not aware of other sources for procuring the chemical, and to that extent the dependence on the external agency continues.

3.Waste management

In most cases, it is found that the issue of waste water/sludge management remains, even though there is a degree of satisfaction on the aspect of arsenic removal. At present, **there seems to be little awareness amongst the community on aspects of sludge management and backwash water management, both of which have a high concentration of arsenic.** While many manufacturers have, in theory, worked out systems of sludge disposal, in practice it has not been carried out in most locations. It is therefore difficult to comment on the efficacy of the systems developed.

4. Availability of ARPs

Another important issue is the non-availability of the household treatment units locally. Those consumers, who feel the need for ARPs and can afford them at present costs, cannot do so due to poor marketing facilities of different available technologies in the local markets. **The study found that the community is on the lookout for cheap household-based units but doesn't really know where to look for it.** Moreover, after sales service need to be linked up with the marketing facility to meet the needs of the community. People using the ARPs want to know whether they are functioning properly. Some locally available water quality testing mechanism needs to be developed which could be run by Youth Clubs.

5. Local initiatives

People in the affected areas are keen to come forward and help. **If they are required to develop some CBOs, like Village Water and Sanitation Committee to operate and manage the systems, they will do so. However, they would prefer an agency to play the role of a facilitator and keep the dealings transparent**. At this point the role of Youth Clubs and NGOs will be very important for a sustainable development of the program. The success of the whole process will however depend on the rapport between the Youth club and the community who will have day-to-day interaction.

6.7 Conclusion

In conclusion, a wider acceptability and long term sustainability of plants requires a more effective overall coordination between the various stakeholders viz. the community, the implementing agency and the manufacturer. This in turn points to **the need for encouraging community participation at the grassroots level who could be involved in all aspects of decision making relating to planning, implementation and operations.** Existing local organizations, or non organized groups such as local youths, who have demonstrated considerable enthusiasm on the issues or have the potential to motivate others, could be involved in a proactive manner in creating and sustaining demand on the one hand and the installation and management aspects of the ARPs on the other. The implications of this would be at two levels: one, relating to the ownership and acceptance of the technology and two, elevating the economic status of the population. In many of the areas where much of the population lives below the poverty line, the involvement of the community in maintenance could be viewed as a possible source of income generation as well.

Surprisingly, the panchayat does not seem to have played a substantial role in most of the areas visited, even though the potential for the panchayat to do so is enormous. In several cases the panchayat was divorced even from basic decisions such as location of the plants. **While other local organizations may not always be sustainable, the panchayat is a more permanent institution, which could play an effective role in the arsenic mitigation process.**

While awareness on the arsenic issue is present, the efforts at increasing this awareness need to be increased. There continue to be many instances of people not appreciating the need to use treated water. Perhaps they feel that since the water that has been used for several years has not created any substantial problem, there is little justification for concern. This is the case when the financial aspects are not an issue, as they are in most cases being borne by the implementing or manufacturing agency. For long-term sustainability, the costs would have to be borne locally. This would be acceptable only when there is considerable appreciation on the need for using treated water.

Similarly, the limited information available to local community on different technologies presents a case for much greater publicity on arsenic removal technology. This would enable the community to demand such technology, as also make informed choices on the technology.

7. FINANCIAL APPRAISAL OF ALTERNATIVES

7.1 Introduction

In India most Drinking Water and Sanitation Projects are implemented, operated and financially maintained by either the Central or State Governments through various social welfare programs. Activities related to arsenic mitigation are no exception barring some pilot projects where research agencies and NGOs have generated funds from other sources. A few ARPs have also been installed by private agencies involved in the trade primarily to try out their systems. No concerted effort except for a few installations of piped water supply system through PHED, have been evident so far to counter the arsenic problem. Consequently, financial appraisals to check the viability of the systems installed have not been done either. The present study is an attempt at this evaluation. It focuses mainly on aspects relating to finance. The first part of the study attempts to determine the cost of arsenic free water using different technologies and the second part looks into ways to recover these costs.

7.2 Existing Financing Mechanism

Schemes for drinking water quality control measures based on alternate safe sources and/or treatment plants are funded under Sub Mission. Usually the fund sharing is 75:25 between Government of India and the State Government. But with the modified programme of providing new incentives to states for institutionalising 'Community Participation', at least 10% of capital cost and 100% of Operation & Maintenance (O&M) cost has to be shared by the beneficiaries. The GOI guidelines also suggest that the proportion of capital cost shared should increase proportionately with increase in service demand. This analysis has been done keeping these guidelines in view.

7.3 Present Situation

Till end of November 2000, only 74% of rural habitations in West Bengal could be fully covered under community water supply facilities while the balance 26% was only partially covered. The arsenic affected areas unfortunately form a major chunk of partially covered habitations.

According to the 1991 Census, 35.54% of rural habitations in the state have population below 500; 24.43% have population in the range of 500-999; and 21.22% have population in the range 1000- 1999. The National Sample Survey reveals that 75.76% of rural households depend on hand pump/tube well sources to meet their drinking water needs. Out of these about 73.2% draw water from community hand pumps/tube wells. A total of 70.5% of households draw hand pump/tube well water for cooking purposes. Hence it could be safely inferred that the hand pumps are here to stay for some time to come.

Since the community is largely dependent on groundwater sources the prudent choice would be to keep the existing infrastructure with necessary modifications instead of going in for fresh investment in creating new systems. A supply of 40 litres of arsenic free water per household per day should suffice to meet requirements for drinking and cooking.

7.4 Alternate Technologies

For providing arsenic free water to the domestic consumers a number of alternate technologies have been discussed earlier. However, we are considering only three alternatives for financial appraisal. They are

- Deep Tube Wells.
- Community based Arsenic Removal Plants.
- Household based Arsenic Removal Filters.

Other alternate methods like Roof Top Rain Water Catchment Systems and Use of Small surface water systems/ Dug wells have not been considered for these are yet to be implemented on a trial scale.

7.4.1 Deep Tube Well

Since deeper aquifers in the arsenic belt are comparatively free from contamination, the State PHED has implemented a number of mitigation schemes to tap this water. Some of these are Multiple Village Schemes, which cater to large populations. Data obtained from the State PHED for eight such schemes show that these cover mostly big villages of population around 5,000. **Investment per village is estimated at more than Rs.5.4 million while the per capita investment is about Rs.1100. The per capita water availability varies from place to place and ranges between 165.8 to 6.76 litres per day.** The piped water supply systems cater to bulk villages irrespective of arsenic contamination. Since the number of people at risk from arsenic toxicity are estimated to be around 6 million the capital investments required would be of the order of Rs.12,600 million—a sizeable amount even by conservative estimates. Besides the difficulty of mobilising such a large sum, it could lead to other problems related to degradation of the existing aquifer. Apart from this high O&M cost, maintenance troubles associated with piped systems, low water availability in the tail end areas, availability of power (electric/ diesel), water availability in the limited time and long queues at the water outlet points are other common problems associated in any piped water supply system and cannot be avoided here as well.

7.4.2 Community Arsenic Removal Plants

The strategy of installing ARPs at the community hand pump source for arsenic free water is advocated because it involves relatively low initial cost and the investment already incurred for installing it can be economically utilised. The seven different technologies discussed in earlier chapters have been considered. To make comparison easy a standard set of norms have been taken. The parameters are: cost of providing 100 litres of treated water, provision of 40 litres of water per household per day and the number of families dependant on one community based ARP being 250. A comparative analysis of O&M charges for different scenarios is placed below.

Table 7.1: Comparative Analysis for O&M Charges

System	*Per 100L Cost*	*Monthly HH Charges 100% Cap. + O&M*	*Monthly HH Charges –repl.cost + O&M*	*Monthly HH Charges with out repl. cost*
PHED – Pipe	*2.67*	*100.2*	*18.4 (10% Com. Contribution)*	-
AMAL	*3.75*	*45.05*	*23.35*	*8.34*
AIIH&PH	*5.87*	*35.23*	*25.41*	*24.06*
APYRON	*14.55*	*175.47*	*72.34*	*16.06*
Ion Exchange	*8.22*	*98.68*	*67.58*	*39.45*
Pal Trockner	*6.22*	*76.76*	*24.13*	*9.13*
PHED	*11.6*	*139.15*	*106.51*	*31.48*
WSI	*10.41*	*124.91*	*34.35*	*15.59*

Assumptions:

1. *One treatment unit serves 50 household with an average consumption of 40L*
2. *Average five persons per family per household.*
3. *In case of capital expenditure the discount rate is 12% per annum.*
4. *In case of O&M expenditure the replenishment expenditure is incurred at the beginning of the year/period and in case of other items of O&M the expenditure are incurred in the middle of the year. The discount rate applicable in their case is 1% per month/ part of it.*
5. *Costs of stoppage of service due to break downs, annual maintenance, sludge removal etc. are not taken into reckoning. Only a mention about them is made.*

7.4.3 Domestic Arsenic removal Filters

The strategy regarding domestic filters is quite different from that of the above two. It is more inclined towards meeting the needs at the household level. It encourages the Government to play a facilitator's role by encouraging entrepreneurs to manufacture domestic units and market them, popularise the filters and carry out periodic water quality tests. A major advantage of the domestic filter is that a householder does not have to queue up for water. But the cost factor may be one of the major deterrents to adoption of the system on a large scale. Four types of systems have been considered. Comparative Cost analysis of Domestic Units is presented below:

Table 7.2 Comparative Cost analysis of Domestic Units

	AMAL	***Pal Trockner***	***AIIH&PH***	***SOES***
Initial Cost	*1650*	*3500*	*200*	*600*
Annual Replen/ Chem. cost	*540.72*	-	*377.7*	*679.36*
Replacement – 5 years	*340.44*	*567.4*	*200.00*	-
Total	*2541.16*	*4167.40*	*777.70*	*1279.36*

7.5 Comparison of Investment Cost

All the systems discussed above call for a high level of investment both by the state as well as the community. As mentioned earlier the recent emphasis is for 10% community contribution. A cost comparison for per capita investment for different systems is tabulated below. For estimation purposes an average family of five has been considered. We predict that a one-time contribution of Rs.250 will be made by more than 70% of the households for community-based units since people's willingness to pay is evident as many poor people are paying for services. For HH based filters it is hoped that 50% of the capital cost will be borne by the household.

Table 7.3 Comparative Analysis of Investment Cost

Community System	*Cost Per Capita*	*Subsidy per Capita*	*Household cost Per Capita*	*Total HH cost*
PHED- piped	*1000*	*900*	*100*	*500*
AMAL	*200*	*180*	*20*	*100*
AIIH&PH	*120*	*108*	*12*	*60*
APYRON	*324*	*292*	*32*	*160*
Pal Trockner	*344*	*310*	*34*	*170*
PHED	*144*	*130*	*14*	*70*
Ion Exchange	*288*	*259*	*29*	*145*
WSI	*348*	*313*	*35*	*140*
Household Units				
AMAL	*330*	*165*	*165*	*825*
AIIH&PH	*40*	*20*	*20*	*100*
Pal Trockner	*700*	*350*	*350*	*1750*
SJCE	*125*	*62.5*	*62.5*	*300*

7.6 Cost recovery

Fund availability is limited. Therefore we have to make sure that institutions managing the sector in both urban and rural areas are reorganised and modern management practices and transparent methods are introduced. This will make them efficient, accountable and financially sustainable. Besides the physical operation and maintenance, the tariff design and tariff implementation will improve considerably. Currently there is no provision of O&M cost recovery in any of the running schemes barring those through NGO interventions. This has resulted in supplying water free of cost and its scarcity never gets reflected in terms of market price. No economic value has been attached to treated water, thus promoting wastage and occasional misutilisation of this extremely essential and scarce commodity.

However, the pricing of water should be such that a certain minimum quantity of standard quality water is available to all sections of the society to help them maintain good health and well being. Nobody should be priced out from availing the socially desirable minimum level of service. Delicate balancing may have to be arrived at over conflicting considerations. In rural areas, the charges have to be more or less uniform unless and until the community members decide for themselves the cross subsidisation mechanism.

To arrive at possible tariff structures two analyses are available--one based on Poverty Level Analysis and the other on National Sample Survey on Expenditure Analysis. From the available data we can assume that more than 70% of rural households are capable of paying a monthly sum of Rs.26 as water charges. If we link this to the table at 7.1 a number of community based ARP units could be paid for by the beneficiaries.

AFFORDABILITY ANALYSIS

1. *1999 – 2000 – Poverty Level West Bengal (Rural) - Rs. 350.17 per capita per month*
2. *Present population below poverty Line - 31.86 percent*
3. *Below Poverty Line family of five income per month - Rs. 1750.85.*
4. *Affordability level at 1.5% of family income – Rs. 26 / month.*

(70% of the rural poor should be able to pay for water charges at Rs. 26 per month)

EXPENDITURE ANALYSIS

National Sample Survey – 54th Round – January – June 1998 regarding Distribution of rural households according to their per capita income.

- *Per capita expenditure below Rs. 265 –300 – 38% of HH*
- *Expenditure on Pan, tobacco and intoxicants of the above mentioned group – Rs. 10.62/capita /month:*
- *Family expenditure for 5 members per month – Rs.53.*
- *Affordability Level estimated at 50% of above – Rs. 26.5.*

- *Lowest Expenditure Group Rs. 0 – 120 – 0.6 % of HH*
- *Expenditure on Pan, tobacco and intoxicants of the lowest group - Rs. 3.2/capita /month.*
- *Family expenditure for 5 members per month – Rs. 16.*
- *Affordability Level at around 50% - Rs. 8 –10/month*

7.7 Willingness to Pay

People in general are unwilling to pay for drinking water because they demand it as a matter of right and the government is duty bound to provide these services. But strangely they are ready to pay exorbitant prices for water when it has to be purchased from a private agency. Therefore, for any cost recovery scheme to be successful it is the perception that needs to be changed.

Fortunately, in the arsenic prone areas most people are aware of the arsenic related diseases and will willingly participate in any cost-sharing programme adopted by implementing agencies. A number of NGOs working in these areas have shown people willingly contributing as much as 30% of the capital cost and 100% maintenance cost once they were convinced that the systems work. In some community based ARP units people contribute as much as Rs.15 per month to operate and maintain the systems.

7.8 Balancing costs with expenses

Working out affordability factors and making institutional arrangements for levying water charges on clients is only one part of the exercise; the second and equally important task is to balance the costs with the charges. This may entail some major policy decisions and exploration of ways by which the costs can be recovered or brought down.

The charges have to be fixed at levels nearest to clients' affordability and willingness to pay. Though we would not like the government to heavily subsidise the service as it has been doing all along, it is necessary that withdrawal of subsidies be affected in a phased manner. This is necessary in order to control and minimise the political backlash of subsidy withdrawals.

A major O&M expenditure in the case of community based ARPs is the periodic replenishment of the media. In the initial phase, the government may agree to bear capital as well as replenishment expenditures. Staff salary is another major chunk of O&M expenditure. Community volunteers could be trained to operate the systems, which would help cut costs. The dealers who get substantial margins from the manufacturers of the equipment for vending their wares could be persuaded to take some responsibility with regard to preventive maintenance for a certain period after the sale. This will also bring down costs substantially.

A comparative study with different alternatives has been done and enclosed in the annexure.

8. INSTITUTIONAL ISSUES AND TRAINING NEEDS

8.1 Overview

The sustainability of any technology depends considerably on the degree of ownership of the community and the financial, social and environmental viability of the technology introduced. Most of these have a bearing on the extent to which the community, towards whom the technology is targeted, understand, accept and demand the technology; which in turn has a bearing on the extent to which the community is involved in the process of technology introduction. At present the community water supply systems are owned and maintained by government agencies. Though the people cannot afford the upkeep of the facilities, they cannot do much about its maintenance either. The Central Government and State agencies have initiated efforts to involve the community in the management programs in selected districts of the country.

8.2 Common perceptions

Water today is perceived by the rural population as a social right – a privilege to be provided by the government rather than a scarce resource that must be managed locally as a socio-economic commodity. This perception has grown mainly because the rural water supply projects are designed and executed by government agencies and imposed upon the end users. This is more of a supply driven approach, which has failed miserably. Studies show that communities participate in operation and maintenance of systems only when the following conditions prevail:

- If they own the assets;
- If they have installed the system themselves or are actively involved throughout;
- If they have been trained to do simple repairs;
- If they know that the government will not maintain the asset;
- If they have sufficient funds to maintain the systems;
- If they have to pay for O&M.

8.3 Community's role

As outlined in some of the previous sections, **the role played by the community in the present system of arsenic reduction in groundwater through the introduction of ARPs at local levels is extremely limited.** Decisions regarding planning, implementation, operation and maintenance are almost entirely taken by the implementing organization or agency manufacturing the ARP. Invariably, it is the implementing and/or manufacturing agency that decides on introducing a particular technology in a location. While they may take local institutions like the panchayat into confidence, decisions such as the site of the plant are taken by these agencies in most cases. Even most operational and maintenance aspects are taken care of by a specific person appointed by the implementing or manufacturing agency. Costs of installation and maintenance are borne by the company too.

While on the one hand the community is dependent upon the implementing/manufacturing agencies, these agencies are dependent upon the government for the introduction of their technologies. There is little in the way of proactive marketing, or training the local people in operations and maintenance of the plants, thereby minimizing the need for direct demand from the community.

But there are exceptions to this theory too. **The community based units installed by NGOs using technologies by AMAL and AIIH&PH has achieved a fair amount of community participation.** In case of some units installed with AIIH&PH technology, the community has paid as much as 30% of the capital cost. In case of AMAL and AIIH&PH, CBOs have been created to generate funds and operate and maintain the systems. Here the local Youth clubs and institutions that have developed the systems play a major role in providing training and knowhow in routine maintenance.

However, in a majority of districts the community's role is that of a bystander. While the absence of local capacity would have created this situation to begin with, the lack of concerted action towards developing this capacity would merely perpetuate such dependence. Thus, not only does the dependence continue, but there is also an absence of ownership and therefore of sustainability of the technologies introduced. Clearly, this needs to be addressed if the demand for the technologies is to grow and sustain itself. Addressing this implies that specific training needs be identified and capacities developed at various levels.

8.4 Institutional Issues

The State government and its lead sector agency – in case of West Bengal it is Public Health Engineering Department, will be coordinating the program with a changed role of facilitator rather than implementor. The other government agency like Department of Health and Panchayat and Rural Development Department will have a supporting role to play to make the program a success. An exclusive institutional structure consisting of State-level, district-level and grass root level units will be set up for project planning and facilitation.

For institutionalizing community based rural water supply systems the following basic principles need to be incorporated

- Adoption of demand –responsive and adaptable approach based on empowerment of villagers to ensure their full participation in the project through a decision making role in the choice of scheme, design, control of finances and management arrangements.
- Shifting role of Government from direct service delivery to that of planning, policy formulation, monitoring and evaluation and partial financial support.
- Partial capital cost sharing either in cash or kind or both and 100% responsibility of O&M users.

8.5 Role and Responsibilities of various units

Overall the State level Water and Sanitation Agency will be responsible for the following activities:

i) Overall policy guidelines;
ii) Liaison and coordination with various concerned departments of the State Government and other sector partners;
iii) Monitoring and evaluation of the project implementation
iv) Ensuring coordination among various district level projects;
v) Ensuring of Audit by competent authority;
vi) Interaction with the Central Government.

The role of District Water and Sanitation Unit will have the following role to play:

i) Formulation and management of project implementation in the district;
ii) Receipt of central funds
iii) Selection of private sector agencies/ NGOs for project implementation and supervision;
iv) Sensitize Panchayat Raj functionaries;
v) Formulation of Village level Water and Sanitation Committee (VWSC- a CBO) with the assistance of concerned NGO for generation of demand for implementation of sector reform concept.
vi) Development of common IEC material with the active participation of concerned NGOs.
vii) Interaction with Government agencies at the center and state level.

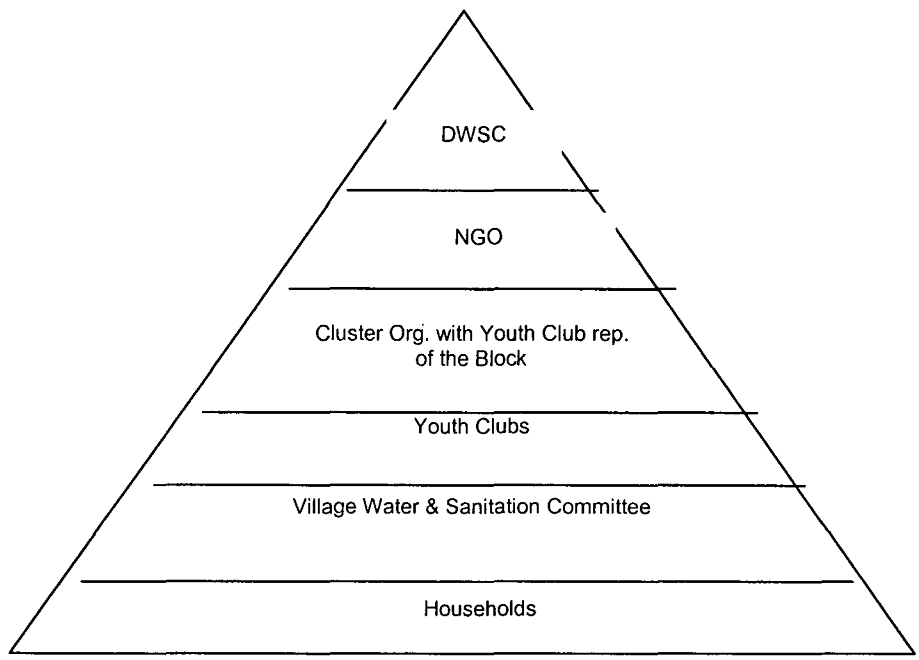
The Village Water and Sanitation Committee will play the major role in planning, implementation, operation and maintenance of the water supply systems. NGOs will play a major role in providing them with the facilities. The activities VWSC are supposed to handle will include:

- Ensuring Village Panchayat support to the program;
- Ensuring community participation and decision making in project activities;
- Arranging community contributions to capital costs as well as O&M costs;
- Opening and managing financial transaction in a transparent manner;
- Procuring construction materials/goods and selecting contractors with active participation of NGO concerned or its representatives;
- Stock regular maintenance material.
- Participation in HRD and IEC activities.
- Ensuring trained manpower to operate and maintain the systems.

8.5.1 Role of NGOs

The NGO selected for implementation and institutionalizing the demand driven approach must be a member of the District Level Committee. It will work through a network of volunteers preferably drawn from Youth clubs located within the village setup.

Youth organizations (referred to as Youth clubs) located in almost all villages/ habitations are a boon for the poor and distressed villagers and are involved in various socio-economic activities along with health, education, water and sanitation and awareness programs. The Youth clubs, through their cluster organizations will coordinate with the main NGO involved in the program in the area. The project will use this grass root level existing structure so as to strengthen the planning, implementation and post implementation management activities, which are to be carried out with the full co-operation of the community. Since the representatives of the community form these Youth clubs, therefore, there will be little doubt about their authenticity among the community, leading to easy acceptance. Based on the existing network the institutional structure adopted in the project will look somewhat like this:



8.5.2 Community Participation

Community participation is a long drawn out process and every actor in this process has a major role to play. This is also very time consuming and may take anything between 4 to 12 months.
The system also requires increased awareness and the community's demand for the improved system. Since contribution to finances is involved the community will ask for transparency at every stage of the process. A failure at any stage may have snowballing effect and could jeopardise the future of the program.

8.6 Arsenic Mitigation Centre

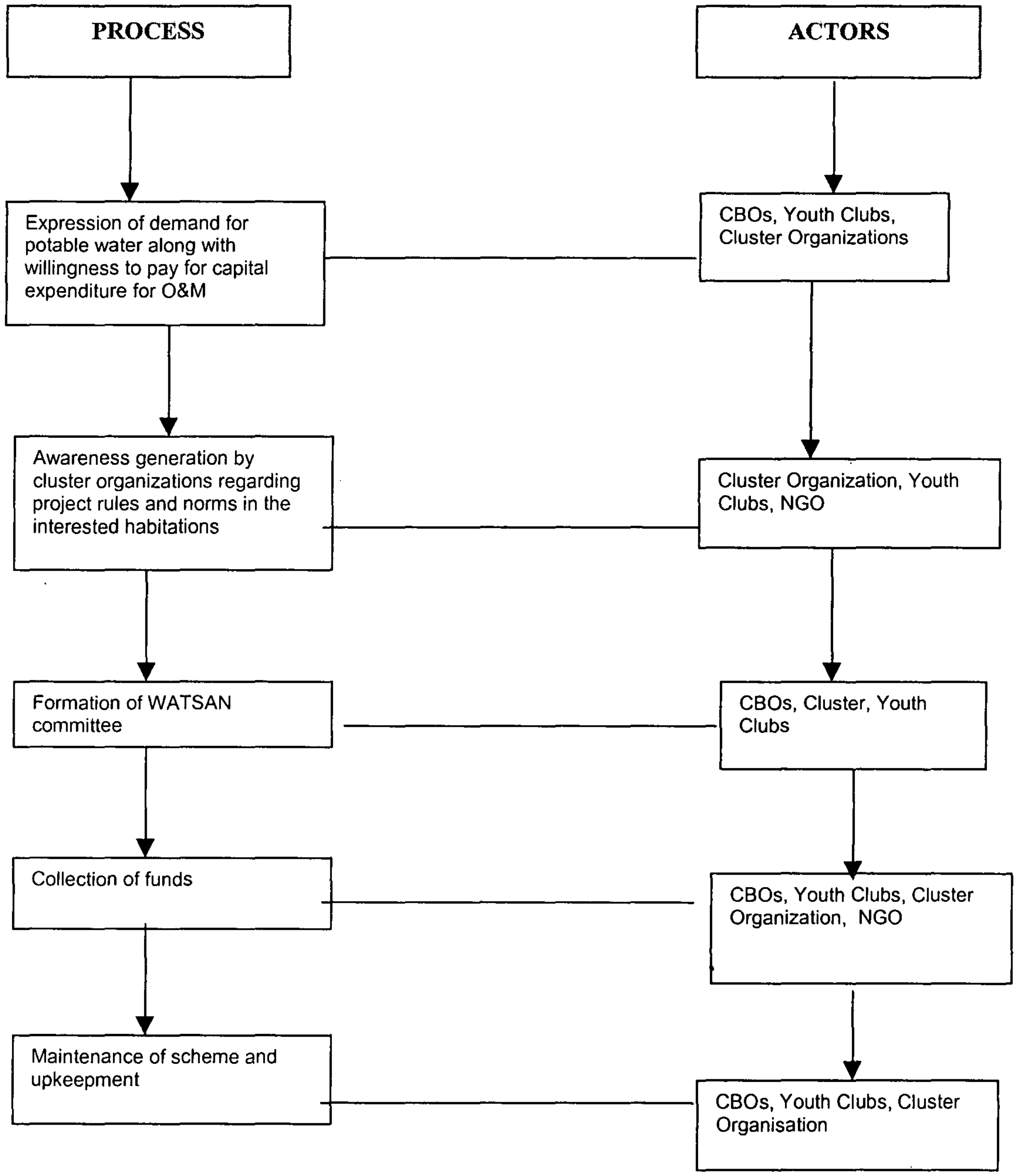
To enhance coordination among various agencies and to streamline arsenic mitigation efforts under one roof, Rajiv Gandhi National drinking Water Mission, Department of Drinking Water, Ministry of Rural Development, Government of India has decided to set up an Arsenic Mitigation Centre (AMC) at Calcutta. **This will be an autonomous institution of excellence for sector partners involved in planning and implementation of arsenic mitigation activities not only in India but in neighbouring countries as well.** The broad scope of AMC's activities include:

- Collection, analysis and dissemination of information.
- Providing state of the art laboratory facilities.
- Validation of new technologies and processes in the area of water treatment, water quality analysis and medical treatment procedures.
- Facilitate awareness generation, motivation and sensitization.
- Facilitate capacity building for project implementation.
- Assist in planning, coordination and monitoring.
- Identification of sources of contamination and suggest remedial measures.
- Carryout R&D activities related to arsenic in environment.

The AMC has been planned keeping in view the functional requirements in various allied fields such as:

- Public Health and Environmental Engineering.
- Hydro-geology
- Laboratory for water testing.

- R&D including Library and Information Technology
- Social Science including Health
- Administration and Finance.



The Centre will be headed by a Director. Section Chiefs will be heading each of the wings mentioned above. It will have a Governing Body and an Executive Committee. The Executive Committee will have sub committees dealing with different subject matters such as Policy, Technology and Social issues concerning day to day functioning. It is expected that external support agencies and various research organizations will serve as members of these various sub committees. The AMC is expected to meet the immediate technological, policy and social needs to plan and implement the arsenic mitigation program of the district authorities. The Center is still in the planning stage and is expected to be functional by the year-end.

8.7 Training Needs

Based on the constraints encountered in the existing system, it is felt **that training needs to be imparted in two basic areas: enhancing the community's knowledge base on arsenic and arsenic removal technologies and ensuring long term sustainability in use of ARPs.** Hence, training is required on both technical and non-technical aspects.

NGOs or other local organizations need to work with the local people to educate them about the arsenic problem. To do this successfully these NGOs or local organizations themselves would need training on:

- Basic issues of the arsenic problem;
- Technical aspects of arsenic removal;
- The different technologies available for arsenic removal; and
- Mobilizing the community for planning and use of ARPs- motivating them to switch to safe water sources
- Identification and screening of patients with symptoms of arsenic poisoning
- Initiating awareness program and advocacy activities with respect to use of safe water for drinking and cooking.

The next level, more directly related to operating arsenic removal technologies, would be aimed at the local community (through VWSC committees formed).
More specifically, training needs for the community would include the following:

- Leadership training for mobilizing the community and forming committees;
- Training of committee for generating awareness on arsenic issues and technology options;
- Management training, for operation and usage of plants;
- Financial and accounting training to manage financial aspects;
- Basic technical training for operations and maintenance of plants.

Members of the village Youth Clubs who are involved in social, education and health related activities would be trained to take up the role of facilitator on behalf of the NGO. They will be trained to carry out:

1. Water quality tests of raw and treated water and document them in the prescribed format.
2. Supervise construction of the facilities and their maintenance.
3. Organize community participation campaigns and facilitate formation of the VWSC.
4. Facilitate availability of chemicals and other spare parts through existing outlets like "Sanitary Marts" or develop one as per requirement.
5. Arrange trained skilled manpower to maintain the facilities in case of special repair.
6. Facilitate members of the VWSC to handle the financial matters including banking operations.

8.8 Institutional Training

Several institutions are currently involved, in varied ways, in the arsenic mitigation process. There are others who are not at present directly involved in arsenic mitigation, but have displayed the potential for involvement through existing expertise.
In view of the social and technical nature of training needs, a variety of institutions were considered as potential sources for providing training. Institutions that are already involved one way or the other in arsenic mitigation activities are:

- *All India Institute of Hygiene and Public Health;*
- *The Technical Teachers' Training Institute;*
- *Ramakrishna Mission Lokasiksha Parishad;*
- *Society for Equitable Voluntary Action;*
- *Economic Rural Development Society.*

All these bodies have infrastructure and expertise in various aspects related to arsenic poisoning. Some, such as the Technical Teachers' Training Institute, Ramakrishna Mission Lokasiksha Parishad and Mass Education have an extensive network of local level institutions through which they work. However, some of these institutions might need some trainers training program so that the existing faculty is equipped with the latest material to be used.

But before initiating training programs in a systematic way **it will be essential to standardize the material and documents to be shared with the community so that there is uniformity in the message.** Similar

action is needed for the development of awareness camps where a unified message will reach the people. All these materials need to tested in a pilot scale before being launched on a mass scale.
It is suggested that some of these institutions be identified as nodal institutes for undertaking training and capacity building aspects. Those with an extensive local level network should be preferred, because of the obvious logistic ease in imparting training to local organizations. These training institutions would then train local organizations, which would in turn facilitate the formation of committees and train the committee members.

Training needs to be made an ongoing program and not a one-time job. This will help in updating the knowledge of the beneficiaries and also upgrade the training material based on feedback from the community. A regular annual training program needs to be chalked out and made available to the concerned people including VWSC members and Youth club members to avail of the facility.

Funds available under a national Human Resource Development programme launched by the Rajiv Gandhi National Drinking Water Mission, ministry of Rural Development may be utilized to undertake the training programme.

9. PRIVITISATION AND MARKETING ISSUES

9.1 Background

As mentioned earlier, an integral part of the socio-economic study relating to elimination/reduction of arsenic in groundwater in West Bengal included an assessment of the opportunities and constraints in privatization of adopted technologies. At present marketing activities are considerably limited, and the commercial viability of the technology remains to be established. While there are several companies manufacturing arsenic removal plants, much of the activity continues to be dependent upon grants and linked to development programs. Unless marketing efforts are increased along with significant local level privatization, the scale of acceptance of ARPs (Arsenic Removal Plants) would not increase.

For this purpose, personnel from major companies manufacturing and marketing ARPs, dealers of domestic filters and members of the user community were met with, to assess the existing efforts in marketing and delve into the constraints and options for privatization.

9.2 Findings

Given the somewhat elementary stage in the use and acceptance of arsenic removal technology, the privatization and marketing of these technologies are in a nascent stage as well. Private entrepreneurs are yet to visualize the extent of the problem. They are not even sure of the community's demand for the systems. The local people on the other hand are not yet convinced that the technology brought in by private agencies are indeed foolproof and will serve the purpose. **Clearly, there exist distinct links between awareness and acceptance levels of ARPs and the maturity of marketing systems.**

9.3 Marketing Strategy

Currently, the major companies manufacturing ARPs depend primarily on the government for bulk orders. This is not surprising, since the government installs most ARPs, directly or indirectly, and rarely as a consequence of direct community demand. For instance, four private companies have presently procured trial orders as part of the Arsenic Mitigation Joint Action Programme of PHED and UNICEF.

It is quite rare that private companies employ other mechanisms of marketing. **Pal Trockner is one such exception, which has collaborated with the West Bengal Agro Industries Corporation to market its community-based plants.** Pal Trockner provides training to the Corporation's personnel, as well as the local community. The Corporation, in turn, provides all other services through a supervisor. The corporation network spread throughout the affected districts can be utilized to provide servicing support to the established units. This system of local participation allows the manufacturing company to reach out to many more potential customers.

In line with their relatively aggressive approach to marketing, Pal Trockner takes part in several fairs, exhibitions and seminars to demonstrate their units. There are also plans to take up mass media advertising as a means to spreading awareness about its products.

Amongst the domestic filters, such proactive marketing has been found in the case of AMAL, the filter developed initially by B E College, but later manufactured and marketed by Oxide India. Oxide India has appointed dealers for selling these filters, who give demonstrations at fairs and workshops. As part of sales efforts, the dealers also visit schools, banks, shops, clinics, homes, etc to create awareness. The company shares the costs for promotional activities with the dealers. Moreover, the training for backwashing the units are provided to the customers, the dealer providing free service to the customer for a period of two years.

Our studies reveal that a successful grassroot level private entrepreneurship was attempted by an NGO called *Swamiji Sewa Sangha* in the North 24 Parganas district. It adapted the technology for household ARPs developed by AIIH&PH. It was part of the Demonstration Project implemented by the Ram Krishna Mission Lok Shikha Parisad with financial support from the Central Government. The kit consists of locally made earthen pots, modified and fitted with indigenously made filters. And the best part is that these household units cost less than Rs. 200. More than 150 such units are presently in use and if properly publicized it is possible to increase the number manifold. A majority of rural households can afford it without straining their monthly budget. However, the technology used is based on oxidation–coagulation--filtration method with a daily input of chemicals. This doesn't make it user friendly. Improving the system with adsorption technology could make it more acceptable to the household.

A proactive approach of this nature is usually missing amongst most manufacturers.

9.4 Financial issues

Finances are a major factor in view of the limited direct demand from the community. While the cost of community plants can range upwards from Rs 25,000, the domestic ones range between Rs 2000 to Rs 2500 with the one exception of Rs 200 mentioned above. Since R&D is currently at an experimental stage, little thought seems to have given to the financial aspect. In most cases the costs are borne by the manufacturer or support agencies through specific programs. Furthermore, the domestic filters in use are currently subsidized; but despite subsidy it is still beyond the reach of most of the community. Presumably, once the technologies are conceptually and technically acceptable, efforts will be made to reduce the costs at the consumer level.

There are several ways by which costs can be reduced. The cost of maintenance and operations can be done away with or reduced considerably with planning. The limited involvement of the community in operations and maintenance and their lack of training in handling the plants have resulted in a situation where company personnel are appointed for these tasks. In a particular site it was observed that Rs 3000 were being spent per month on operations and maintenance alone, of which 90 percent was incurred on travel and food costs of the maintenance staff. Were this task to be carried out by local people, the travel and food costs would immediately be cut out, reducing overall costs at the user end.

Similarly, production costs could be reduced through local manufacture of the plants; especially those items which are being imported. Excise and customs duty on the imported arsenic removal media is quite high and could be reduced if manufactured locally. Besides cutting costs it will stimulate the local industry.

9.5 Potential for privatisation

Even though most manufacturers rely primarily on the government for sale of their units, the potential for privatization is significant. Widespread arsenic contamination in eight districts of West Bengal, with spreading awareness on the issue prepares the ground for the demand for such technology. On one hand media attention on the issue is leading to increased awareness and concern; on the other, the absence of any concrete cure for arsenic toxicity points to the need for arsenic free water as the only alternative to the problem.

The existing involvement of different agencies, both government and non-government, however limited nevertheless paves the way for building upon the existing demand for ARPs. NGOs, as also the media, can play a greater role than at present to build upon the present levels of awareness, thereby enhancing the potential for increased demand for ARPs. Hence factors that favour privatization can be listed as follows:

- Widespread arsenic contamination in different districts that continues unabated
- Increased media attention and ever increasing number of patients of arsenism.
- Absence of any comprehensive medical treatment – therefore drinking arsenic free water gets importance.
- Both governmental agencies and NGOs playing an active role in the field.
- Pockets of high arsenic contamination with presence of sizeable number of patients looking for mitigation measures.

9.6 Constraints relating to privatisation

9.6.1 Limited choices

Just as there exist opportunities for marketing and promoting ARPs, there simultaneously exist various constraints, which would need to be addressed to enhance marketing efforts. For one, awareness on the technology options for arsenic removal is considerably limited; in most areas, the community is aware of only that technology which has been set up in their area. The absence of adequate service backups in most cases prevents appropriate and widespread acceptance of the technology. Constraints with the technologies themselves continue as well, with the safe disposal of sludge and backwash water being amongst the primary ones.

9.6.2 High cost

The cost of the plants, in both the community and household ones, also acts as a deterrent. If the manufacturing companies were to reduce costs, acceptance levels would increase substantially.

Alternatively, innovative marketing schemes can be explored, specially targeted at the rural sector. These could include a shared filter concept (in the case of household units), easy EMI facility or the commercial supply of treated water by vans to remote areas.

Since the manufacturing companies currently address after-sales service and most aspects of operations and maintenance, it affects the degree of ownership and acceptability of the products. The greater the extent to which the local community takes this on through training, the wider would be the demand for such plants.

9.6.3 Poor marketing network

As for marketing itself, while some companies have adopted innovative or proactive strategies, most have relied upon the government. This lack of a marketing network has limited the potential for greater coverage for ARPs. An extensive marketing network would need to be combined with sales promotional activities such as participation in various fairs and exhibitions and product advertising through mass media. In the case of domestic filters, the sanitary marts at the block level could be used as retail outlets, whereby they cater not merely to sales but to service aspects as well.

Rural Sanitary Mart: One stop shop

The Rural Sanitary Mart is an outlet dealing with materials required for the construction of latrines and other sanitary facilities in rural and peri-urban areas. Beside this they also stock those items which are required as part of the sanitation package. It is a commercial enterprise with a social objective. They store spare parts of hand pumps and ORS packets and have a list of local mechanics and masons who can handle sanitary services. In fact, the Rural Sanitary Mart can be considered as a one-stop shop to meet all the requirements of the community pertaining to drinking water supply and sanitation in the rural areas.

West Bengal possesses a large number of functional Rural Sanitary Marts (RSMs) in the Block HQs as well as in important villages. These are mostly run by the leading NGOs of that area. A number of CBOs are also attached with these marts. The RSMs located in arsenic prone areas could be used as an outlet for storing chemicals; household based arsenic removal units and necessary spare parts for maintenance of the units. The local mechanics could be trained to carry out the required jobs.

RSMs will facilitate the commercialisation of sanitary facilities and rural water supply by providing private entrepreneurs a readymade grass root level network.

9.6.4 Lack of community development

The reliance on government and the absence of direct involvement of the community, in relation to enhancing awareness, choice of technology, maintenance of the plants has constrained the privatization potential of ARPs. The greater the direct involvement of the community, the greater would be their understanding and acceptance of the technologies; which in turn would reduce the need for technology providers to depend upon the government for orders. Since demand for these technologies emerges directly from the community, the interest in and viability of privatization would grow.

In order to enhance this direct demand, there is a need for community mobilization to make the people welcome ARP options. Linkages with key stakeholders such as panchayat representatives and NGOs would help. Plant selection should be carried out with the active participation of the community, based on informed choices. The responsibility for operation and maintenance should also be handed over to the community. The formation of a committee for financial, technical and management responsibilities would be recommended in the case of community plants. Some of these aspects would require training to be imparted to the local people.

9.7 Recommendations for Private agencies

The private companies desirous of marketing their products need to explore the following possibilities:

- Establish linkages with the key stakeholder e.g. the Panchayat representatives, NGOs concerned who could be potential customers.

- Adopt aggressive sales promotional activities
- Advertise products through mass media and local outdoor advertisements
- Communicate benefits of using ARP-treated water –better health & better quality of life
- Keep costs within affordable limits of the community. Make efforts to reduce the present cost of the product.
- Consumers need to be given a choice of technology and also a variety of products within the same technology
- In the case of domestic filters, the Sanitary Marts at the block level can also be roped in to act as a retail outlet.
- The concept of annual maintenance contract needs to be introduced along with the facility of replacements, guarantees and after sales service.
- An easy to understand maintenance manual should be provided.
- The product test results should be made available to the customer upon payment of a nominal fee.

Clearly, the potential for privatization and enhanced marketing for ARPs is enormous, as long as certain pre-requisites are addressed to optimize the privatization efforts.

10. Monitoring and Evaluation

10.1 Overview

The monitoring and evaluation mechanism currently prevailing in the Rural Water and Sanitation Sector of West Bengal leaves a lot to be desired. The system produces periodic reports at local levels (mostly by the government implementing agencies) and then aggregates them to state and central levels. This rarely captures the progress of program activities and fails to indicate the following:

- Availability of the quantity of water to the average household
- Adequacy of the system to meet the needs of the community
- The quality of water supplied and level of user satisfaction

The existing monitoring system only reflects the overall physical and financial indicators for the state as a whole but does not help in carrying out any corrective measures at the local level. **The community, which has the biggest stake in the sector, has no say in this system.**

The Government of India has initiated steps to have a new institutional arrangement for the rural water and sanitation sector. Therefore, the monitoring and evaluation system needs to be tailored to this new institutional mechanism. Monitoring and evaluation is quite essential both for the community as well as the state agencies. It is necessary to have a mechanism, which provides both qualitative and quantitative indicators of the system. This helps in future planning and initiating policies. The wider objective of an improved system will be to elevate sector performance to a higher level and cover services at lower costs. This will in turn help long-term sustainability of the services.

10.2 What is Monitoring and Evaluation?

Monitoring is a continuing activity that mainly provides the project management and major stakeholders of the project or programme with an early indication of the progress or lack thereof, in the achievements of project objectives. Monitoring enables the management to identify and assess potential problems and the success of a programme or a project. It provides for the basis of corrective action, improve the project design, if need be, and helps in the manner of implementation by improving the quality of results.

The requirements of effective monitoring are baseline data, indicators of performance and results, and mechanisms to collect information such as field visits, stakeholders meetings and systematic reporting. Monitoring action needs to be planned from the very beginning.

On the other hand, evaluation is a time-bound exercise that attempts to assess systematically and objectively the relevance, performance and success of ongoing and completed projects and programmes. Though all projects and programmes need to be monitored, it is not necessary to evaluate all of them. So the project management has flexibility to decide why and when evaluation is needed based on set criterion. Though monitoring and evaluation differ, they happen to be closely related. They are mutually supportive and equally important. Monitoring provides for qualitative and quantitative data using selected indicators that can serve as inputs to evaluation exercises. Evaluation on the other hand could provide lessons for refining the monitoring tool or devising appropriate indicators for future projects.

10.3 Plan Framework

There is a need to frame a plan for monitoring and evaluation as an integral part of the project/ programme development. The following points should be taken care of:

- Baseline data describing the problems to be addressed.
- Clarify project/ programme objectives in clear terms that are understandable by all stakeholders.
- Set specific targets keeping in view the objectives.
- Establish consensus among stakeholders on the specific indicators to be used for monitoring and evaluation.
- Define the types and sources of data needed and the methods of data collection and analysis required based on the indicators.
- Reach an agreement amongst the stakeholders to use the data.
- Specify the format, frequency and distribution of reports.
- Establish the monitoring and evaluation schedule.
- Assign responsibilities for monitoring and evaluation.
- Provide adequate budget to carry out the activity.

Monitoring and Evaluation need not be a rigid format from the start and could be modified as per the requirement of the project by way of continuous review and adjustment.

10.4 What is to be monitored?

For a sustainable drinking water system in the arsenic prone area, it will be necessary to monitor the following activities on a regular basis:

- Water quality.
- Process monitoring.
- System sustainability.
- Financial monitoring.

10.4.1 Water quality

In the last few decades numerous drinking water sources have been created both by government agencies as well as through private initiatives by tapping groundwater in the arsenic prone areas of West Bengal. Hundreds of thousands of sources are operational in the affected areas. But no water quality surveillance mechanism exists to detect flaws in the system and people are drinking the water quite oblivious of the hidden poison. Since water quality monitoring is yet to be initiated on a large scale, it has become essential for sustainable development.

Monitoring of both raw and treated water at regular intervals will help in providing valuable information on the following aspects:

1. Indicate the quality of source of water.
2. Help in assessing the efficiency of treatment units and whether the available treated water contains arsenic within permissible limits (50 µg/l).
3. Provide useful information on natural and seasonal variations.
4. Identify the need for remedial measures and help in carrying out corrective/ preventive action.

The community-based organisations (CBOs) have to play a major role in carrying out these activities. They have to document the problem areas/ sources and share the data with the co-ordinating government agencies. Since full-scale sophisticated water quality laboratories will not be functional at all the Blocks; the CBOs have to depend on Water Quality Test Kits to carry out this activity. **All drinking water sources whether government or privately owned need to be tested at least twice a year. The members of the CBOs, who willingly participate in these activities, could be trained to take samples, test water quality for required parameters and document the findings. It will be essential to properly number the sources for follow-up action.** The information thus generated will be passed to the co-ordinating state government agency that could use it for development of water quality maps, charting action plans for future activities and remedial measures.

10.4.2 Process Monitoring

Once the water quality monitoring mechanism is in operation, there will be many sources that will require corrective measures. These measures might be:

- Abandoning polluted sources.
- Develop new/ alternate drinking water sources.
- Install treatment units (community or household based) to make the water safe.

To implement any or all of these activities it is essential to have a Process Monitoring mechanism at work. The approaches here have to be more participatory and demand responsive. Process Monitoring will involve observation and critical assessment of the participants. It will be used to identify key problems and bottlenecks in the system caused by flaws in processes and approaches rather than solving problems superficially. Also, it will form a part of the integral monitoring and evaluation system. Process Monitoring will help in an in-depth understanding of what works and what does not work and how the projects could be refined at the grass root level to improve their effectiveness and sustainability of the investments. To make this effective the community and project management have to review bottlenecks selectively and address them. By adopting this approach the project implementation will get benefited by following ways:

- Become innovative, flexible, adaptive and responsive.
- Develop a sense of accountability in project staff.
- Learn from experience and facilitate changes within the project.

- Provide assistance in solving problems through better identification, . analysis and communication of causes and appropriate solutions.
- Improve project planning and monitoring skills.
- Improve project effectiveness and sustainability.
- Have continuity of information and knowledge.
- Empower communities by linking the efficiency and appropriateness of the project to community needs and demands.
- Provide a feedback loop whereby communities and grass root level staff can have a dialogue with the management at the top.

At present, the Government of India is adopting a demand-responsive and adaptable approach. It is driven by empowerment of villagers to ensure their full participation in the project. The CBOs will have to take responsibility to adopt this approach. Selected people from concerned CBOs will be trained to carry out the activities, which will include situation analysis, decision making rules and procedures, information sharing mechanism, listing of tasks and their progress and process indicators. Since information sharing and documentation are the main hubs of process monitoring system, feedback will be provided in easily readable progress reports, case studies, field notes, etc. Information can be shared in a range of formal and informal venues, project-planning meetings, working group meetings, etc.

Process Monitoring will cover all stages of the project both in the implementation and later in the operations and maintenance stage. When problems arise it will investigate for causes, report its findings so that corrective measures can be taken. The Process Monitoring Unit will provide feedback to government agencies that will provide all facilities to implement, operate and maintain the systems.

10.4.3 System Sustainability

Though quite a large number of drinking water sources belong to private households, ownership of a sizeable number lies with the government. Apart from this installation of a good number of sources and treatment units are on the cards. For regular running and maintenance of the systems, it is essential to have trained manpower at the grass-root level. Besides, availability of chemicals, spare parts of equipment/ machinery etc. needs to be ensured. The CBOs who are involved in the Process Monitoring will be further involved in system sustainability and its maintenance. A regular monitoring process will be developed and feed back arrangement will be established. Local manpower will be developed to do routine maintenance. A large number of villagers are also likely to adopt the small household level treatment units presently available in the market. Though it will be difficult to monitor all these units, some sporadic water quality sampling will be done to judge their efficacy.

10.4.4 Financial Monitoring

Partial capital cost sharing either in cash or in kind or both and 100% operation and maintenance cost have to be borne by users. As demand responsive contribution is only possible when people realise the value and benefits accruing out of it, strong advocacy elements need to be introduced at this stage. Since majority of the community is poor and cannot make one-time payments, the CBOs will have to play a major role in the collection of funds. Collection has to be done in instalments on a regular basis and proper records have to be maintained. For regular O&M, the concerned grass root level agency will have to spend from this fund.

10.5 Management information system

For effective planning, implementation, maintenance and monitoring it is desirable to have an information technology based Management Information System. But looking at the remoteness of the affected villages and the available infrastructure it might not be possible to have one below district headquarters level. Hence it will be necessary to have the NGOs/CBOs collect the information manually at the grass root level. These records can then be passed on to the district HQ computer systems. The information that will be generated in the village level is:

- Baseline information of the village/ habitation.
- Social mapping of the water points of the village/ habitation.
- Source wise Water Quality information.
- Overall monitoring schedule.
- Implementation Process Monitoring schedule.
- Maintenance Process Monitoring schedule.
- Capital cost generation schedule.
- O&M cost generation schedule.
- Manpower development and training schedule.
- Awareness camps and advocacy activity schedule.

11.0 Recommendations and Conclusions

A one-day Workshop was organised at Kolkata on 10 August, 2001 to discuss the findings of the Study Report and to get a feed back from the people involved in the arsenic mitigation programme in the country. All the participants were provided with the Study Report for review. Forty six participants from various government, research institutions, bilateral and multilateral external support agencies, NGOs and private agencies involved in the arsenic mitigation programme in West Bengal participated and deliberated on various issues discussed in the Study. The list of participants is annexed. After the presentations, the participants resolved the following in the concluding session:

1. Since groundwater sources are to be tapped for meeting the drinking needs of the community, to tap relatively safe drinking water sources it was felt that the development of Geo-hydrological Profile of the Arsenic rich area for each of the affected Blocks will be essential. This will include:
   - Sedimentological analysis of lithological samples and their mapping.
   - Water quality analysis of all the sources, documentation and mapping.
   - Water table fluctuation data.

2. Since lack of knowledge about the problem area is hampering the planning process for Arsenic Mitigation, a comprehensive village profile of all the habitations having arsenic rich sources is needed to help meet the situation. This information will include:

   - Social structure.
   - Cultural Issues.
   - Health problems.
   - Available Infrastructure.
   - Food habits and intake.
   - Income structure.
   - Agricultural and Industrial products.
   - Water quality map of all sources of the village.
   - Technological status of existing Arsenic Reduction System in the village.
   - Document the possible arsenic reduction technologies adaptable in the village.

3. Apart from village profiles no systematic document is available with regard to arsenic affected people in the villages. There is a need to develop health-screening process in all the affected villages and of patients with arsenic related disease manifestation identified for treatment. To carry out these activities we require:
   - Training of the medical and para- medical staff
   - Concerted Health campaign.

4. As drinking water supply programme is being planned to be operated as community managed system, it was felt that with the help of leading NGOs from the region, the Community based Organisations like Youth club, Mahila Mandal who are interested in participation of water and sanitation programme need to be selected.

5. Since communication is a basic tool for any developmental activity ithere is a need to generate communication material with emphasis on the following:
   - Generate capacity within the CBOs to build awareness within community for participation.
   - Information about the available technologies and their cost-benefit details.

6. Research institutions and Private agencies are to be encouraged to take up research in cost reduction of the treatment processes without sacrificing the removal efficiency.

7. Local entrepreneurs should be encouraged to stock the approved chemicals and equipment for the community to procure the material and help in implementation of programme.

8. CBOs (Community Based Organisations) should be trained to assist in WQ monitoring, selection of treatment processes and upkeep of the systems.

9. The study could evaluate a number of technologies that are suitable for a particular area. Apart from removal efficiency the cost factor (both capital as well as O&M) also decides the suitability of the process to be adopted in a particular place. As the present approach is to involve the community from the very beginning of the project it was felt that CBOs should be provided with pros and cons of all the available technologies to help them select the most suitable one.

10. Lack of Water quality testing mechanism has lead to arsenic pollution in groundwater. The Water Quality surveillance mechanism needs to be established to tie up the situation.

11. Since groundwater is also being used for minor irrigation programme in the arsenic affected areas it was suggested that all food products from project villages be screened for arsenic.

12. The participants strongly felt that UNIDO should select a few arsenic prone districts (at least 2 Blocks each) in West Bengal and Bangladesh and implement the programme with a strong monitoring base with the help of the community.

13. The participants suggested that UNIDO complement the activities with a study on the disposal/ treatment/ management of toxic waste generated by the arsenic removal units installed for drinking water systems. These waste are presently being discharged to the environment with minimal precaution. In the long run these may prove to be a major source of pollution as well.

In addition to the above points the study recommends that to achieve the major long term goal of providing arsenic free drinking water, a comprehensive strategy based on the following criteria needs to be formulated:

- Identify selected water bodies in problem villages and provide them with efficient treatment processes to make the water potable.
- Take up the most affective household based ARP, make it cost effective and easily available to population.
- Involve the local panchayat in all arsenic mitigation efforts in the village.
- Take up waste-sludge management or else we could have another major environmental disaster in our hands.

Clearly, the study found all the arsenic removal plants functioning in the affected districts have certain limitations. These limitations are in some cases technical, in some financial and in others social. Besides, there are the usual constraints of marketing and availability. Therefore, for any future policy to work what is really needed is a holistic approach to the arsenic problem without which no plant can run successfully and the system sustained for long.

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ANNEXURES

WEST BENGAL

Arsenic Affected Blocks
(As on November 1999)

District & Block

MALDA

1. English Bazar
2 Manikchak
3. Kaliachak-I
4. Kaliachak-II
5. Kaliachak-III

MURSHIDABAD

6. Raninagar-I
7. Raninagar-II
8. Domkal
9. Nawda
10. Jalangi
11. Hariharpara
12. Beldanga-I
13. Suti-I
14. Suti-II
15. Bhagwangola-I
16. Bhagwangola-II
17. Berhampur
18. Raghunathganj-II
19. Murshidabad Jiaganj
20. Farakka

NADIA

21. Karimpur - I
22. Karimpur - II
23. Tehatta - I
24. Tehatta - II
25. Kaliganj
26. Nakashipara
27. Nabadwip
28. Hanskali
29. Krishnaganj
30. Haringhata
31. Chakdaha
32. Shantipur
33. Chapra

NORTH 24-PARGANAS

34. Habra - I
35. Habra - II
36. Barasat - I
37. Barasat - II
38. Deganga
39. Basirhat - I
40. Basirhat - II
41. Swarupnagar
42. Sandeshkhali - II
43. Baduria
44. Gaighata
45. Rajarhat
46. Amdanga
47. Bagda
48. Bongaon
49. Haroa
50. Hasnabad
51. Barrackpur II

SOUTH 24-PARGANAS

52. Baruipur
53. Sonarpur
54. Bhangar - I
55. Bhangar - II
56. Budge Budge - II
57. Bishnupur - I
58. Bishnupur - II
59. Jaynagar - I
60. Mograhat - II
66. Basanti

BARDHAMAN

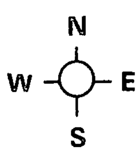
61. Purbasthali - I
62. Purbasthali - II

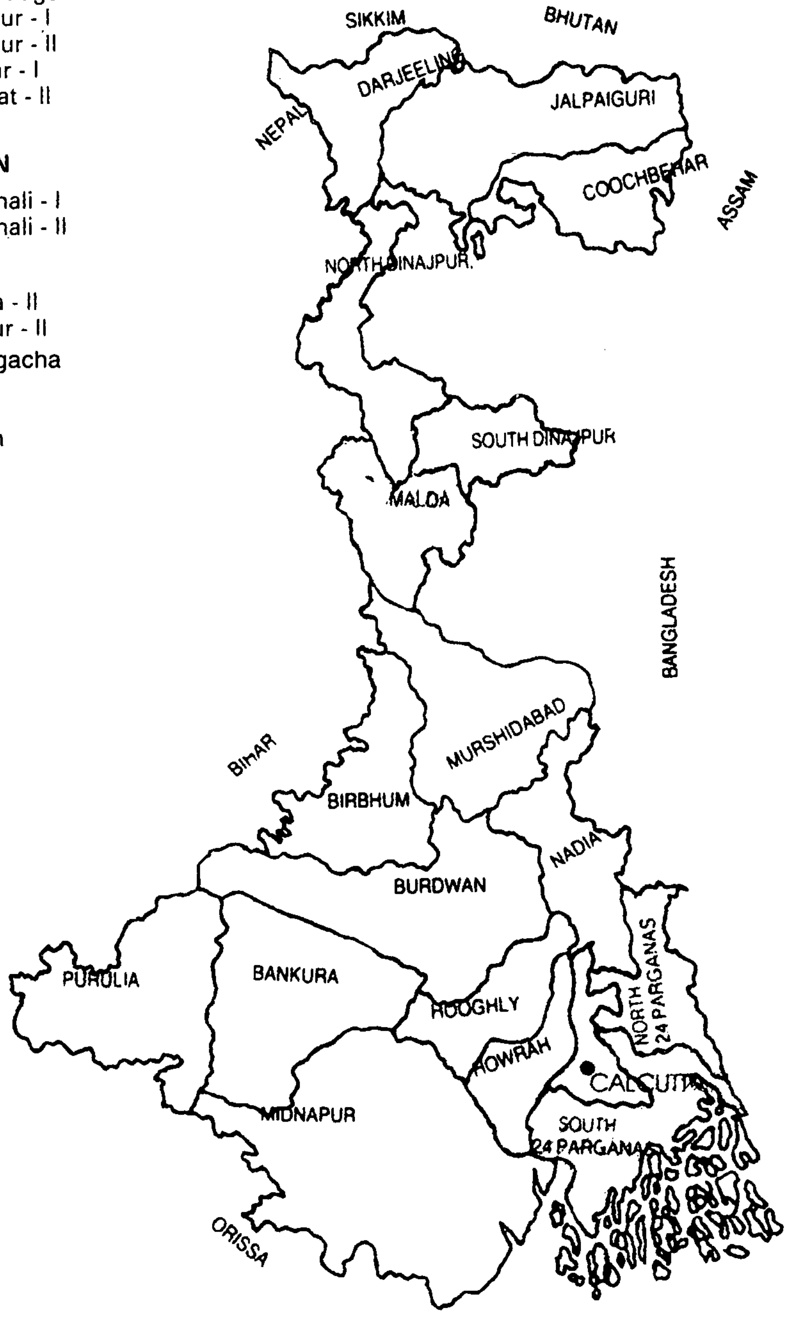
HAORA

63. Uluberia - II
64. Shampur - II
67. Bally-Jagacha

HUGLI

65. Balagarh





Recommendations of the Expert committee constituted by Government of West Bengal vide order No. PHED/716/3D-1/88 Part-1 dated 6 April 1992.

The Expert Committee made the following recommendations in October 1994.

In the districts of North and south 24 Parganas, where deeper aquifers containing arsenic free ground water occurs below the depth of 150-300 meters, should be tapped for drinking water supply. The deeper aquifer is in general separated from the shallow aquifer containing arsenic rich ground water by appreciably thick clay bed.

In the district of Bardhavan I,e. in Purbasthali Block similar deeper aquifer exists below the depth of 100m. Tubewell for drinking water may be constructed in these aquifers, instead of the upper ones which have been found to contain arsenic rich ground water.

In the districts of Nadia and Murshidabad the aquifers occurring below the depth of 100 m. generally have not been found to contain arsenic rich ground water. However, at some sites ground water contains arsenic beyond permissible limit even at the depth of 100m.bgl. As such the drinking water supply for this part of the district has to be drawn very cautiously and all care should be taken so that the arsenic rich ground water of the upper part of the aquifer does not mix with the aquifer of the lower part. The problem is very acute in some places where the upper aquifer separated from the lower one by a thin semi permeable sandy clay or silt clay bed. In such cases endeavour should be made to construct tubewells tapping the aquifer occurring below 200m depth. Utilisation of nearby surface water sources available round the year, if any, after proper treatment for drinking water supply may also be thought of.

In Maldah district where the thickness of the aquifer itself is restricted within 80-90m it will be difficult if not impossible to get arsenic free ground water at deeper level the bedrock occurring below 80-90m has also not been investigated for its ground water worthiness. However, it is quite unlikely that even that aquifer in the hard rock can meet the drinking water requirements of the effected areas. As such it may be necessary to make water supply from the nearby surface water sources after treatment if not technically unfeasible. However, such surface water sources like tank, 'bill' or river are not available and maintaining water supply for such sources are not economical due to water availability and technical constraints, it may be necessary to treat arsenic rich ground water so that arsenic free water is available for drinking purpose. As an interim measure, dug wells with proper sanitary protection and affective decontamination can also be attempted.

It has been noticed that a number of domestic filters for removal of arsenic have been developed by AIIH&PH in collaboration with School of Tropical Medicine. And it has been reported by School of Environmental Studies Jadavpur University that while these domestic filters by and large fulfill the drinking water requirements for small family, it may be encouraged to use such filters in arsenic affected areas of the state of West Bengal.

It has been found that special type of filter has been developed by technical collaboration of PHED at DELCO Laboratory, Sonarpur, which when fitted on the mouth of the handpump or tubewell, can remove arsenic from ground water almost instantaneously and filter can be used for a period of six months. In case, these type of filter is commercially produced and made economically viable by bringing down the present cost, this may offer a tangible solution and the tubewells that have already been constructed can be put touse by incurring marginal expenditure. Apart from this it is reported that a similar module is being developed by AIIH&PH on trial basis under sponsorship of Min. of Rural Development, GOI.

Disposal of filter candles of domestic filter and sludge from filters fitted to tubewells can be done easily by putting it in to a pit filled up with cowdung and other biological waste and exposing them to the atmospheric changes as reported by SOES, Jadavpur University. The base of the pits should not touch ground water and where such pits have to be dug in sandy soil the base and walls of the pits should be lined with clay to prevent possible seepage of toxic arsenious compounds to the ground water reservoir. The arsenic co-precipitating out from ground water is accumulated in sludge. Such sludge from arsenic removal plants needs to be disposed carefully. Study conducted by AIIH&PH Calcutta indicated that dense sludge, if burnt at high temp. solidifies with other precipitates. Such solids have been found to be safe for disposal as arsenic does not come out as leachate further.

However, for large scale water supply schemes it may be required to design arsenic elimination plant to be fitted in such water supply system. A number of methods have already been tested in different parts of the world having the arsenic menace in ground water. It is found that the one having activated alumina such adsorption may be more effective. Designing of such plants which not only should be cost effective, but also will be technically most feasible, has to be developed through RD efforts. Department of PHE in collaboration with AIIH&PH has already made some progress in this line. It will be necessary to take up the work most expeditiously so that in the arsenic affected areas of Malda district where water supply from ground water may be difficult such plants can be used without any further delay.

Since it has been found that in the major part of the arsenic affected areas ground water level shows considerable recession during the period of January to April-May, the resulting oxidised medium use groundwate for boro-paddy may be discouraged for cultivation in these areas to avoid further lowering of water level. Instead of borro-paddy cultivation that is a water intensive crop, cropping patterns should be changed and crops that require much less irrigation should be encouraged. This may reduce the possibility of linking up of arsenic affected pockets.

Although the arsenic content is not excessive, it is to be studied as to why so much arsenic remains dissolved in the groundwater that is apparently only mildly alkaline (pH 7.2-8.5). Although studies in Arizona USA have indicated tat arsenic occurs in groundwater as HasO4-2 anion, we have to determine whether this is the case in West Bengal too. In this connection, special devices to collect ground water samples in situ need to be fabricated specially to estimate the actual dissolved oxygen content of the water In the aquifer.

Electron probe study of mineral grains in selected arsenic rich parks of the aquifer is needed in order to identify the arsenic bearing phases present there. The SEM studies conducted so far by the CSME seem to indicate that much of the arsenic occurs as ultra-fine coatings on grains of quartze, biotite and other minerals, but it was not possible to identify the arsenious phases in the absence of electron probe facility.

Experiments to conduct artificial recharge in some small selected arsenious ground water zone should be undertaken in an attempt to dilute the arsenic concentration in the ground water. Non polluted clean surface water is to be pumped in through a number of large dia. Recharge wells upto the base of the arsenic yielding aquifer. Such recharge to start with may be done in parts of Malda district where non arsenious water aquifer is not available.

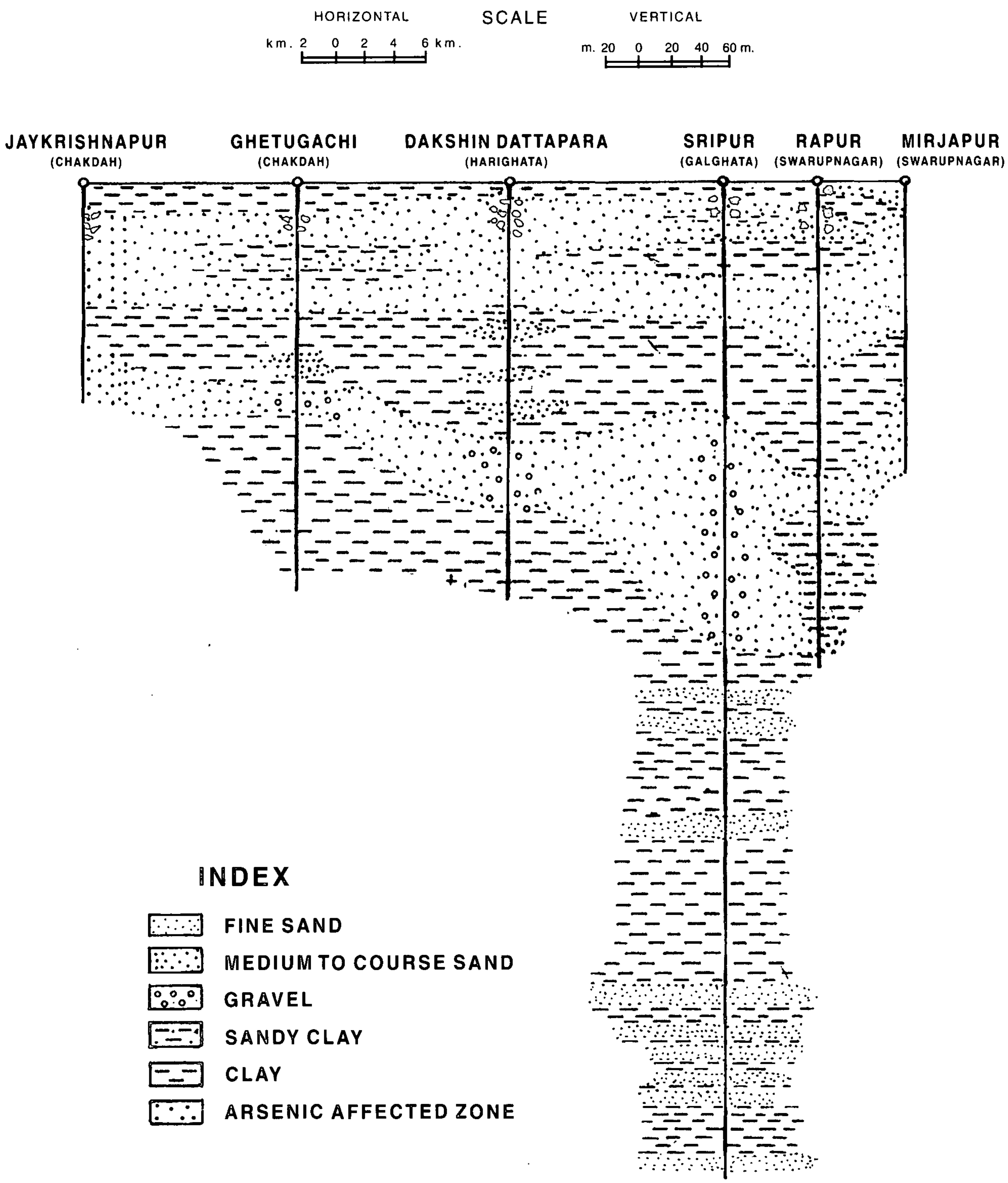
Monitoring of ground water quality for the state of West Bengal has to be conducted periodically at least four times in a year to study the seasonal variation of arsenic level consequent to recharge /discharge phenomenon of ground water. Pumping tests have also to be conducted to observe the change of arsenic content with time.

It should be made imperative that in future, tubewells are to be constructed in arsenic affected areas only after testing of chemical quality of ground water.

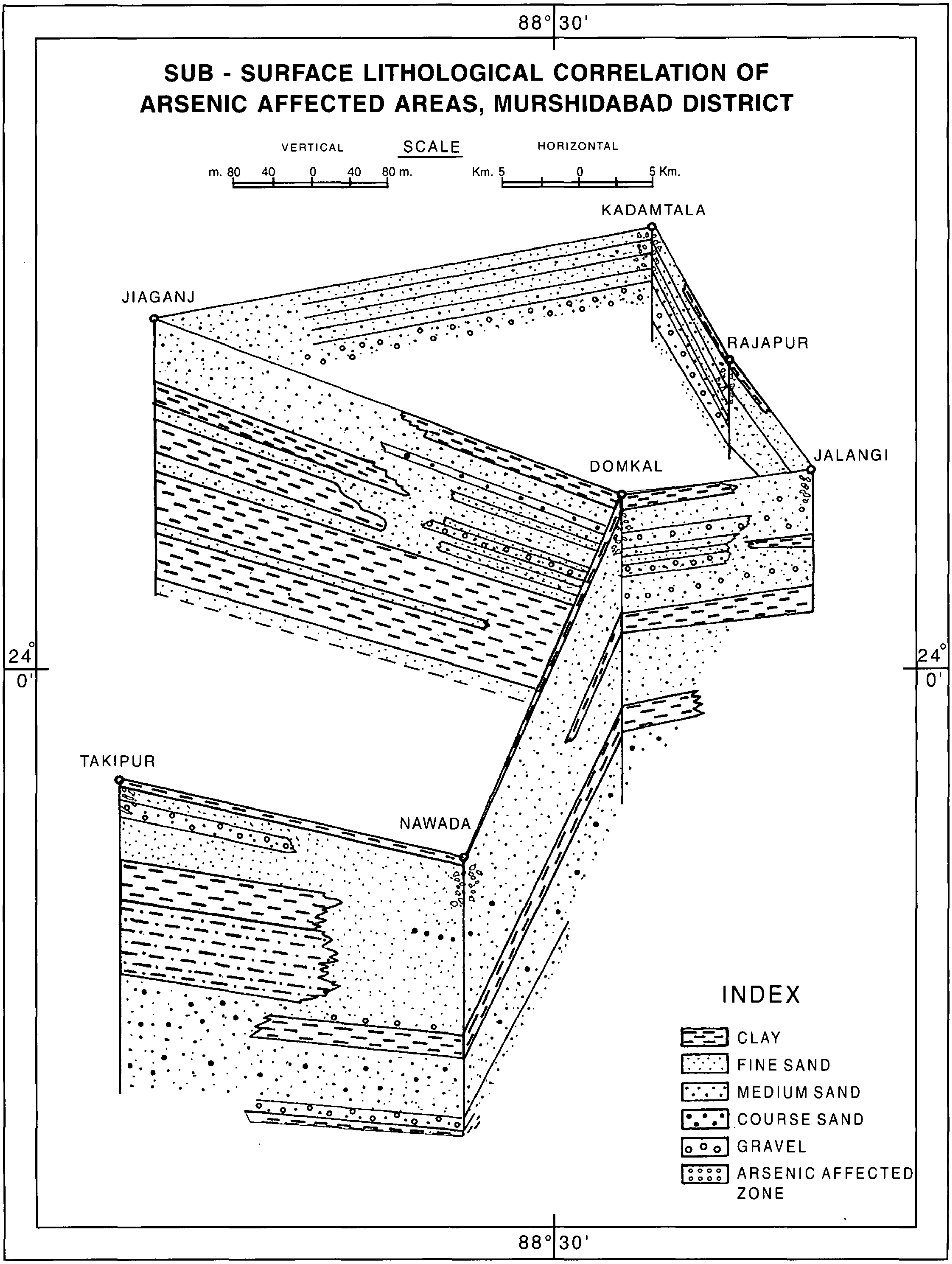
The quality of monitoring conducted by AIIH&PH in association with PHED has already helped to delineate arsenic affected areas in the state. Some work in this line has also been conducted by SWID, DOWB, CGWB (ER) and SOES under their various project activities> It may be necessary to exchange data of various departments tó create data bank of the purpose. This will help to delineate the arsenic affected areas and the areas likely to be affected by arsenic contamination in ground water.

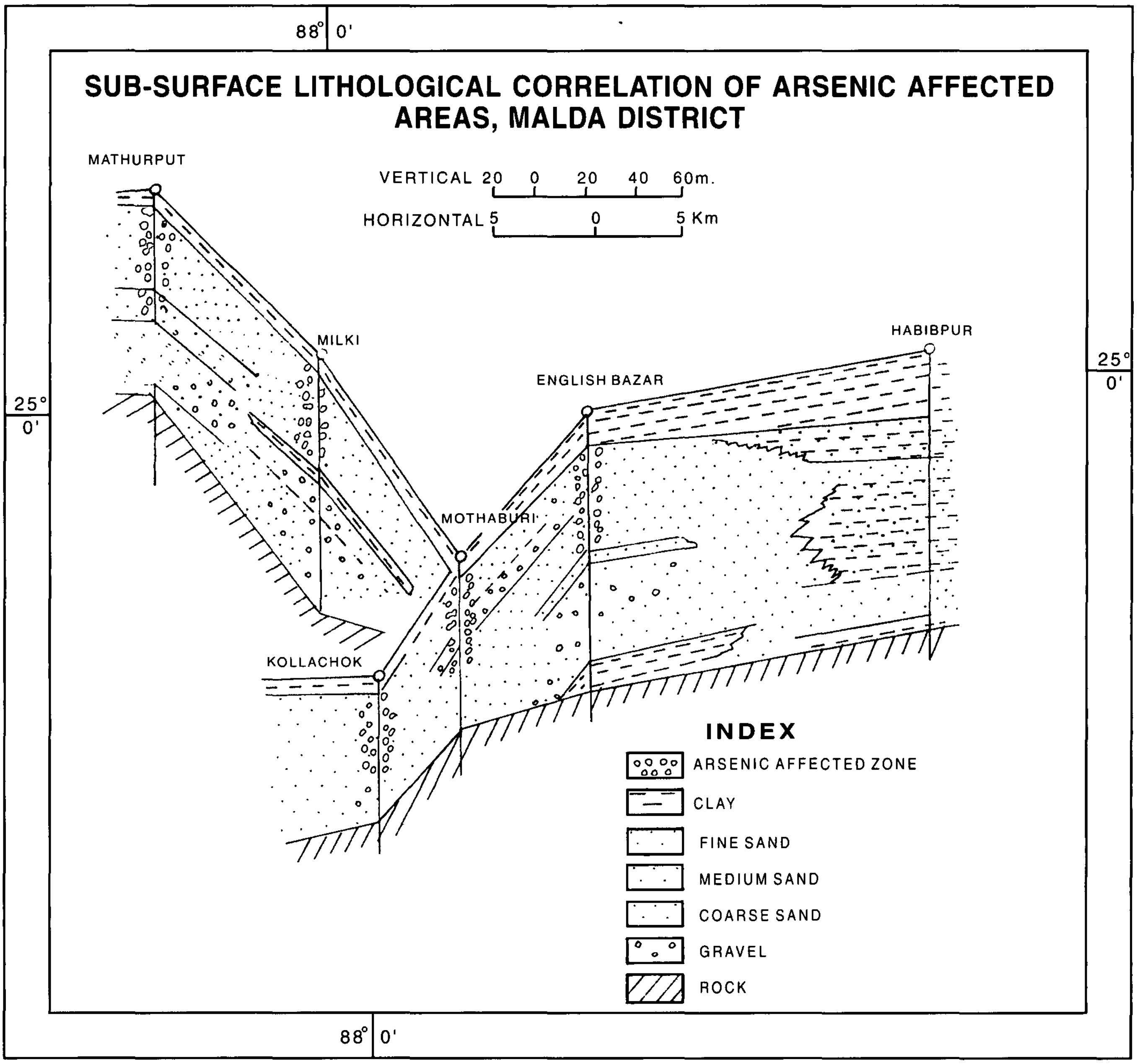
Arrangement for providing adequate fund and other support are to be made in favour of different organizations entrusted with carrying out of the various items of aforesaid investigation work

SUB SURFACE AQUIFER DISPOSITION CHAKDAH-SWARUPNAGAR TRACT NADIA AND NORTH 24-PARGANAS DISTRICTS, WEST BENGAL

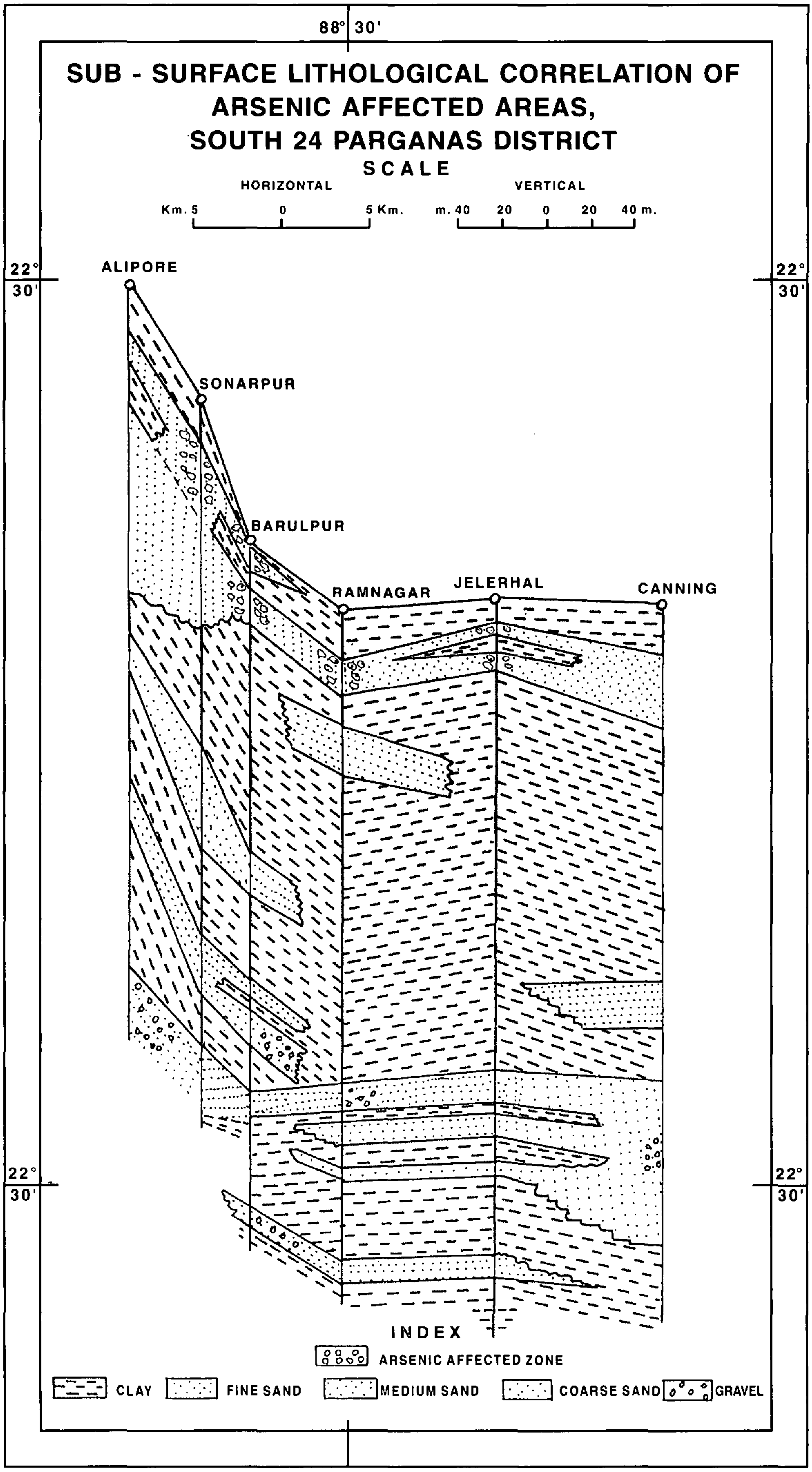


SUB - SURFACE LITHOLOGICAL CORRELATION OF ARSENIC AFFECTED AREAS, MURSHIDABAD DISTRICT

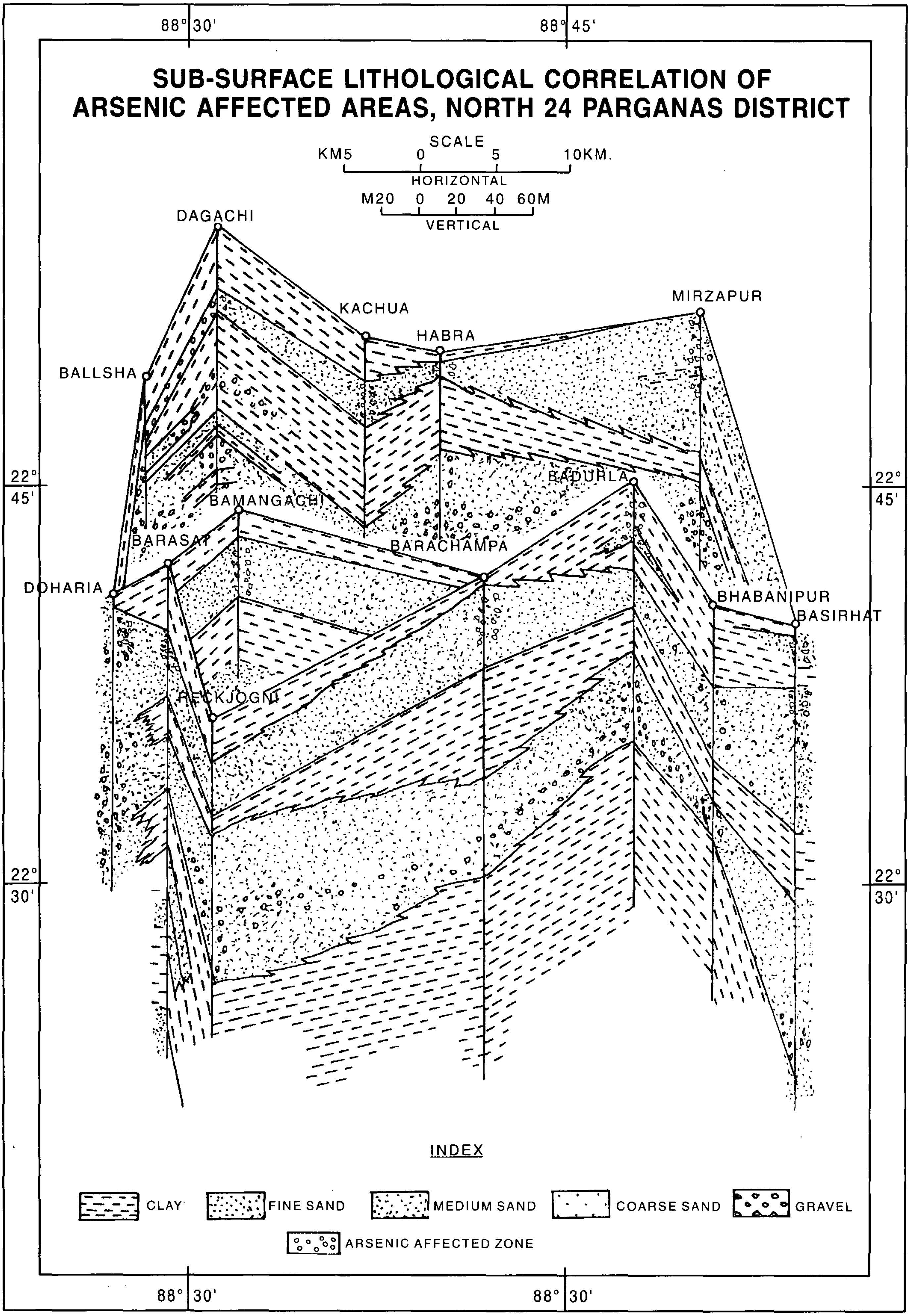


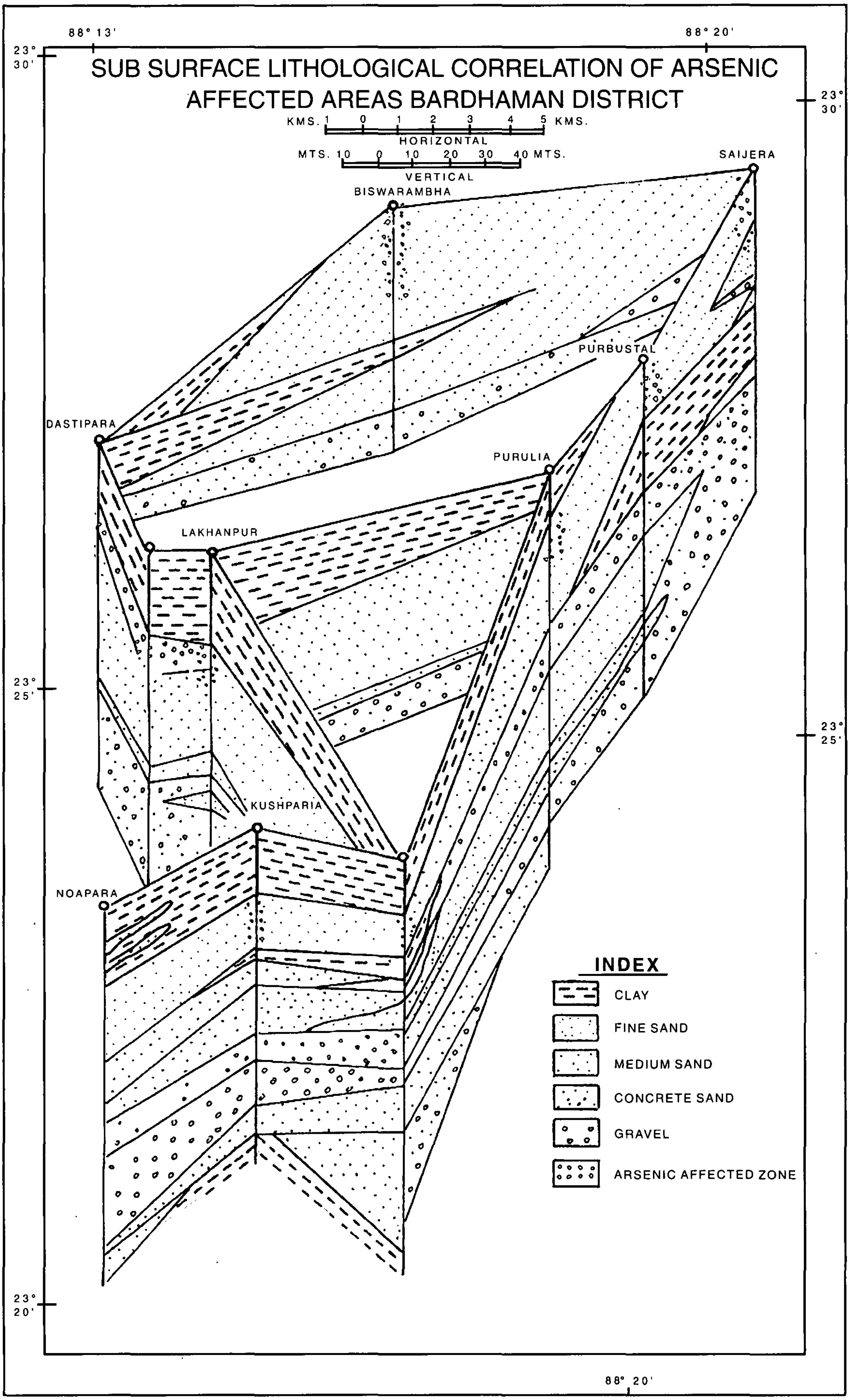


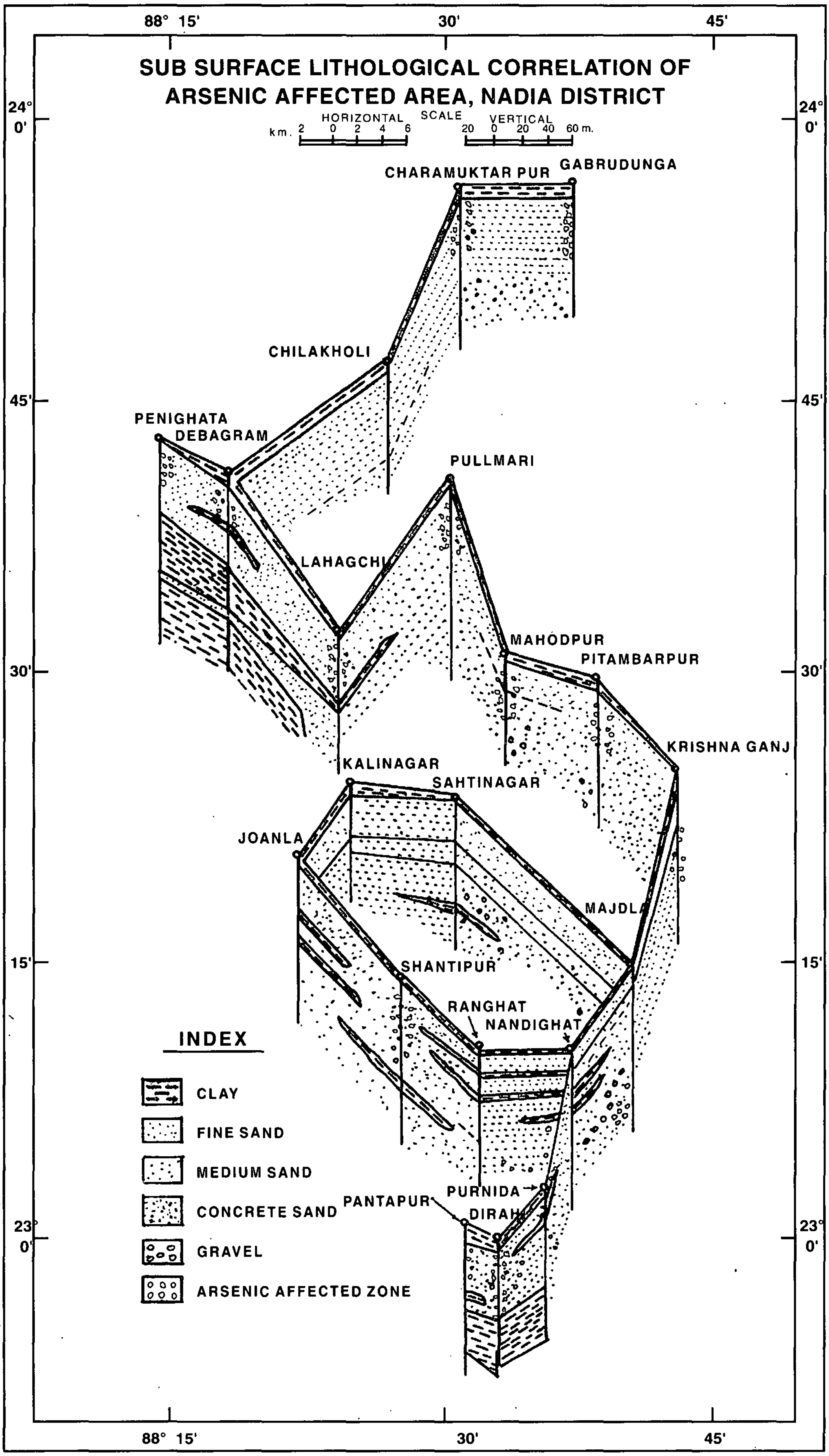
88° 0'
SUB-SURFACE LITHOLOGICAL CORRELATION OF ARSENIC AFFECTED AREAS, MALDA DISTRICT
MATHURPUT
VERTICAL 20 0 20 40 60m.
HORIZONTAL 5 0 5 Km
MILKI
HABIBPUR
ENGLISH BAZAR
25° 0'
25° 0'
MOTHABURI
KOLLACHOK
INDEX
ARSENIC AFFECTED ZONE
CLAY
FINE SAND
MEDIUM SAND
COARSE SAND
GRAVEL
ROCK
88° 0'


88° 30'
SUB - SURFACE LITHOLOGICAL CORRELATION OF
ARSENIC AFFECTED AREAS,
SOUTH 24 PARGANAS DISTRICT
SCALE
HORIZONTAL
Km. 5 0 5 Km.
VERTICAL
m. 40 20 0 20 40 m.
22° 30'
ALIPORE
SONARPUR
BARULPUR
RAMNAGAR
JELERHAL
CANNING
INDEX
ARSENIC AFFECTED ZONE
CLAY
FINE SAND
MEDIUM SAND
COARSE SAND
GRAVEL

SUB-SURFACE LITHOLOGICAL CORRELATION OF ARSENIC AFFECTED AREAS, NORTH 24 PARGANAS DISTRICT

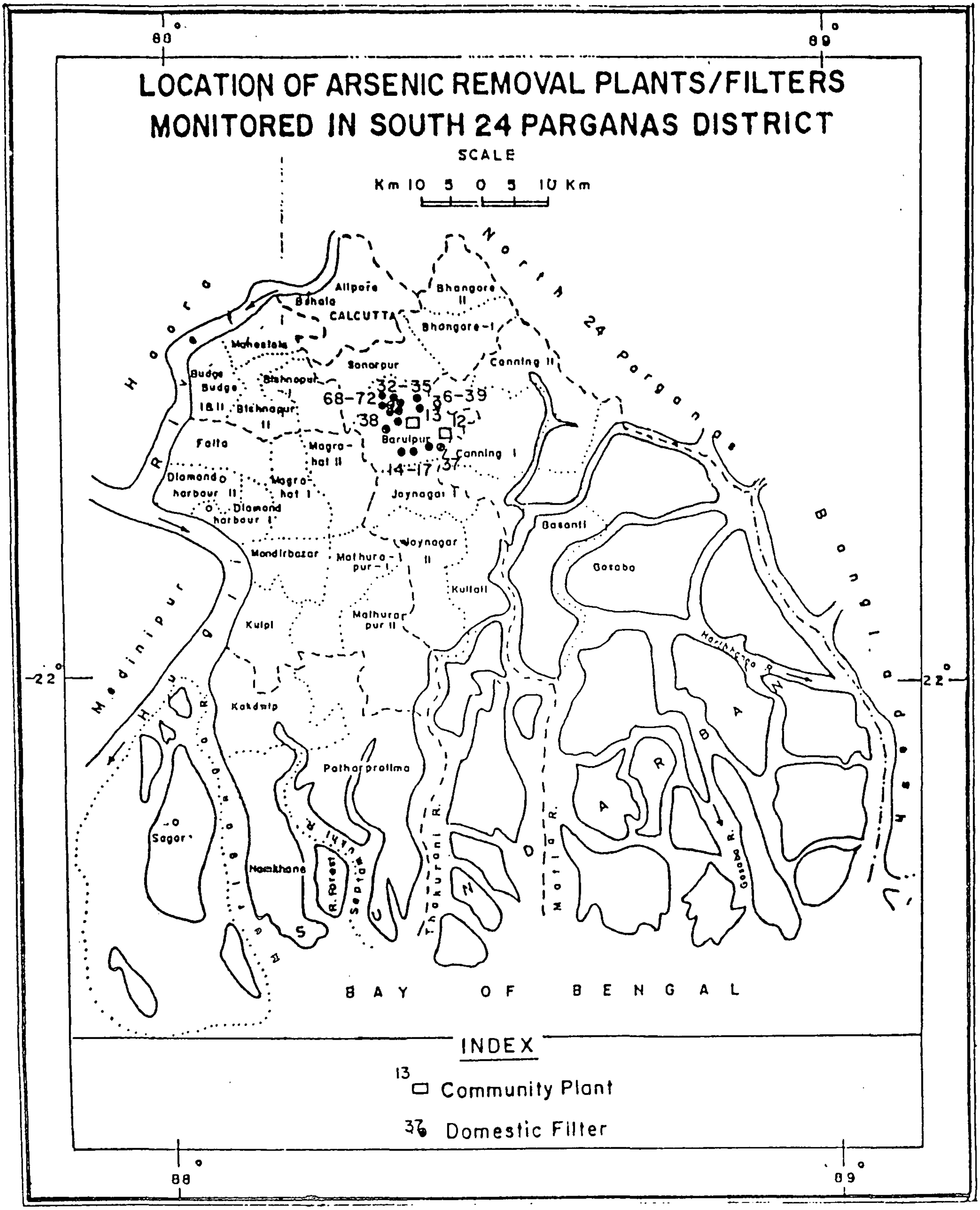



SUB SURFACE LITHOLOGICAL CORRELATION OF ARSENIC AFFECTED AREAS BARDHAMAN DISTRICT
KMS. 1 0 1 2 3 4 5 KMS.
HORIZONTAL
MTS. 10 0 10 20 30 40 MTS.
VERTICAL
88° 13'
88° 20'
23° 30'
23° 25'
23° 20'
BISWARAMBHA
SAIJERA
PURBUSTAL
DASTIPARA
PURULIA
LAKHANPUR
KUSHPARIA
NOAPARA
INDEX
CLAY
FINE SAND
MEDIUM SAND
CONCRETE SAND
GRAVEL
ARSENIC AFFECTED ZONE

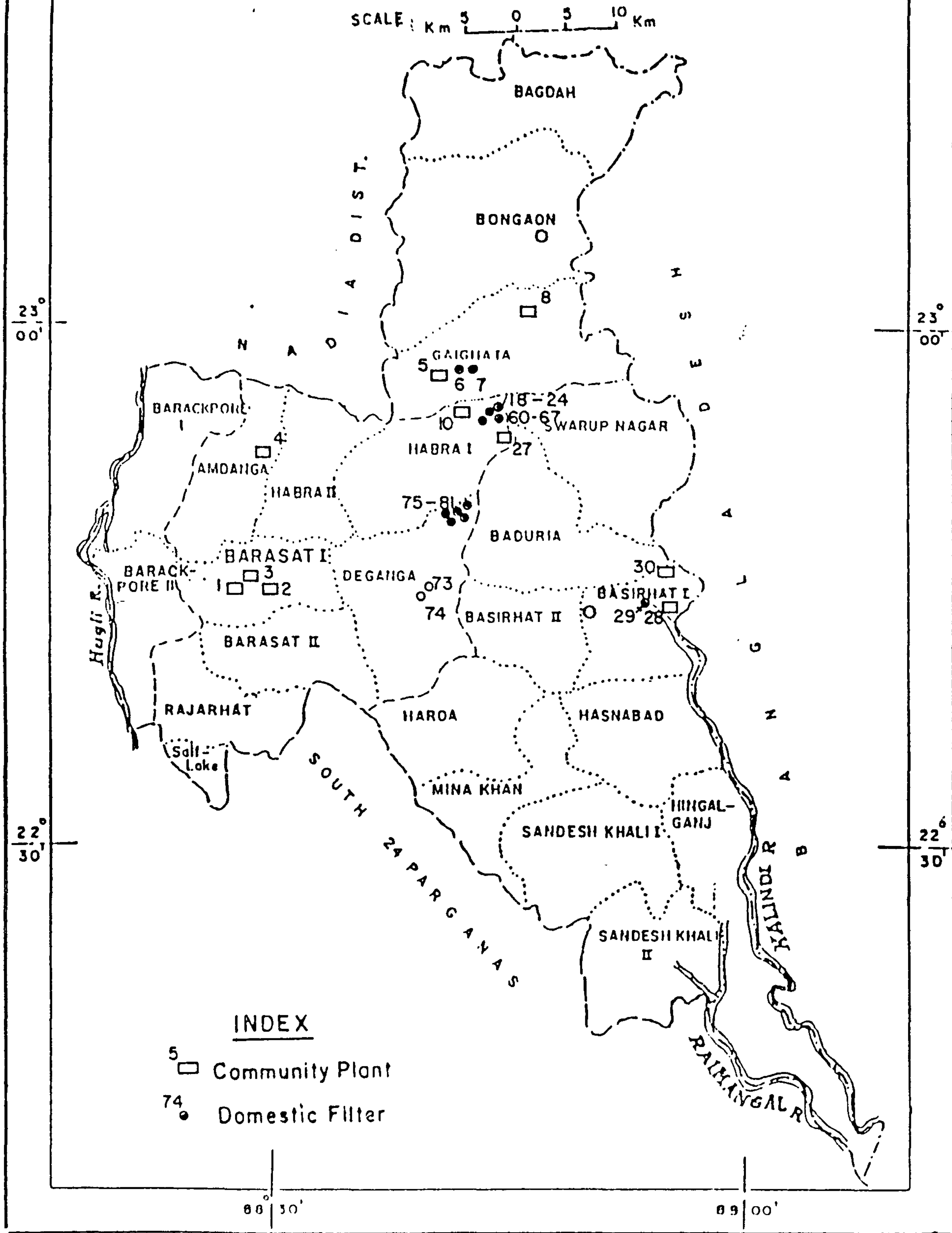


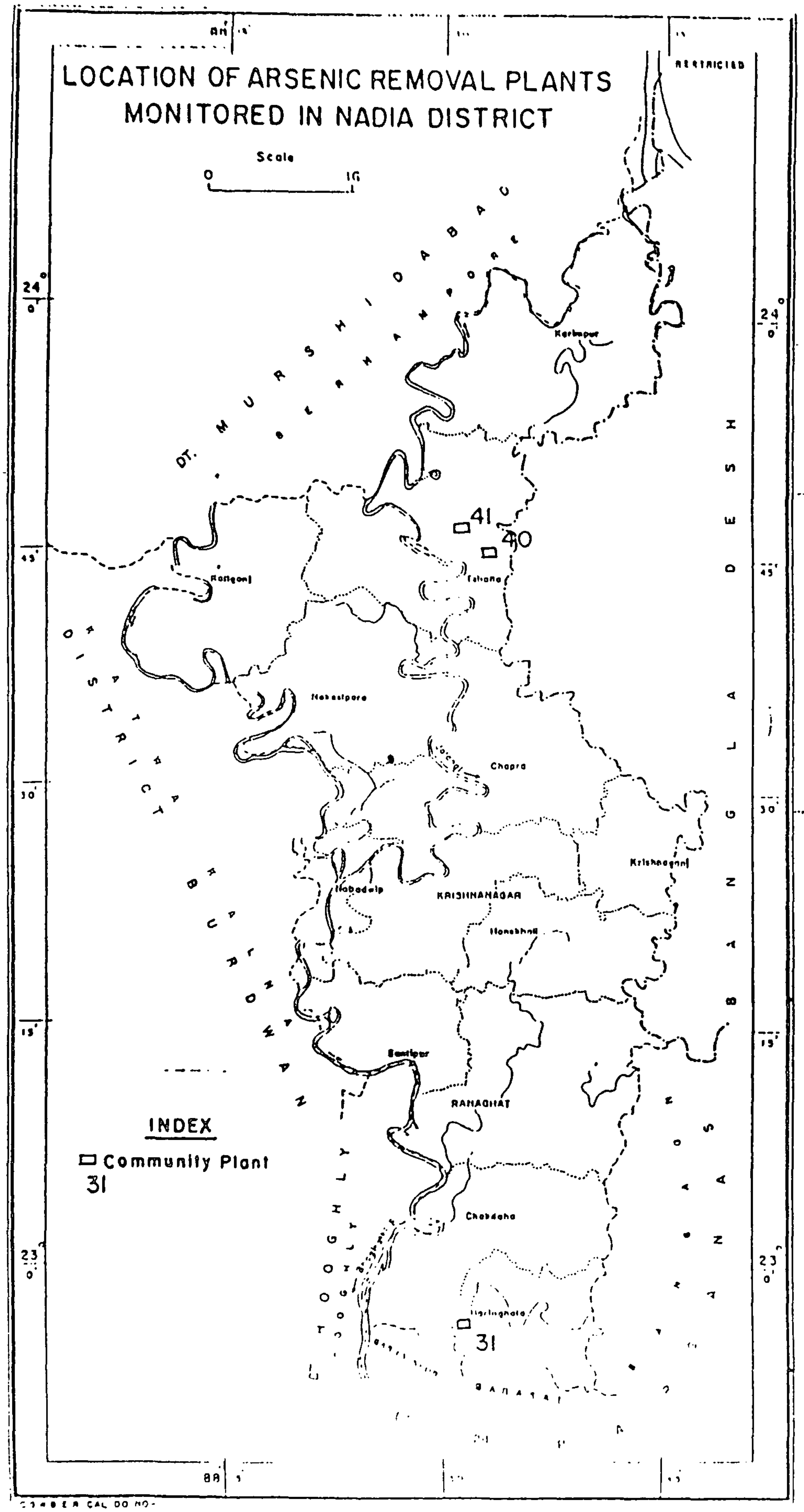
SUB SURFACE LITHOLOGICAL CORRELATION OF ARSENIC AFFECTED AREA, NADIA DISTRICT
HORIZONTAL SCALE VERTICAL
km. 2 0 2 4 6
20 0 20 40 60 m.
88° 15'
30'
45'
24° 0'
45'
30'
15'
23° 0'
CHARAMUKTAR PUR
GABRUDUNGA
CHILAKHOLI
PENIGHATA
DEBAGRAM
PULLMARI
LAHAGCHI
MAHODPUR
PITAMBARPUR
KRISHNA GANJ
KALINAGAR
SAHTINAGAR
JOANLA
MAJDLA
SHANTIPUR
RANGHAT
NANDIGHAT
PURNIDA
PANTAPUR
DIRAH
INDEX
CLAY
FINE SAND
MEDIUM SAND
CONCRETE SAND
GRAVEL
ARSENIC AFFECTED ZONE

LOCATION OF ARSENIC REMOVAL PLANTS/FILTERS MONITORED IN SOUTH 24 PARGANAS DISTRICT



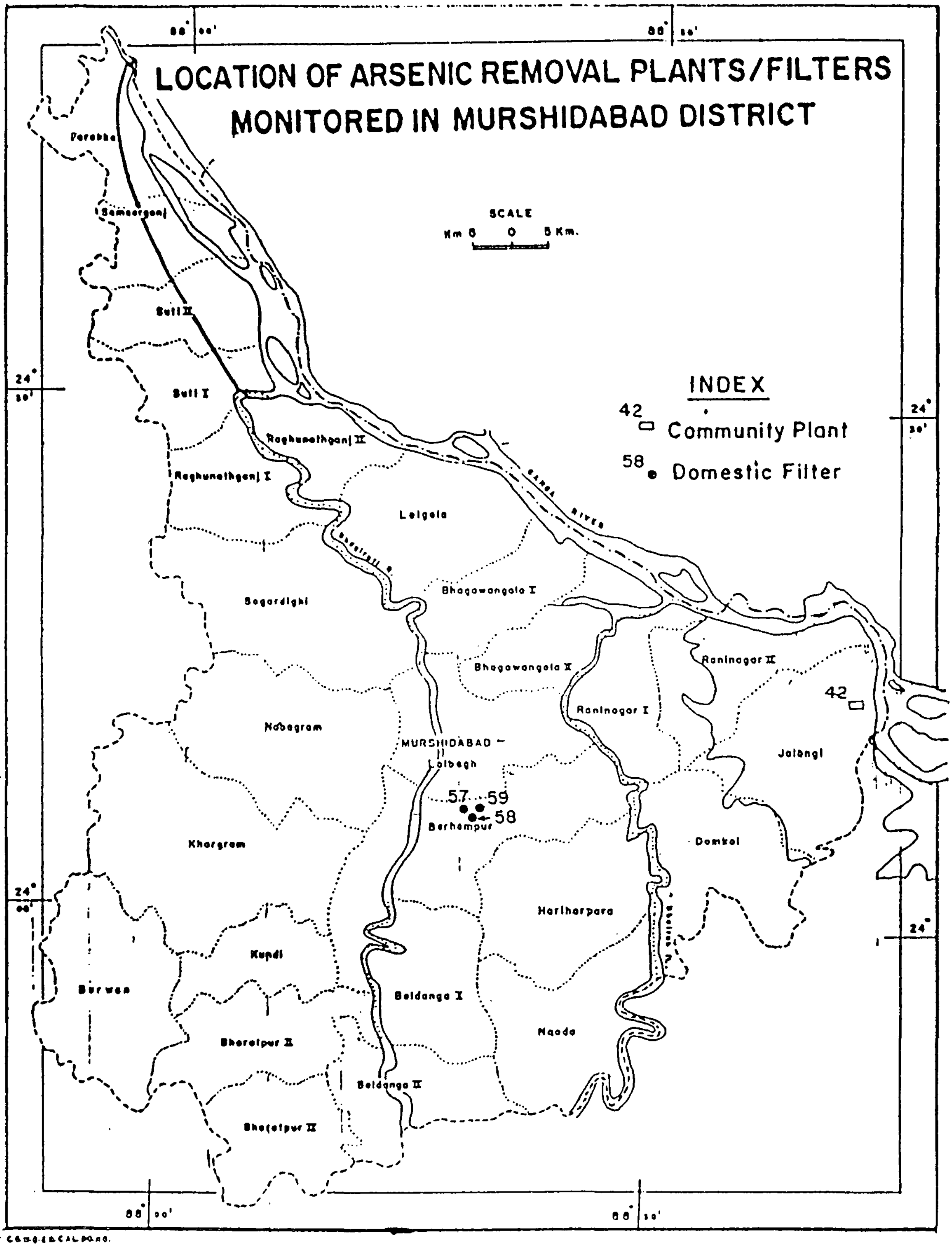
LOCATION OF ARSENIC REMOVAL PLANTS/FILTERS MONITORED IN NORTH 24 PARGANAS DISTRICT



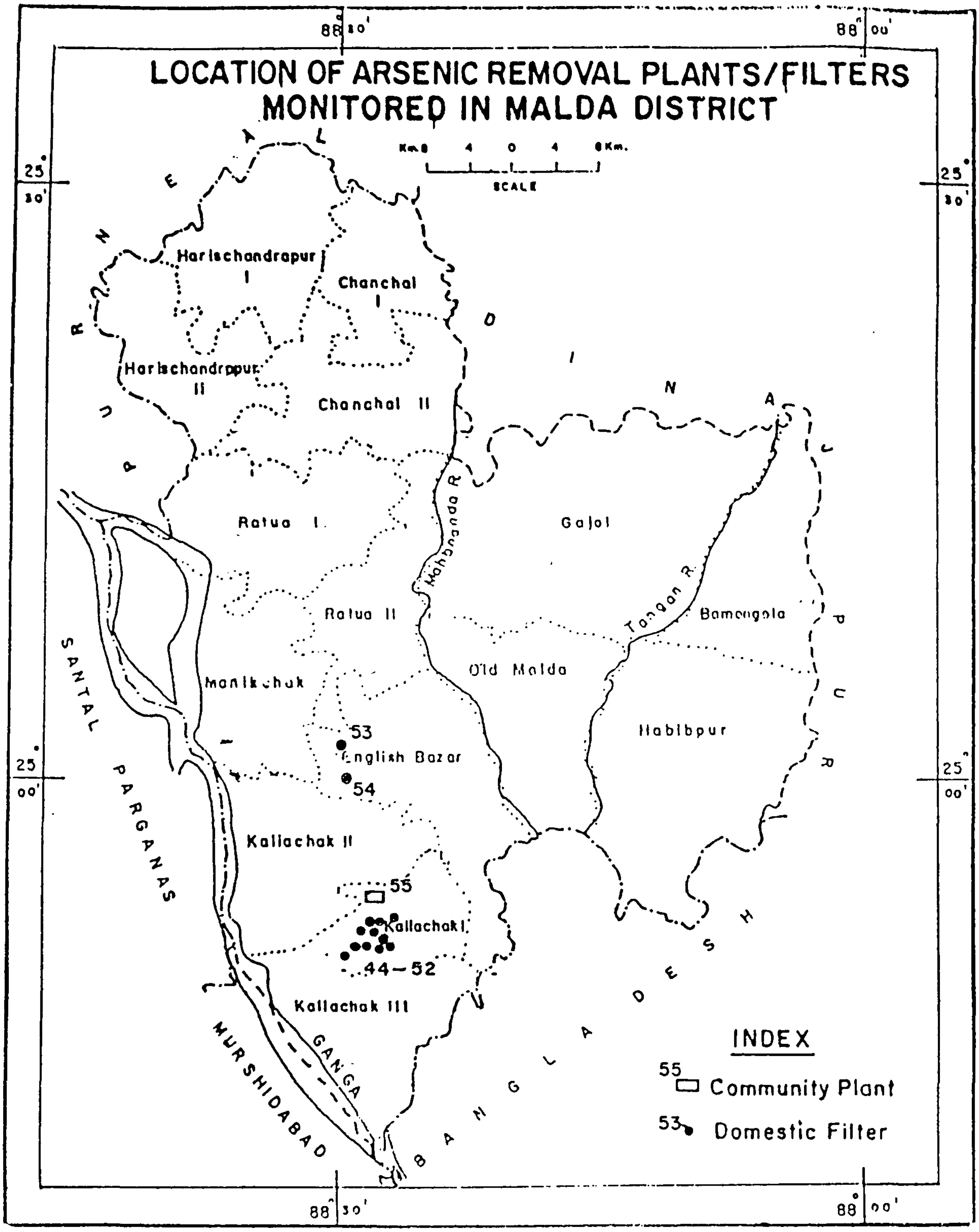


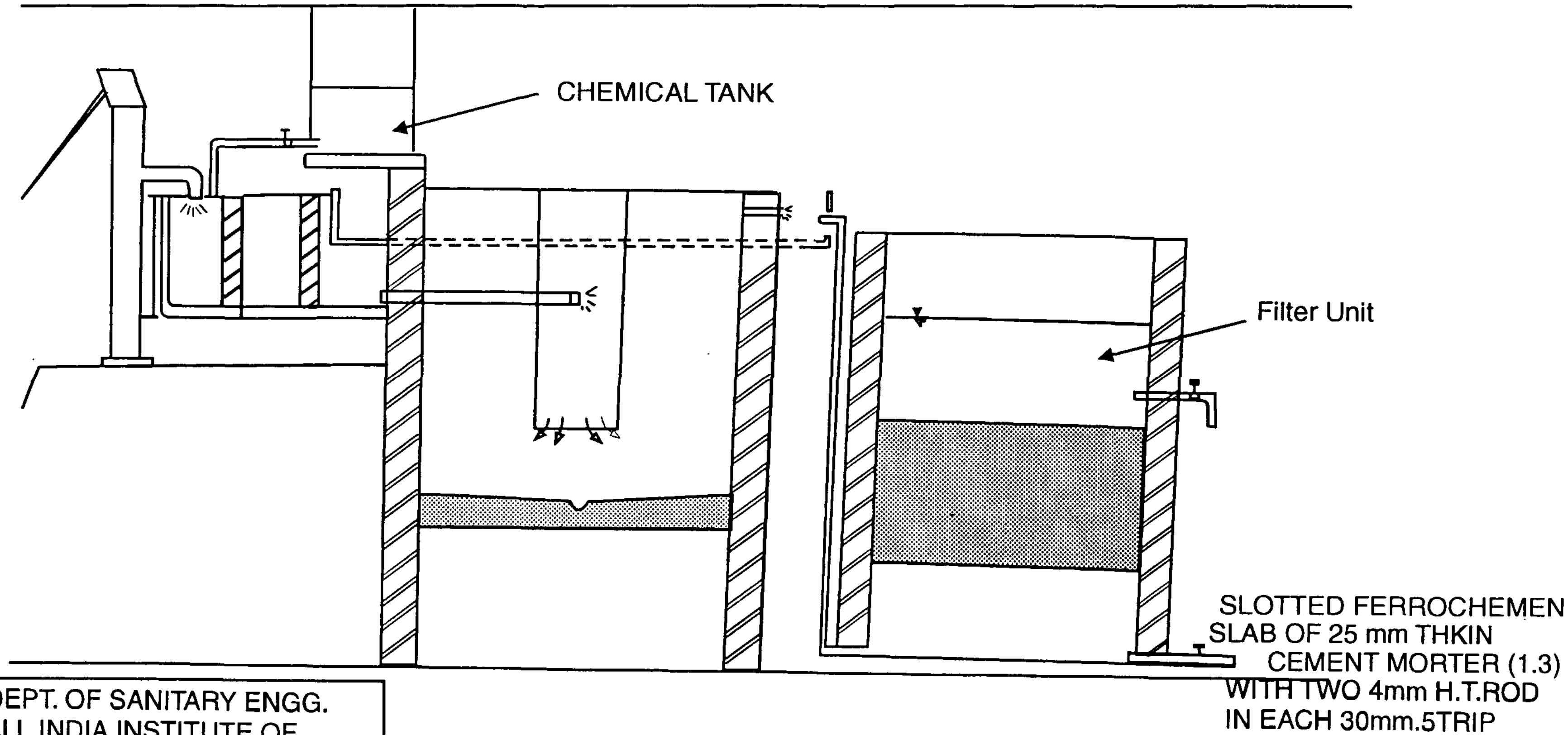
LOCATION OF ARSENIC REMOVAL PLANTS
MONITORED IN NADIA DISTRICT
Scale
DT. MURSHIDABAD
BANGLADESH
BURDWAN
HOOGHLY
Chapra
KRISHNANAGAR
Santipur
RANAGHAT
Chakdaha
41
40
31
INDEX
Community Plant
31

LOCATION OF ARSENIC REMOVAL PLANTS/FILTERS MONITORED IN MURSHIDABAD DISTRICT



LOCATION OF ARSENIC REMOVAL PLANTS/FILTERS MONITORED IN MALDA DISTRICT





DEPT. OF SANITARY ENGG.
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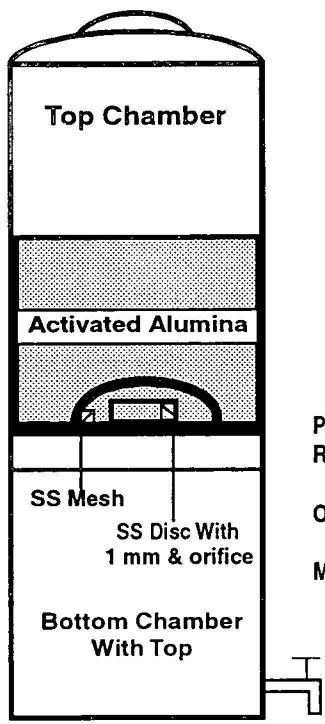
HYGIENE AND PUBLIC HEALTH
110. C.R. AVENUE, CAL; 73.

ARSENIC REMOVAL PLANT
(Handpump attached model)

Domestic Unit

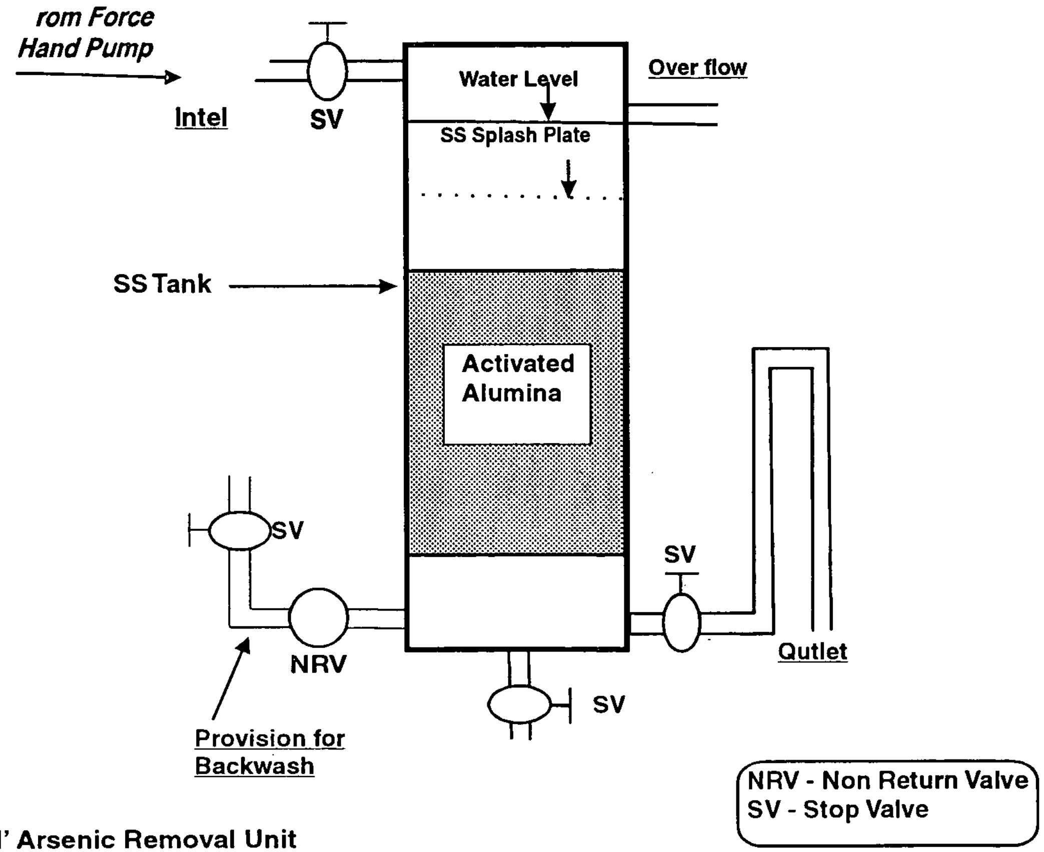


Pre-treatment
Requirement of Media

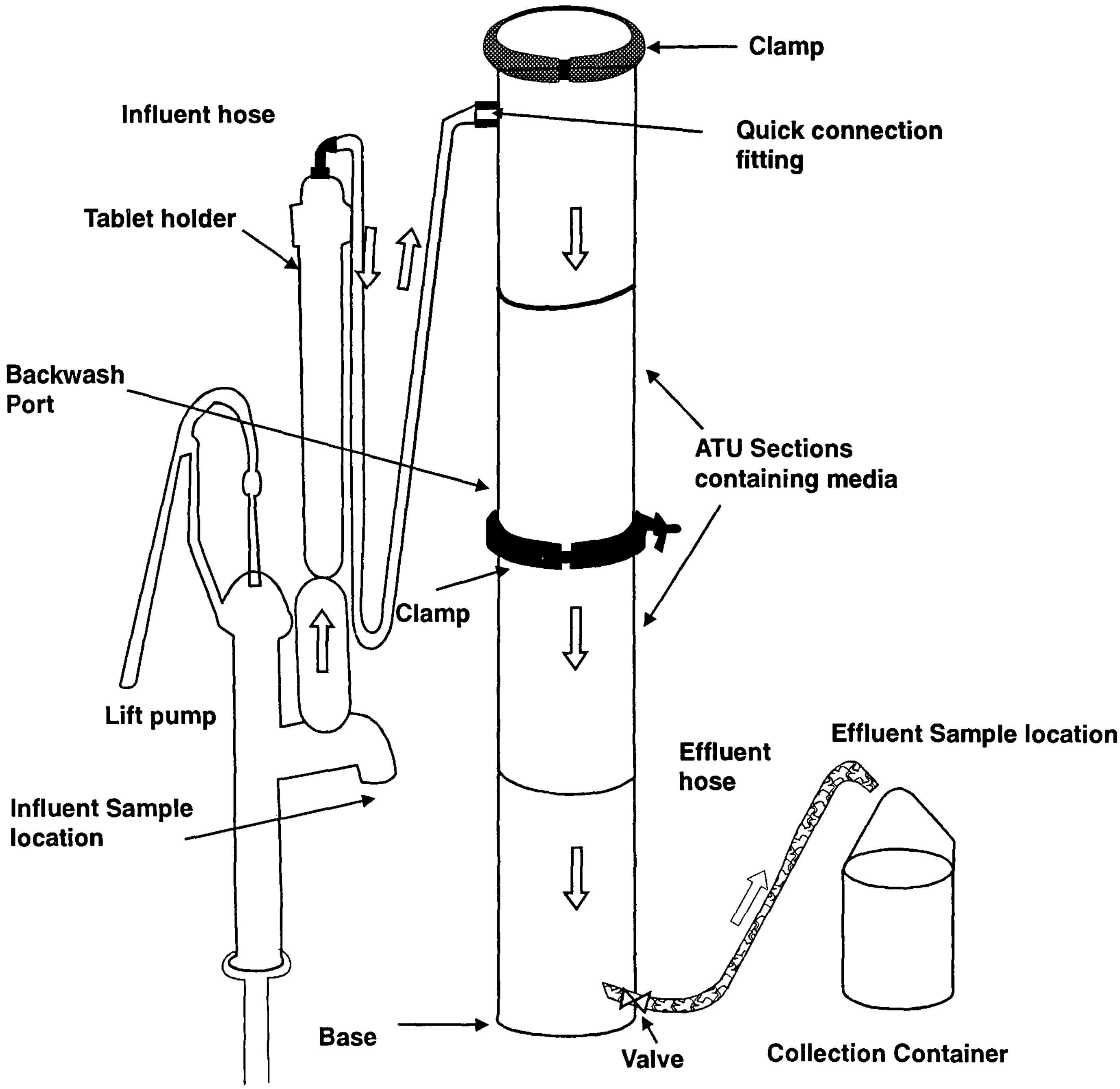
Operation

Monitoring Requirement

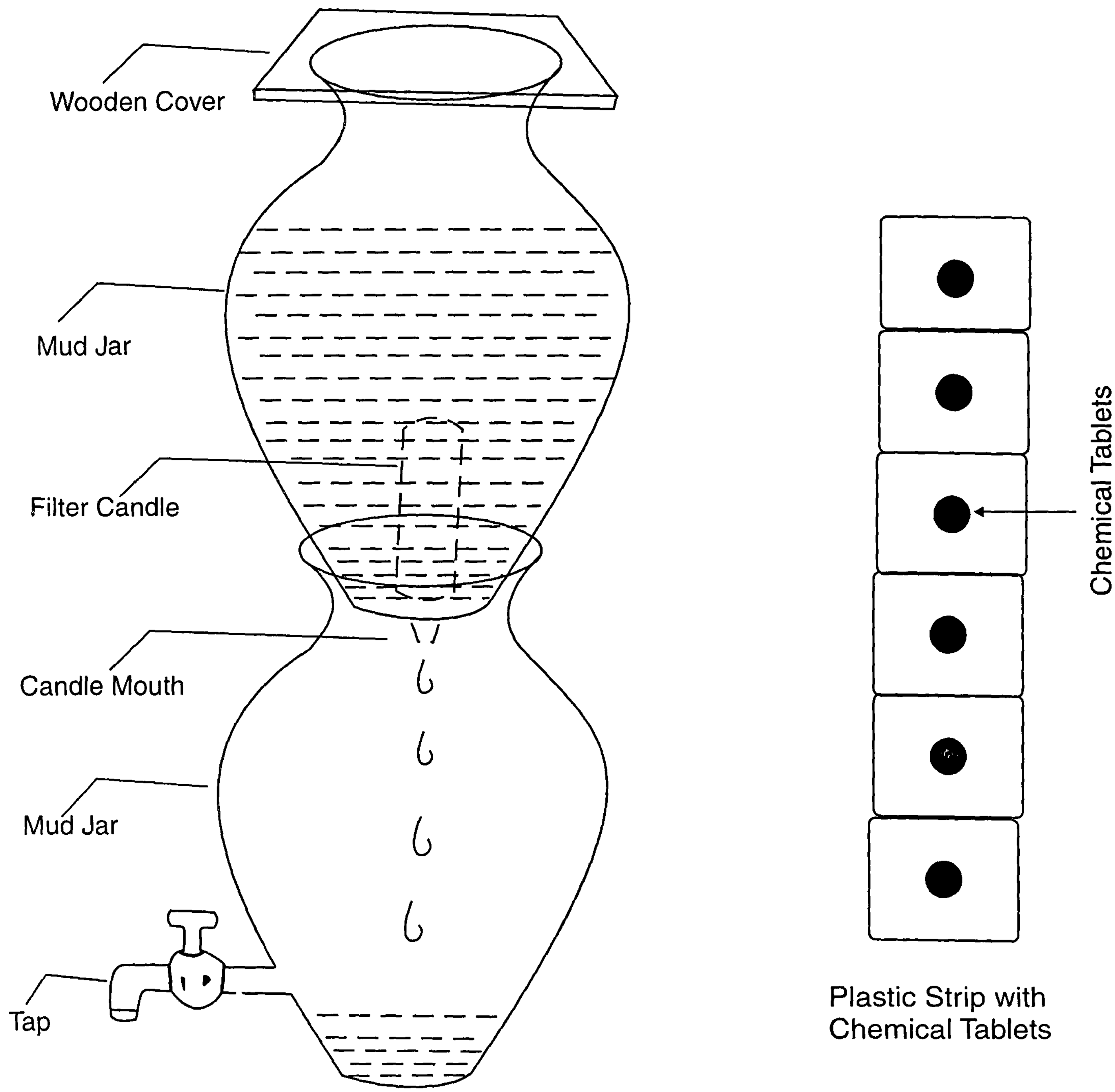
Community Unit



'Amal' Arsenic Removal Unit



Arsenic Treatment Unit (ATU)
Apyron Technologies, Inc.



Arsenic Removal Filter-Tablet System of School of Environmental Studies, Jadavpur University

RESULTS OF ARSENIC CONTENT OF SOME RAW FOOD CHAIN SAMPLES FROM NORTH, SOUTH 24 PARGANAS AND NADIA DISTRICTS.
(Irrigated by Ground Water varying in Arsenic concentration from 0.06 to 0.40 mg/l)

Sl. No.	Location	Food Chain Samples	Results mg / kg
1.	Madanpur, Nadia	Coriander	0.3
2.	Joypur, N 24 Parganas	Spinach	0.9
3.	"	Bean (F)	0.5
4.	"	Tomato	2.0
5.	"	Cabbage	1.65
6.	"	Potato	1.8
7.	"	Chilli	1.3
8.	"	Brinjal	0.5
9.	"	Pumpkin	1.3
10.	"	Papaya	1.45
11.	"	Banana	1.50
12.	Madanpur, Nadia	Tomato	0.55
13.	"	Cabbage	1.1
14.	"	Bitter Gupri	0.9
15.	"	Papaya	Nd
16.	"	Pumpkin	1.3
17.	"	Brinjal	1.6
18.	"	Potato	1.85
19.	"	Chilli	1.25
20.	"	Banana	0.35
21.	"	Mustard	4.90
22.	"	Masur Dal	Nd
23.	"	Wheat	1.25
24.	"	Rice	Nd
25.	Joypur, N 24 Parganas	Corianoen (seed)	Nd
26.	"	Wheat	0.4
27.	"	Mustard	0.65
28.	Kamdevpur	Tomato	1.65
29.	"	Spinach	0.8
30.	"	Cabbage	3.35
31.	"	Banana	Nd
32.	"	Lal sag	Nd
33.	Kamdevpur	Cauliflower	1.85
34.	"	Pumpkin	0.30
35.	"	Flat Beans	1.25
36.	"	Chilli	0.30
37.	"	Papaya	Nd
38.	Ramnagar, S 24 Parganas	Jamrul	0.2255
39.	"	Tomato	1.729
40.	"	Pea	2.534
41.	"	Potato	3.969
42.	"	Pea	2.018
43.	"	French Beans	1.473
44.	"	Guava	7.088
45.	"	Flat Beans	2.393
46.	"	Papaya	3.747
47.	"	Banana	2.3095
48.	"	Leman	3.532
49.	"	Safeda	4.658

50.	"	Lalbag	4.7705
51.	"	Flat Beans	1.941
52.	"	Flat Beans	2.3525
53.	"	Jamrul	5.7075
54.	"	Papaya	2.5075
55.	"	Tomato	2.622
56.	"	Drumstick	2.038
57.	"	Leman	2.916
58.	"	Chilli	2.4115
59.	"	Bitter Gourd	3.4605
60.	"	Brinjal	2.191

ARSENIC CONTENT OF RAW & COOKED FOOD IN DHABDHABI S-24 PARGANAS.

Serial No.	Items (dried)	Arsenic (mg / kg)
1.	RICE (RAW)	0.3
2.	RICE (BOILED)	0.8
3.	POTATO (RAW)	1.15
4.	POTATO (BOILED)	1.05
5.	PAPAYA (RAW)	0.90
6.	PAPAYA (BOILED)	1.10
7.	GUAVA (RAW)	1.10
8.	GUAVA (BOILED)	1.00

COMPARATIVE EVALUATION OF FIELD KITS

S.N.	Parameter	AAN	E.Mark	Aqua	NIPSOM	AIIH&PH
1.	Kit Design	Compact and Light	Compact and Light	Not compact & heavy	Not compact & heavy	Not compact & very heavy
2.	Kit Capability	Semi-quantative	Qualitative (As upto 0.05mg/l)	Semi-quantative	Qualitative (As upto 0.05mg/l)	Semi-quantative
3.	Minimum detection limit of As	0.02 mg/l	0.1 mg/l	0.05 mg/l	0.02 mg/l	0.05 mg/l
4.	Presence of essential chemicals (HCl, $SnCl_2$, KI, $HgBr_2$, paper)	HCl – locally procured	Present	$SnCl_2$ & KI not included	Present	Present
5.	Quality of Chemical used	$SnCl_2$ effected by humidity Zn in powder form	Reagent 1 (Zn, KI & $SnCl_2$) affected by humidity. Air lock– Reagent 2 (HCl)	HCl acid fumes affect kit box and $HgBr_2$ paper. Zn in granular form.	$SnCl_2$ effected by humidity Zn in powder form	HCl in glass bottle. Zn in granular form.
6.	As detection Range	0.02 – 0.7 mg/l	0.1 – 3.0 mg/l	0.05 – 3.0 mg/l	0.02 – 3.0 mg/l	0.05 – 3.0 mg/l
7.	Colour comparator Chart	The hue of developed colour does not match at 0.02 mg/l	Colour matches with chart	Not provided	The hue of developed colour does not match at 0.02 mg/l	Only one colour – 0.05 mg/l
8.	Effect of Interference	Sulfide interference	Sulfide interference	Lead acetate trap removes sulfide	Sulfide interference	Lead acetate trap removes sulfide
9.	Time Required	15 mins.	30 mins.	15 mins.	5 mins.	30 mins.
10.	Cost	Rs.1600	Rs.1900	Rs.3033	Rs.800	Rs.950
11.	Availability of Kit	Import	Import	Local	Import - Bangladesh	Local
12.	Occupational hazards	Accidental escape Arsine gas	Accidental spillage of acid & escape of arsine gas	Accidental spillage of acid & Arsine gas escape. $HgBr_2$ papers effect fingers.	Accidental spillage of acid and escape of arsine gas.	Spillage of acid, $SnCl_2$, KI Accidental spillage of arsine gas..

COMPARATIVE COST ANALYSIS WITH AR TECHNOLOGIES

Assumptions:

- Concentration of arsenic in ground water varies from place to place but within 3mg/l.
- Ten arsenic affected villages with average population of 1000 per village.
- Average family size of 5 members.
- Household consumption 40L per day for drinking and cooking.
- Community will share min. 10% capital cost and O&M cost including replenishment cost of chemicals.
- Max. community capital cost share Rs.50 per head and O&M cost Rs.20 per family.
- One community unit will provide 2000L/day and meet the needs of 50 families.
- 25% of household will have household AR units.
- Calculations have been made covering all ten villages with a particular type of system.

AR System	Units no.	Population	Per capita cost	Capital cost (in million)	Cost subsidy (in million)	Annual O&M cost	Annual O&M subsidy
AMAL	40	10 000	200	2	1.5	560,400	80,400
AIIH&PH	40	10 000	120	1.2	0.7	609,840	129,840
APYRON	40	10 000	324	3.24	2.74	1 736,160	1 256,160
Ion Exchange	40	10 000	288	2.88	2.38	1 669, 920	1 189 920
Pal Trockner	40	10 000	344	3.44	2.94	579,120	99,120
PHED-Multimedia	40	10 000	144	1.44	0.94	2 556 240	2 076 240
W S I	40	10 000	348	3.48	2.98	824,400	344,400

Conclusion: Since all the AR removal units are not functional at a long range, it will be better to select the units based on total cost inputs and as per water quality report and As concentration.

WORKSHOP ON ARSENIC MITIGATION
A Search for Sustainable Solution
Org. by UNIDO
KOLKATA- 10 August, 2001

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