Chapter-4
Mitigation and Remediation Update from West Bengal and Bihar : Studies and Projects Initiated

4.1 West Bengal

Though, the groundwater arsenic contamination first surfaced in the year 1983, the initiative to combat the menace of arsenic hazards, in true sense, came into existence in the year 1992 from the Government of West Bengal with the constitution of a state level expert committee. By then, as against 33 villages in 4 districts namely, South 24 Pargana, North 24 Pargana, Nadia, and Murshidabad reported in the year 1983 as many as 93 villages covering 6 districts namely, Murshidabad, Nadia, North 24 Parganas, South 24- Parganas, Barddhaman and Malda were identified as arsenic contaminated. The expert committee was formed to investigate the causes and sources of arsenic contamination in groundwater and to suggest possible remedial measures to combat the growing hazards. From 1992 onwards, Government of West Bengal and Central Government, along with several academic Institutions and Non-Governmental Organizations, have initiated a number of restorative and substituting measures coupled with action plan. Their main focus was on the detailed investigations to understand the physiochemical process and mechanism, alternate arrangement to supply arsenic free water to the affected populace and the development of devices for arsenic removal and their implementation at the field, etc. As of year 2005, the State Government has operationalized number of schemes spending a sum of nearly **Rs. 2100 crores**. Despite number of corrective and precautionary measures, the spread over of arsenic contamination in groundwater continues to grow and more new areas are added to the list of contaminated areas. The problem resolving issues, thus, have appeared to be partial and inadequate. As of 2008, 9 districts covering 3417 villages in 111 blocks have been reported as the groundwater arsenic contaminated. These contaminated areas are in patches and encompass the districts of Murshidabad, Nadia, North 24 Parganas, South 24- Parganas and Kolkata to the east and Howrah, Hoogli, Barddhaman to the west of River Bhagirathi/ Hugli, and Malda to the north of the River Ganga. Even with every additional survey, more new areas are being added to the list of groundwater arsenic contamination from the state. Although the occurrences of groundwater arsenic contamination are in patches within shallow depth measuring 100m bgl., people staying around those affected areas are not abated from the potential risk of arsenic contamination owing to use of contaminated groundwater in different forms. About 16.26 million population (35.48% of the total population of the State) covering 17533 number of habitats are located in the potential risk zone of groundwater arsenic related threat and diseases. The basis of categorizing the contaminated areas are groundwater sampling from hand pumps and tube wells located in those places. Therefore, a hand pump or a tube well identified as arsenic affected means denial of use of that hand pump or tube well for further usages. It may be mentioned here that in most of the arsenic affected areas people are largely dependent on the hand pumps and tube wells for their potable and irrigation water requirement. Thus, scarcity of potable and irrigation water in the affected areas has become inevitable. Usages of those contaminated wells, to meet the basic need of water, mean accelerating the process of arsenic hazards and aggravation of its spreading.

In order to combat arsenic menace in the state, a number of counteractive measures, steps and research studies have been initiated and put into practice broadly as per the recommendations of the expert committee constituted by the Government. The measures and steps have mainly been focused towards providing arsenic free drinking water to the entire population in the arsenic infested areas by arrangement of alternate freshwater sources and by treating contaminated groundwater using arsenic removal techniques. The research studies have been focused towards identifying: (i) extent and nature of arsenic contamination in groundwater, (ii) causes and mobilization, (iii) mitigation strategies, and (iv) Research & Development studies for devising cost effective remediation techniques and for developing sustainable ground water resources management strategies.

How far the counteractive measures and steps, initiated by the Government, are effective in terms of restoring, resolving and remediation of the problem, attaining sustainability to combat the menace, understanding the physical processes, etc. needs a critical appraisal to ensure its effective implementation in other arsenic contaminated areas.

4.1.1 Steps and measures taken by the Government

Since 1992 the Govt. of West Bengal has taken a number of counteractive steps and measures to combat the natural calamity of groundwater arsenic menace like; public awareness programs, devising and demonstrating some of the results acquired from scientific analysis. Some of the important steps taken by the govt. are as follows:

(i) As the first step, most of the infected hand pumps and tube wells, which were being used for domestic usages in the arsenic affected areas, have been largely identified and put into hold for further usages;

(ii) The problem of groundwater arsenic contamination has been prioritized in the state and an 'Arsenic Task Force', comprising technical experts from different disciplines working in the state, has been constituted to prepare an arsenic mitigation action plan report for the aquifers in the arsenic infested districts;

(iii) A 'Master Plan' has been prepared for the entire state under the guidance of the 'Ar senic Task Force'; to provide arsenic free water to the arsenic affected villages using surface water and groundwater based schemes with the provision of Arsenic Treatment Unit.

(iv) Public Health Engineering Department, Government of West Bengal has established district level chemical laboratories for detecting arsenic content in groundwater. Those chemical laboratories have been equipped with equipments to trace elements other than arsenic;

(v) A number of surface water based schemes have been put into operation in places, wherever they are feasible, with provision of chemical treatment;

(vi) Arsenic removal plants, based on various treatment technologies to treat arsenic con taminated groundwater, have been installed in many places and put into operation to provide potable water to the affected populace where there were no access of other sources of potable water supply;

(vii) Arsenic free deeper aquifers and wells explored and constructed by CGWB have been put to use by the state agencies for public water supply;

(viii) Arsenic content in food chains and their effect on ingestion have been analyzed. However, what forms of arsenic, organic or inorganic, are present in groundwater and the degree of consequential impact of arsenic containing food chains on human health is yet to be established;

(ix) Many R & D studies focusing towards understanding source and causes, geochemical processes, extent of mobilization, social and health hazards, impact on food chains, etc. have been initiated.

In addition to the above steps taken by the Government, a number of non-governmental organizations, academic and R & D organizations have come forward to rescue the affected populace, in supply of potable water through installation of a number of arsenic-free hand pumps and treatment devices under the community participation. Despite such considerable steps and measures, the task of ensuring potable water supply in many areas has remained a big question because of: (i) lack of proper coordination, (ii) poor operation and maintenance of arsenic removal devices, and (iii) unsatisfactory performance of the arsenic removal filters used in the devices.

The source of irrigation in most of the arsenic affected areas is groundwater from shallow aquifer within 100 m bgl. In the absence of alternate source of arsenic free irrigation water, rural people continue to tap arseniferous aquifer resulting in further aggravation of the problem in different forms, such as, mobilization of arseniferous groundwater to freshwater zones, spreading of the sources by the cycling process of water and use of fertilizers and pesticides, transport through food chains, etc. The crux in the management of the whole problem has boiled down to single point as to how to ensure arsenic free irrigation water into the arsenic affected areas. Wherein the use and reuse of contaminated groundwater, on one hand, have the threat of arsenic contamination through food chains; on the other hand, infiltration of arsenic contaminated water, together with residual of fertilizers and pesticides, may provoke contamination of vadose zone, and mobilization of arsenic in the freshwater zones. Ensuring supply of potable water alone, thus, seems to be inadequate to attain sustainability in terms of resolving the arsenic menace. It is, therefore, necessary to consider a framework of problem-solving curriculum linking one issue to another, one's favoring and posing condition to another, and resolve those systematically in a judicious manner to achieve the target of human-land-water resources man agement in the arsenic affected areas.

4.1.2 Findings of initiated R & D studies

A number of research studies have been pursued to investigate extent, mobilization process, geochemistry, hydro-geological properties and processes by different organizations. Findings of various research studies have broadly been discussed in chapter-3. The Central Ground Water Board-Eastern Region (CGWB-ER), in addition to the above aspects, undertook tasks to identify potential arsenic safe zones aquifer. Findings of CGWB-ER are given below:

(i) Arseniferous aquifers are mainly observed within the shallow depth (within 100 m below ground level), while the deeper aquifer (>100 m bgl) in the same area is found free from arsenic. The shallow and the deeper aquifers are separated by a thick impervious clay layer and the thickness is above 10 m. The deeper aquifer is capable to yield 5 to 20 lps of water. It is further observed that when the deeper aquifer is pumped creating a drawdown of 6 m, there is not much impact on the overlain arsenic contaminated zone.

(ii) Groundwater in the arsenic affected area is characterized by high iron, calcium, magne sium, bicarbonate with low chloride, sulphate, fluoride and sodium.

(iii) Geologically, the arsenic affected areas are the parts of the Ganga-Bhagirathi delta comprising succession of thick Quaternary sediments. The arseniferous tract is restricted in the upper delta plain within shallow depth, which is mainly built up of sediments deposited by meandering streams and levees composed of sands of various grades, silt, clay and their admixtures.

(iv) The groundwater mostly occurs in thick zone of saturation within the unconsolidated alluvial sediments in the affected areas; and the aquifers are made up of sands of vari ous grades. Groundwater occurs generally under unconfined hydro-geologic conditions.

(v) The arsenic groundwater contamination is attributed to the geogenic origin, and the source of arsenic in localized patches is due to presence of Arsenopyrite in clay and sand. Arsenic concentration is more in clay than in sand.

(vi) In arsenic affected areas, all tube wells harnessing shallow aquifers do not yield arsenic contaminated water. Some are arsenic affected and some others are free from such contamination.

(vii) All shallow dug well aquifer zones are not free from arsenic contamination rather it is the mode of abstraction that makes the difference. The very shallow tube well tapping the dug well zone aquifer has also been found to yield arsenic contaminated water.

(viii) There are places where the number of arsenic yielding tube wells are more in number but the degree of arsenic concentration is comparatively less and vice versa.

(ix) Physical manifestation of the arsenic diseases among the affected population does not always reflect the degree of concentration of arsenic in the affected area. Arsenic affected persons may be less in number in places where the degree of concentration is greater and the number of arsenic yielding tube wells are more in number and viceversa. The reason of the disease may be the quality of food consumed by the people residing in the area and/or the presence of ionic in groundwater in which arsenic occurs.

(x) The effect of dilution, created by artificial recharge of arsenic free surface water & rainwater onto the shallow arsenic contaminated aquifer, is found to reduce the concentration of arsenic in the groundwater.

(xi) The artificially injected dissolved oxygen in contaminated aquifer, as a measure of in-situ remediation of arsenic, is found to reduce arsenic and iron concentration in the aqueous phase. The arsenic concentration in the vadose zone is observed below detection limit (<1 µg/L).

(xiii) The detection of origin and age of groundwater in few arsenic affected areas showed that the shallow aquifer water is of recent recharge (< 50 years); whereas deep groundwater is of old recharge (5000 to 13000 years).

(xiv) The analysis of arsenic content in food items (cereals, vegetables & fruits), produced in arsenic affected areas using arsenic contaminated water, revealed possibility of arsenic intake through food items. This may affect not only the people residing in the arsenic affected areas but also the other areas where these food items are marketed.

(xv) The efficacy of arsenic removal units in arsenic affected areas indicated that community based arsenic removal treatment plants and domestic filters could be a promising alternative. However, the extent to which the arsenic removal devices could be effective requires a thorough evaluation. In order to evaluate the performance of different arsenic removal devices, installed by various agencies in the arsenic affected areas in the West Bengal, the CGWB and United Nations Industrial Development Organization (UNIDO) jointly studied 16 community-based arsenic removal units en compassing six different removal technologies and 40 domestic units relied on four different removal technologies. It is observed that although, by and large, the arsenic removal devices are effective in bringing down the concentration of contaminated water to less than 50 g/L, there are instances when they failed to produce desirable outputs. It is mainly found attributed to poor maintenance and monitoring than any inherent weakness in the technology itself.

(xvi) The study of mobilization mechanism carried out by CGWB in association with UCL, London, revealed that arsenic is released from solid phase to aqueous phase by reductive dissolution of FeOOH and corresponding oxidation of organic matter. This process is mainly driven by reduction of natural organic matter buried in sediment or buried peat deposits.

4.1.3 Projects Initiated/Implemented as Remedial Measures

The source of arsenic in groundwater is of geogenic origin, whose immediate restoring solution may not be feasible, unless physicochemical process is adequately understood. Thus, the possible remedial measures have been to find alternate source or to adopt suitable technological options to ensure supply of potable water in the arsenic affected areas. The schemes adopted as remedial options can broadly be grouped as under:

(i) Uses of surface water sources,
(ii) Exploring and harnessing alternate arsenic free aquifer,
(iii) Removal of arsenic from groundwater using arsenic treatment plants/filters,
(iv) Adopting rainwater harvesting/ watershed management practices.

4.1.4 Uses of surface water sources

Supply of surface water from ponds, rivers etc. for drinking purposes through pipe network system after suitable purification by conventional method of treatment viz. coagulation, flocculation, rapid sand filtration and disinfections, as an alternate option, have been put into practice in some places by the State Govt. Horizontal roughing filter with slow sand filter have been adopted, in case of supply of pond water. Eight such surface water based schemes in the state have been operationalized by the State Government in different places, covering population of 3.85 million in 1266 mouzas with estimated cost of **Rs. 1254.2 crores**. Out of them the main five schemes are: (i) Malda water supply scheme of 75 MLD capacity covering 1.43 million population; (ii) South 24 Parganas water supply scheme of 145.31 MLD capacity covering 2.951 million population; (iii) North 24 Parganas water supply scheme of 34 MLD capacity covering 0.751million population; (iv) Mahyampur water supply scheme in Murshidabad district for 3.95 MLD capacity covering 68,975 populations; and (v)) Balupur water supply scheme in Malda district of 5.23 MLD capacity for 72,883 populations. Photographs of two such schemes, one at Malda, and another at North 24 Paraganas, which are successfully running, are shown in **Figs. 4.1 and 4.2**, respectively. Needless to mention that all surface water based schemes are successfully running to provide potable water supply to masses covered under the schemes. Large scale implementations of surface water based schemes are constrained by number of factors, namely; (i) technical feasibility, (ii) water availability, (iii) cost factors, etc.

Figure 4.1: Malda surface water supply scheme, West Bengal

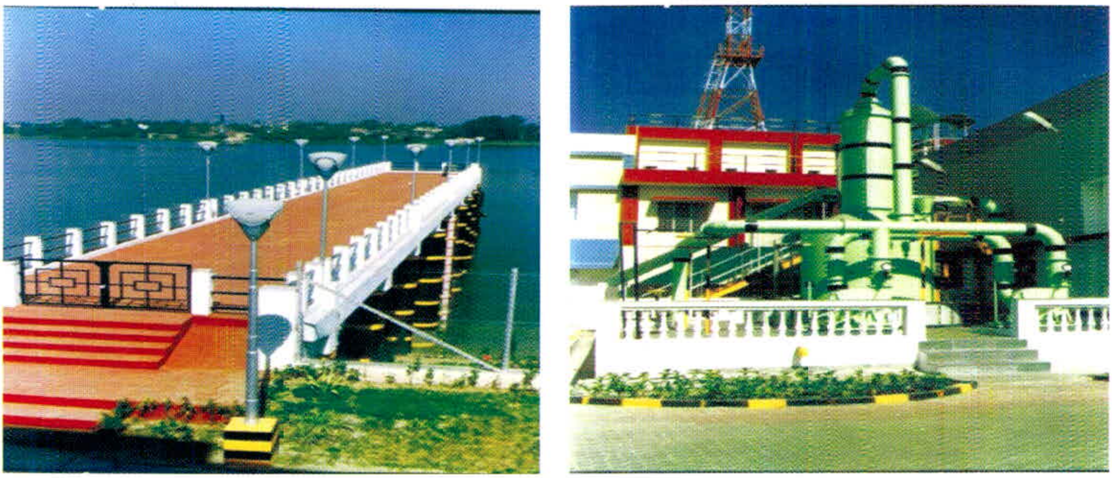


Figure 4.2: North 24 Paraganas surface water supply scheme, West Bengal

Surface water based schemes are constrained by the following factors:

a) ***Water availability:*** Surface water sources, that can be harnessed, are not omnipresent, and, therefore, cannot be located and extended everywhere. Moreover, water in some of the flowing/ stationary bodies remains only for a specific period of a year and cannot form the regular source for public water supply system. In addition to that, due to changes in the river discharges and its flow course, it is difficult to keep a sustainable intake point of water for the whole year.

b) ***Maintenance of water treatment units:*** Periodical maintenance of water treatment units, generally installed at various sites, requires a close monitoring. Efficacy of any treatment unit depends not only on the merit of technology but also on the regular maintenance and vigilance.

c) ***Networking/Transportation:*** A long transportation is required for supply of surface water from intake point/ treatment unit to the delivery points, particularly in the areas where water is to be supplied. This would involve: i) maintenance to avoid leakage damage in pipe lines during transportation ii) considerable cost of pipe line & its maintenance, iii) upholding of pressure for long transportation, etc.

d) ***Acceptability of using surface water for drinking purposes:*** Generally, rural people are habitual in using groundwater for drinking purposes and use of treated surface water, specially chlorinated water & its smell, is not conventionally practiced. There fore, switching over from routine groundwater uses to surface water sources, particularly for potable water would need an effort for social empowerment.

4.1.5 Uses of arsenic free groundwater by tapping deep aquifers

The arsenic contaminated zones mostly lie within the shallow aquifer (<100m bgl). But in many places the shallow aquifer is free from arsenic contamination because of hydrogeological set ups and is also free from the probable threat of contamination. Such risk free potential zones in the shallow aquifer provide scope for tapping. The deep aquifers (>100 m bgl) underneath the contaminated shallow aquifer, in many places of Bengal Delta Plains, are normally seen arsenic free. The deeper aquifer is separated by a thick clay layer of appropriate composition from the shallow aquifer. From the isotopic studies carried out in West Bengal, it is observed that there is no hydraulic connection between the shallow and deep aquifers as they belong to different age groups. Those deep arsenic free aquifers have the potential to yield nearly 5 to 20 lps of water, which is largely adequate to meet demand of water in the domestic sector. It is observed in the field studies that properly designed tube wells are capable to harness deeper arsenic free aquifer without posing any future threat of arsenic mobilization from the overlain contaminated zone. Similar experiences are observed from coastal areas where fresh deeper aquifer is separated from upper saline/brackish water by a thick clay layer. For example number of wells constructed using cement sealing techniques could yield fresh water for a very long period. However, in some cases, the deep tube wells are reported to be contaminated with arsenic, which might have attributed due to the following reasons:

(i) Tube wells constructed in the past might have not been properly designed with cement sealing techniques,

(ii) Tube wells constructed in the past might have been designed to screen both the upper and deeper aquifer to get higher discharge,

(iii) Tube wells constructed with cement sealing might have not been constructed properly.

Taking into consideration the above scientific propositions, the Public Health Engineering Department (PHED), Govt. of West Bengal, has put into operation few direct aquifer tapping schemes for supply of arsenic free water to the affected habitations. These schemes are: (i) 166 ring wells, each covering 500-600 population; (ii) 8037 tube wells fitted with hand pump, tapping deeper aquifers each covering 1000-1200 population; (iii) 244 piped water supply scheme with large diameter tube well for harnessing arsenic free aquifers benefiting 10000 population by each scheme. These schemes could stand alone to provide potable water to reasonable sections of population in the arsenic affected areas, and are running with a satisfactory level.

The successful implementation of deep aquifers, tapping from underneath arsenic contaminated shallow aquifer and freshwater zones in the shallow aquifer, could provide scope for an alternate option of dependability on groundwater resources. In arsenic affected areas, where the underneath deep aquifer possesses the characteristics of potential groundwater yields, and is risk free from potential arsenic threat by tapping deeper aquifer with proper sealing of the upper arseniferous aquifer for prevention of leaking arsenic contaminated water from the overlain aquifer groundwater withdrawal can provide an alternate sustainable solution to meet water demand.

In order to delineate potential deep aquifers and their prospect of harnessing, CGWB-ER, Kolkata, has started and continued groundwater exploration, down below the depth of 350 m bgl (maximum) in a number of arsenic affected districts in the State. By 2008, nearly 120 exploratory wells have been constructed and most of production wells have been handed over to the State Govt. department for operation. While carrying out the explorations, some interesting results are noted, which could help researchers and planners for future planning and management of groundwater resources in those areas. They are:

- A three layer aquifer system comprising thickness within 100 m bgl, 120 to 160 m bgl and 200 to 250 m bgl exists in the Bengal Delta Plains. The top layer (shallow aquifer) within 100 m bgl is mostly arseniferous, while the other two deep aquifers (120 to 160 m bgl, and 200 to 250m bgl) are separated from the overlying aquifers by clay layers of thickness above 10 m. They are arsenic free. The clay layer acts as a barrier to arrest the transport of arsenic from shallow arseniferous aquifer to the deep aquifers.

- A properly designed well with screen length tapping the desired aquifer, along with cement sealing of interface of shallow arseniferous aquifer and deep aquifer, is proficient in safe withdrawal of water from the deep aquifer having no risk of arsenic rich water. A schematic of two such exploratory wells, constructed at Beldanga village in Murshidabad district in West Bengal, is shown in **Fig.4.3.**

- Arsenic free deeper aquifers have the potential to yield 5 to 20 liter water per second and can cater to the need of potable water for large section of affected populace. By considering the capacity of each tube well, constructed in the arsenic affected areas of North 24 Parganas district, against a projected demand of 10 liters per capita per day for drinking & cooking purposes, a conservative estimate shows that about 48 tube wells could meet water requirement. The estimated figures are given in Table-4.1.

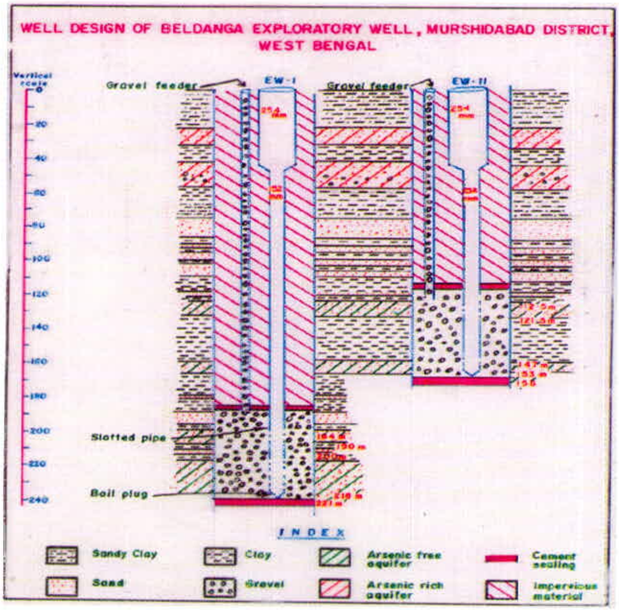


Figure 4.3: Schematic of two exploratory wells constructed at Beldanga in Murshidabad district in West Bengal to tap arsenic free deep aquifers.

Table 4.1: A conservative estimate, showing requirement of a number of deep tube wells for tapping arsenic free groundwater to meet domestic requirement in the North 24 Parganas district, West Bengal.

Block	Expected yield of arsenic free water (litre per sec)	Supply of arsenic free water, if run for 8 hrs in a day (litres)	Population in arsenic risk areas	Water requirement for drinking purposes (litre per day)	No of tube Well required for arsenic mitigation in the block
Barasat I	13	3,74,400	2,38,000	23,80,000	6
Habra I	17	4,89,600	1,88,000	18,80,000	4
Habra II	15	4,32,000	1,50,000	15,00,000	4
Bongaon	8	2,30,400	3,44,000	34,40,000	15
Barrackpur I	15	4,32,000	1,57,000	15,70,000	4
Barrackpur II	10	2,88,000	1,59,000	15,90,000	6
Gaighata	12	3,45,600	3,00,000	30,00,000	9
Total		25,92,000	15,36,000	1,53,60,000	48

A hydrogeological map showing formations and characteristics of potential deep aquifers, underneath of arsenic affected areas in West Belgal, prepared by CGWB-ER, is shown in Fig. 4.4. However, in order to ascertain responses of overlain contaminated zone and the probable threat of contamination to the deep aquifers, due to different stresses in the groundwater domain, a multi-aquifer system based flow and contaminant transport modeling need to be carried out to secure the fate of the groundwater domain before such schemes are planted.

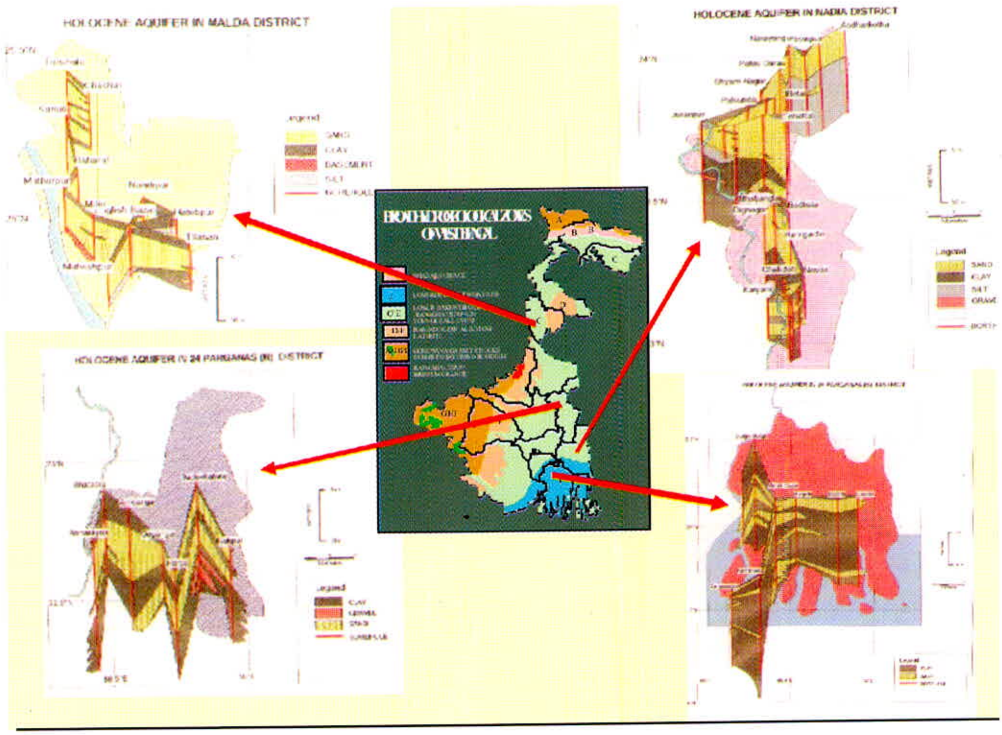


Figure 4.4: Disposition of delineated arsenic free deep aquifers in some parts of arsenic infested areas in West Bengal (Source: CGWB-ER, Kolkata)

4.1.6 Use of arsenic removal filters for supply of arsenic free groundwater

Surface water sources and deep aquifers are practiced in places wherever they are found feasible in terms of technical and financial aspects, and as such schemes are few in numbers. However, usages of arsenic contaminated groundwater, by removing arsenic with the help of arsenic removal filters, have been extended in a large scale in the West Bengal. A number of arsenic removal devices, developed by various organizations, based on different scientific propositions have been put in practice under a number of schemes. Central government, state government, academic institutions and few private organizations have come forward with arsenic removal devices and implemented them in many places to provide treated arsenic free water to the populace in the affected areas. Govt. of West Bengal alone has spent more than Rs.832.46 crores on arsenic removal schemes. Different types of arsenic removal schemes have been devised. These devices vary in size, filtering mechanisms, and mechanisms of operation. Based on the size, the schemes can be categorized as 'Arsenic Removal Unit (ARU)' and 'Arsenic Removal Plant (ARP)'. ARUs are those, whose inlet are directly connected to a hand pump or tube well. They are complete units. Arsenic Removal Unit is normally a small assembly which can meet requirement of water for a smaller section of people. ARPs, on the other hand, are those units, which have the capacity to treat a large quantity of water and can cover a large section of populace. Nearly, 77 ARUs, each having coverage of 15000 populations, have been installed with the existing piped water supply scheme. And 2396 ARUs, each having coverage of 600-800 population, have been fitted with the existing hand pumps. Nearly 1900 ARPs have been put in operation in many places. A photograph of an ARP connected with an existing piped water supply scheme is shown in **Fig.4.5.**

However, most of the arsenic removal devices particularly, ARUs, failed to produce satisfactory results mainly due to the shortcomings in operation and maintenance. The arsenic removal devices, whose O & M aspects are managed by community participation, could produce a satisfactory performance. In addition to the ARU and ARP, a large number of domestic filters have been developed by various academic and R & D institutions, which have been successful in reducing arsenic to a safe level. They have been marketed to affected habitats at a marginal cost. As a measure to render services to the people and for water quality surveillance, PHED has established 17 chemical laboratories at the district level. Besides that, United Nation International Children Emergency Fund (UNICEF) entered into a strategic alliance with the Govt. of West Bengal in a Joint Plan of Action (JPOA) to address issues related to the arsenic menace in the State. The JPOA includes testing of tube well water yielding arsenic free water, taking appropriate mitigation measures by way of construction of deep hand pump fitted with tube well, development of arsenic removal filters, supporting research & development facilities, providing platform for information sharing and creating awareness programme. The proposed plan of action under the JPOA is given in Table-2.

Figure 4.5: Arsenic Removal Plant (ARP) connected to an existing piped water supply schemes (PWSS).

Table 4.2: Scheme wise coverage and estimated cost of the schemes planned to cover for the arsenic affected areas under JPOA (Joint Plan of Actions) with UNICEF.

Sl. no.	Type of scheme	No. of schemes	Nos. of Mouza covered.	Population as per 2001 census (lakh)	Population covered (lakh)	Estimated Cost (Rs. lakh)
1	Surface water based scheme	8	1266	38.510	58.875	125420.38
2	New groundwater based scheme with ARP	361	1579	44.710	68.97	74976.07
3	New groundwater based scheme without ARP	21	39	0.924	1.433	1380.07
4	ARP in existing ground water based scheme	165	663	28.840	36.62	8269.23
	TOTAL	**555**	**3547**	**112.984**	**165.898**	**210045.75**

4.1.7 Rain Water Harvesting/Watershed Management

Rain water harvesting and conserving, by appropriate conservation structure to facilitate collection on ground or recharging to aquifer in order to use it later, is being practiced successfully in many water scarce regions of the country. Rain water harvesting, by watershed management practices in arsenic affected areas, where groundwater withdrawal has been restricted by overexploitation of the aquifer, can prove to be a promising alternative for managing water demand. This approach, besides increasing surface water accumulation and reduction of stresses on the use of groundwater, will enhance to recharge the underneath aquifer, that in turn will arrest decline of groundwater table. Water conservation, by this practice, will also require filtration and disinfections before put into use for public supply. Artificial recharge of rain water into overexploited/ overstressed aquifers through suitable recharging structures may also be a favorable proposition for permissible hydro-geological conditions.

4.1.8 Social Responses and Impacts

Social responses, in terms of socio-economic, socio-culture and socio-composite structure consequent to the affect of groundwater arsenic contamination, in the arsenic infested areas have not been worked out quantitatively in scientific terms. Few non-governmental organizations have made some qualitative analyses, which are as follows:

- Number of arsenic infected patients was more in the past (during eighties & early part of nineties) as compared to the number being reported in the later periods.
- Economically under privileged persons in the arsenic affected areas are more affected. This could be because of their low intake of protein & vitamin through food items.

Supply and usages of arsenic free water, and the awareness, generated through various campaigns and awareness programmes, are helping people in the affected areas to overcome the adverse impact on their health to a large extent.

- Earlier people suffering from arsenic related diseases used to get indifferent treatment from the rest of the people in the area as the disease was considered to be an infectious one. Based on this baseless apprehension that prevailed for a long time, even the mar riage alliance to a family, having arsenic patient, was rejected. Gradually, with the help of social and health awareness programmes, people started believing that the disease is purely water borne and not infectious; this in turn, helped people to re-store social acceptability .
- With the help of awareness programmes and water quality analysis facilities, people can be identified having arsenic related disease by the local health workers. They can also differentiate the tube wells yielding arsenic free water with blue mark.

4.2 Bihar

Groundwater arsenic contamination in Bihar first surfaced in the year 2002 from two villages, Barisbhan and Semaria Ojhapatti in the Bhojpur district located in the flood-prone belt of Sone-Ganga. A number of scientific studies, focusing mainly on physicochemical analyses of arsenic contaminated groundwater, assessment of extent, mobilization pathways, and possibility of tapping deeper aquifers, arsenic in food chains and its effect on health, were initiated by state and Central government organizations and by different academic institutions working in the State. In addition to R & D studies and exhaustive investigations, Govt. of Bihar, has started a number of schemes, as the precautionary measures to ensure supply of risk-free potable groundwater particularly, in community based localities, and as counteractive steps to combat probable arsenic related threats. As an outcome of scientific investigations and surveys, by 2008, out of 38 districts in the state, 15 districts covering 57 blocks, have been identified as groundwater arsenic contamination above 50 µg/L. No studies, so far, have been initiated, exclusively on arsenic mitigation, except deriving insight of tapping alternative arsenic-safe aquifers and understanding of physicochemical and hydrogeological behaviors of arsenic contaminated groundwater. Findings of some of the studies carried out by CGWB-MER, Patna are given below:

(i) From investigations, carried out to understand the pattern and extent of arsenic distribution in groundwater, physicochemical constituents of groundwater, lithologic characteristics and hydraulic properties of the aquifer materials, in the arsenic affected areas, it is observed that spatial variability in arsenic contamination have patchiness in distribution around the affected wells (Hand Pumps), with depth wise variation within top 50m bgl. Only newer alluvial deposits are found to have been arsenic affected, and the Pliestocene deposits are free from arsenic contamination. In the Sone-Ganga inte fluves region covering Bhojpur and Buxar districts, the deeper aquifer of depth ranges from 100-120m to 230-260m bgl. This is separated from the shallow contaminated zone by an aquitard, which has been found risk free from arsenic. If tapped through deep tube wells, deeper aquifer is estimated to have yield about 150-200 m3/hr of water. The geological map and lithological features of the arsenic affected areas are shown in **Figs. 4.6 and 4.7**, respectively. The lithological features **(Fig. 4.7)** showed that top soils of thickness about 2-5 m comprise clay, sandy clay and silty clay followed by fine to me dium sand with occasional sand layers, having disconnected lenses of coarse to very coarse sand with occasional gravel beds. The geological units **(Fig.4.6)** of these formations can be linked to Siwaliks, Rajmahal traps, and Vindhayans ranges.

(ii) A joint study, by CGWB-MER, Patna and BARC, Mumbai, has been carried out to investigate hydrodynamic behavior of arsenic affected aquifers, age of arsenic contaminated groundwater, its relationship with the age of aquifer water, and to study the mechanism of arsenic mobilization. From the analysis of major chemical and envi ronmental isotopes like Tritium, O_{16}/O_{18} and radio carbon, it was found that the shallow aquifers, influenced by arsenic contamination, are replenished by rainfall recharge, and, therefore, shallow aquifers with young groundwater is contaminated (< 40 years). Deeper aquifers, which posses' water of much older age (> 3000 years), are arsenic-free. This indicates that deeper aquifers are not influenced by direct vertical percolation of over lain strata. A positive correlation between arsenic and iron, and a concentrated distribution of arsenic in bicarbonate rich water, are also observed.

(iii) In addition to the above studies, several other studies have also been initiated by various organizations. GSI-Patna has initiated a study, covering 2400 sq. km in Bhojpur, Buxar and Patna districts and 1200 sq km area in Saran and Vaishali districts, to examine distribution and physiochemical behavior of arsenic in soil-water and mineral phases. Deptt. of Environment and Water Management, A N College, Patna, is studying effects of arsenic in food chain considering crop plants, like; wheat, maize, and rice irrigated by groundwater arsenic contaminated water.

In short, the outcomes of the studies carried out so far are as follows:

(a) Groundwater arsenic contamination is confined to Newer alluvial belt along the river Ganga,

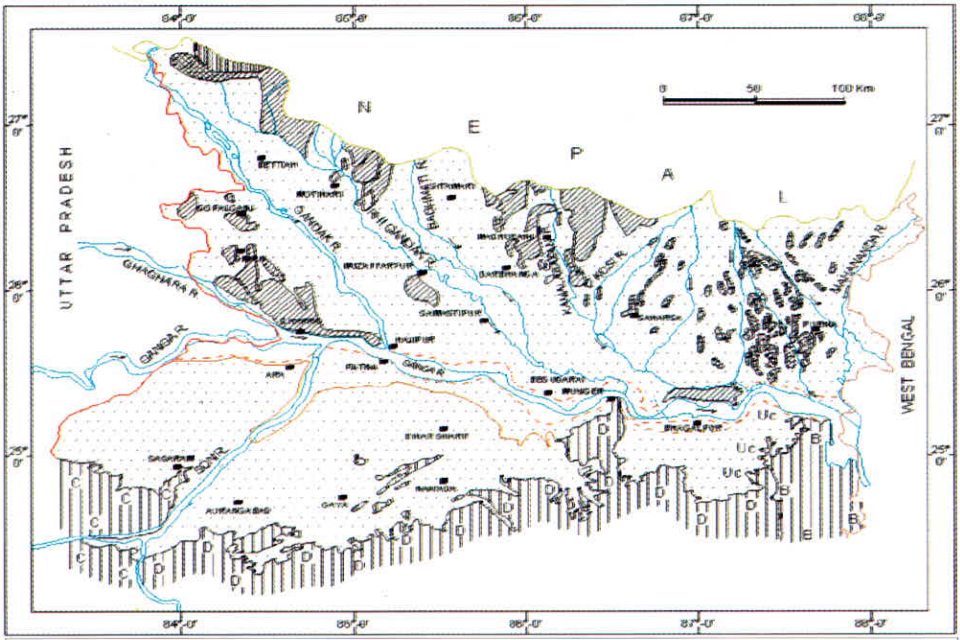
(b) Arsenic contamination is mostly in shallow aquifer (<50 m bgl) of young groundwater (< 40 years old), and is in localized pockets,

(c) Dug wells are free from arsenic contamination,

(d) Arsenic concentration, in the aquifer, reduces during monsoon season possibly due to recharge from monsoon rainfall,

(e) Deeper aquifers, which occurs under semi-confined to confined conditions, are arsenic free and hold groundwater of about ~3000 yrs,

(f) The deeper arsenic-safe aquifer has potential to yield about 150-200 m3 /hr, which can be taped through heavy duty deep tube wells.



LEGEND

	GEOLOGICAL UNIT	GEOMORPHIC UNIT	DOMINANT LITHOLOGY
(blank)	Diara/Kamla Formation Vaishali/Jaynagar/Kosi-Mahananda/Fatwa/Ganga Formation	Present(active) flood-plain & Older flood-plain	Unoxidised to feebly oxidised sediments, usually lacking soil cover, dominantly sand and silt with clay in flood basins.
(outline)	Purnea (Alluvial fan) Formation	Relict dissected alluvial fan	Partly oxidised sediments with thin soil cover, dominantly sandy.
(diagonal hatch)	Hazipur Formation/Khajauli Formation & Madhubani Formation.	Relict older alluvial surfaces	Partly to moderately oxidised sediments with significant soil cover, dominantly clayey at top with ferruginous concretions and minor kankar, underlain by sand.
Uc	Jamui/Nawada/Older alluvial Formation (South of the Ganga)/unclassified part	Older alluvial surface of the south Ganga plain	Feebly to highly oxidised sediments with soil cover of variable thickness, dominantly clayey at top, often with profuse kankar.
(cross hatch)	Ganauli Terrace Formation	High level terrace sediments	Highly oxidised sediments with ferrolitic soil cover, dominantly pebbles, cobbles and minor boulders in sand, silt or clay matrix.
(vertical lines)	Pre-Quaternaries A. Siwaliks B. Rajmahal traps C. Vindhyans D. Proterozoics and Archaeans	Pediplains, Hills etc	Sedimentaries, traps, metasedimentaries, grieisses, grsnite etc.

Formational contact — Ganga Meander Belt

Figure 4.6 : The Quaternary geological map of the Middle Ganga Plain, Bihar *(Source: Bihar Nepal earth Quake, GSI Special publication, 31).*

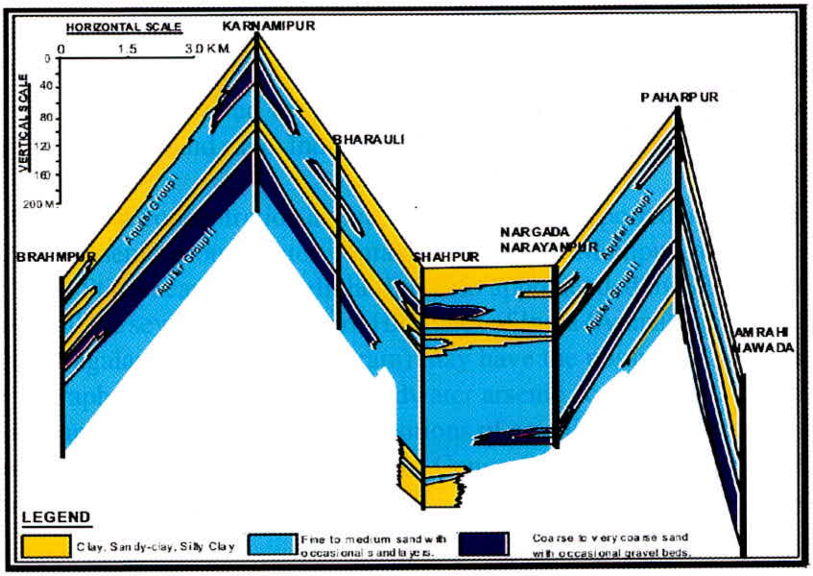


Figure 4.7 : Lithological formations of the arsenic affected areas.

4.2.1 Schemes Initiated on Remedial measures

As counteractive and precautionary measures, against the probable threats emerged out from the groundwater arsenic menace, the Public Health Engineering Department (PHED), Govt. of Bihar, has implemented the following schemes:

(i) Open dug wells, located in the arsenic affected areas, had been cleaned and put into operation for the villagers. The dug well water is free from arsenic contamination and acceptable to the people as those are the age old abstraction structure. Nearly, 186 new wells have been constructed and fitted with India Mark III hand pumps. In addition to that, construction of sanitary wells in 133 schools is in progress.

(ii) Twenty rain water harvesting structures have been constructed in different schools in the arsenic affected areas.

(iii) PHED has planned to install arsenic removal plants in 700 schools with two filters in each school to supply arsenic free groundwater after treatment,

(iv) PHED has taken up the task to construct hand pumps to tap arsenic-free deep aquifer, with provision of 5 hand pumps, in each of the arsenic affected areas.

(v) Deep tube wells, tapping arsenic free deeper aquifer for community based piped water Lsupply scheme, has been installed in the Semaria Ojhapatti village, Bhojpur district.

(vi) A number of surface water based pipe water supply schemes are under construction. These schemes will have their intake from the Ganga River with multi-village supply. The schemes are at:

a) Mauzanpur, Bhojpur district, covering 39 villages,

b) One in Bidupur in Vaishali district; and one in Simri block in Buxar district for which work is about to start,

c) One each in Mohiuddinnagar and Mohanpur blocks in Samastipur district; one each in Kahalgaon and Pirpainti blocks in Bhagalpur district; and one each in Sultanagalganj and Nathnagar blocks in Bhagalpur district; one each in Matihani, Begusarai and Barauni blocks in Begusarai district, are in final stage of implementation.

In order to identify and assess the potentiality of deeper aquifers and their sensitivity towards overlain contaminated shallow aquifer, CGWB-MER, Patna, has carried out the task of exploration through drilling in the affected districts. Twenty deep tube wells, in different locations in 6 districts, have been constructed with proper sealing to prevent any vertical percolation of contaminated water from the overlain aquifer. These tube wells have been handed over to PHED for use as groundwater production well. These wells are as given in Table-4.3.

Table-4.3: Arsenic-free exploratory well constructed by CGWB-MER, Patna in different places in Bihar as on 31st March 2009.

Sl. no.	**Location**	**District**	**Sl. no.**	**Location**	**District**
1	Barisban		12	Barh	
2	Shahpur		13	Gyaspur	Patna
3	Paharpur		14	Maner	
4	Nargada Narayanpur		15	Madudabad	
5	Bharauli	Bhojpur	16	Vidyapati Nagar	
6	Karnamipur		17	Kancha	Samastipur
7	Amrahi Nawada		18	Shahpur Patori	
8	Arjurnpur		19	Gangajal	
			20	Sitabdiara	Saran
9	Brahmpur	Buxar		Narapur	Begusarai
10	Churawanpur				

4.2.2 Social Responses and Impacts

Due to lack of awareness about the ill effects of consuming arsenic contaminated groundwater, on the one hand, and unknowingly and compellingly (because of no other option), on the other, the rural people in the arsenic affected areas are continually using arsenic contaminated groundwater. Nevertheless, due to some spiritual notions, rural people are in normal habit of using groundwater. Furthermore, people using arsenic contaminated groundwater were not aware that the diseases and health hazards, they were experiencing, originated from water being used. To avoid societal fears and rejections, arsenic affected people used to hide their diseases. These eventually have given rise to aggravation of the problem both in terms of health hazards and spreading the contamination in the groundwater domain. Continuous efforts, to make people aware about the ill effect of consuming arsenic poisonous groundwater, helped some of the village heads to realize importance of taking precautionary measures against emerging threats. They facilitated PHED, Govt. of Bihar to implement the following:

(i) Community based surveillance system for arsenic groundwater monitoring, in some of the affected villages, has been provided, equipping these villages with Field Test Kits for regular water quality testing.

(ii) In order to generate social awareness about the uses of contaminated water and hygiene practices of water, PHED, in collaboration with CGWB-MER, Patna, has organized a number of mass awareness programmes particularly, in Maner and Sampat chawk in Patna district, Shahpur, in Bhojpur district, Mohiuddinnagar in Samastipur district, etc.

In Bihar, the general awareness of populace about groundwater arsenic contamination and its effects is very less. And people are unaware that the skin skeletal and other health related diseases, experienced by them, are of water origin. Rural people have some phobia of not switching over from habitual use of groundwater to alternate surface sources of water. Therefore, there is a need of breaking such orthodox approach by mass awareness programmes. The corrective and precautionary measures, initiated by the Govt. of Bihar, are too less in comparison to the scale up of the problem. Unless a comprehensive and socially relevant programme, on a war footing, is conceived and implemented, the arsenic related problems in the State would multiply many folds.

4.3 Summary

Even after 25 years, since first surfacing of arsenic groundwater contamination in West Bengal, the problem resolving steps are still not sufficient and there is no sustainable solution. Neither, the understanding and knowledge base, accomplished from R & D activities, is adequate to resolve the problem completely. Nor the counteractive and precautionary measures initiated by the government, are sufficient to provide sustainable solution to meet the water demands of the rural populace. Numerous investigations have come out with a number of findings, alternatives and propositions, which varied from identification of shortfalls to success stories. Undoubtedly, each research study has its own merits and adds new information; however, there is a need to translate research outcomes to problem resolving issues through a framework of activities. Now, the present state of affairs of the problem, exposed in many States of India, demand a systematic translation of success stories of one place/region to another, and overcoming the shortfalls by conceiving R & D studies in areas wherever they are deemed fit. Some of the important achievements, which could help derive a comprehensive framework of activities leading to mitigation and remediation of the issues emerging out of arsenic menace, are advancement in understanding of geochemical and mobilization processes, devising satisfactory arsenic removal filters, identification of shortfalls in operation and maintenance of arsenic removal techniques, delineation of risk free deeper aquifers for groundwater tapping as an alternate source of groundwater, developing surface water based water supply schemes in many arsenic affected areas, success stories of community participation in running arsenic removal plants, etc.

The calamity of groundwater arsenic contamination in the state of Bihar is not as old as, and as serious as it is in West Bengal, however, scaling up and surfacing of groundwater arsenic with every new additional survey, in a number of districts, pose a serious threat towards further exploitation and usages of those contaminated aquifers. It also poses a threat to the people using the contaminated groundwater in different forms. Studies, carried out, and action, taken so far in the State of Bihar to understand the problem resolving issues, counteractive measures, etc., are meager in comparison to the State of West Bengal. While characteristics and features of the problem, geological formations and causes of the problem are largely similar and represent the hydro-geological setups of the same river basin, except the difference in socio-economic, socio-cultural and social composite structure. Thus, these meager findings from the state of Bihar, together with the experiences and knowledgebase acquired so far, from West Bengal, will help to evolve a framework of activities and sustainable mitigation strategies for the state of Bihar as well.