Arsenic Contamination of Ground Water in West Bengal- Milestones Reached and Hurdles Ahead

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Abstract

Arsenic contamination in ground water and related health hazards are serious concerns in many countries of the world. A number of large aquifers in the world have been identified with problems of high Arsenic concentration in ground water. Arsenic contamination in ground water of West Bengal in the range of 0.001-3.20 mg/l, occurs in isolated patches, spreading over 79 blocks in eight districts of the state. At present about 162.6 lakh people (35.48% of the total population of the State) occupying 17533 habitats live in the risk zone of potential threat in terms of Arsenic related diseases in the future. Central Ground Water Board and the Government of West Bengal have made successful endeavors to provide arsenic free drinking water to the entire population in the arsenic infested area. Arsenic free deeper aquifers have been explored by CGWB .Three aquifer systems have been identified within 100 mbgl, 120 – 160 mbgl and 200 –250 mbgl. The top aquifer within 100 m bgl is mostly arseniferous, whereas both the deeper aquifers which are separated by a thick clay (>10 m) from the overlying aquifers, capable of yielding 5 to 20 lps. water, are arsenic free. The paper emphasizes for the adoption of advance techniques for dilution of Arsenic concentration and also the role played by Central and State Government departments in providing Arsenic free water supply.

1. Introduction

Arsenic contamination in ground water and related health hazards are serious concerns throughout the world. A number of large aquifers, in various parts of the world, have been identified with problems of high arsenic concentration in ground water. The most note worthy occurrences of arsenic in ground water, are in parts of Argentina, Bangladesh, Chile, China, Hungary, India, Mexico, Romania, Taiwan, Vietnam, and many parts of U.S.A.

Excessive intake of arsenic in human body causes health hazards and is manifested in the form of arsenic poisoning. The main source of poisoning is through drinking water. The limit of Arsenic in drinking water standard as per BIS (Bureau Of Indian Standards) is 0.01mg/L. (IS 10500 -1993 Amended 2003). However affected West Bengal State is following the earlier standard as per BIS(1993) of maximum permissible value 0.05 mg/L (for detection) and 0.01mg/L (for removal). There is no immediate effect on the health of the consumer, if small doses are consumed. But due to slow accumulation of arsenic from continuous or repeated exposures, various symptoms may appear in the body of the consumer. Both, geogenic (natural) and anthropogenic sources of arsenic contribute to the enrichment of the element in groundwater

In the early years of the eighth decade of the last century, a few cases of arsenic poisoning were detected through epidemiological study by the School of Tropical Medical (S.T.M.) and All India Institute of Hygiene and Public Health (AIIH & PH). It was observed that the people suffering from arsenical dermatosis, were all consuming ground water and when the samples of ground water of the respected area were chemically analysed, they were found to contain arsenic beyond the permissible limit of 0.05 mg / l.

Arsenic contamination in ground water of West Bengal in the range of 0.001-3.20 mg/l, occurs in isolated patches, spreading over 79 blocks in the eight districts of the state. The districts of Murshidabad, Nadia, North 24 Parganas, South 24- Parganas are located to the east of river Bhagirathi/ Hoogly and Haora, Hoogly , Bardhaman to the west of the same river, and Malda to the north of river Ganga. The eastern part of Bhagirathi/ Hugli river is much more affected than the rest. The people staying in such areas are in the risk zone of getting affected by arsenic poisoning in the event of more number of ground water structures are tested to yield high arsenic water in due course of time. At present about 162.6 lakh populations (35.48% of the total population of the State) occupying 17533 habitations stay in the risk zone of potential threat in terms of arsenic related disease in the future.

In order to combat arsenic menace in the State of West Bengal, various measures and steps were recommended and put into practice by the experts and organizations, associated with arsenic investigation work. Since 1992, Central Ground Water Board has been working in various fields to study the extent & nature of arsenic pollution in ground water, its causes & mobilization, mitigation measures, and Research & Development studies on various field of arsenic pollution. Lot of work has been carried out, mainly by the Government Departments to device means and ways to provide arsenic free drinking water to the people living in such areas, where sporadic occurrences of high arsenic in groundwater has been established.

2. Extent and magnitude of High Arsenic in Ground Water:

Central Ground Water Board, Public Health Engineering Department, Government of West Bengal, Academic Institutions, Non Government Organizations, have carried out studies in Arsenic infested areas of West Bengal to find out the extent, nature & magnitude of Arsenic in ground water.
Various studies carried out indicates that

i) Since the concentration of arsenic even in traces (of the order of 0.05mg/L) is harmful for human consumption, the presence or absence of arsenic is considered with respect to 0.05mg/L and therefore its presence above the concentration of 0.05mg/L is found to vary between wide limits and this concentration is found only in isolated pockets. This variation is nothing unusual as all the radicals of water *when considered in traces* varies appreciably in different places.

ii) The contamination of ground water is attributed to geogenic origin. It is therefore difficult to conceive the spread of arsenic, both in space and time, over a period of 20-30years. The fact of the matter is, with intense and increased monitoring of water quality by various Government and non government organizations, the knowledge and awareness of the actual spread of arsenic contaminated area is coming to the notice of all in a comprehensive manner. In other words the area which was not considered to be arsenic affected earlier simply because the ground water samples were not analysed, have come under the arsenic belt with high degree of surveillance.

iii) Geologically the arsenic infested area of West Bengal forms a part of the Ganga-Bhagirathi delta, comprising succession of thick Quaternary sediments. The arseniferous tract is mainly restricted in the upper delta plain within shallow depth (mainly within 100m below ground level), which is mainly built up of sediments deposited by meandering streams and levees that are composed of sands of various grades, silt, clay and their admixtures. The ground water in the area occurs in thick zone of saturation within the unconsolidated alluvial sediments. The aquifers are made up of sands of various grades. Since the area lies in the Ganga-Bhagirathi delta, lateral variation in lithology is observed, in shallow aquifers (within 100m bgl). Ground water occurs, in general, under unconfined hydrogeologic condition.

iv) Even in arsenic affected mauzas, at the most only about 25% tube wells harnessing shallow aquifers, yield arsenic contaminated (above the permissible limit) water. Rest of the wells, tapping shallow aquifer within the blocks considered arsenic affected, still yield arsenic free water.

v) Although arsenic concentrations of the order of 3.2, 2.9 etc (mg/L), have been detected in a few samples, by and large concentration above the permissible limit in the state, ranges between 0.05 to 0.1 mg/l.

vi) It is not that the very shallow dug well aquifer zone is free from arsenic contamination. It is the mode of abstraction that makes the difference. It has been experimentally established that the very shallow tube well, tapping the dug well zone aquifer also, yields arsenic water.

vii) There are places where the number of arsenic yielding tube well is more but the degree of arsenic concentration is comparatively less and vise versa.

viii) Physical manifestation in the form of arsenic diseases among the affected population, does not always reflect the degree of concentration. Arsenic affected persons may be less in number in places, where the degree of concentration and the number of arsenic yielding tube wells are high and vise versa. The reason may be attributed to quality of food intake of the people residing in the area and/or the presence of ionic form in which arsenic occurs in ground water (As^{3+} being more toxic may predominate less toxic As^{5+} and vice versa).

3. Outcome of Studies Carried out by Central Ground Water Board

i) Periodic monitoring of water level & water quality in arsenic infested area reveals that arsenic concentration varies within a season. This may be due to the rainfall and change of water level behavior of the aquifer. The level of arsenic in ground water is maximum during premonsoon period and minimum during monsoon/postmonsoon period. This may be due to the natural recharge of arsenic free rain water in to the shallow arseniferous aquifer. Ground water in arsenic affected area is characterized by high iron, calcium, magnesium, bicarbonate with low chloride, sulphate and fluoride.

ii) CGWB has carried out detailed ground water exploration deploying its own 3 nos of drilling rigs in arsenic affected parts of Murshidabad, Nadia, North 24 Parganas, Hughli, Haora, South 24 Parganas, Malda and Bardhaman districts exploring down to the depth of 350 mbgl (maximum) to identify arsenic free deep aquifers as a mitigation measure against the arsenic menace of West Bengal. Till March 2009, 122 Exploratory wells have been constructed in 63 villages in 36 blocks of West Bengal.

iii) Hydrogeological tests on arseniferous aquifers (within 100 mbgl) have been conducted in different arsenic infested areas to observe the arsenic concentration in ground water consequence to pumping of arsenic water from the tube well. The results indicate that there is not much impact on arsenic concentration of ground water due to pumping when the drawdown created remains within 6m. Impact due to higher rate of pumping is yet to be ascertained. Effects of pesticides and inorganic fertilizers on the arsenic infested ground water regime have been studied in selected areas. In this regard arsenic content in commonly used pesticides & fertilizers concentration has been analyzed and the content of inorganic arsenic in these chemicals has not been detected to be high. Artificial Recharge studies have been conducted at Ashoknagar, Habra-II block, North 24 Parganas district, West Bengal to observe the nature of dilution through artificial recharge of arsenic free surface water & rain water into the shallow arsenic contaminated aquifer. It is observed that arsenic concentration of 0.12 mg/l in ground water has been diluted to < 0.001 mg/l in 3 non monsoon months by recharging arsenic free water into it.

iv) Experiments have been conducted in a shallow exploratory well at Birohi, Chakdah block, Nadia district to study the role of dissolved oxygen for mobilisation of arsenic in ground

water. Compressed Air has been injected in shallow arsenic rich aquifer and it is observed that Arsenic & Iron concentration has been reduced due to injection of compressed air.

v) Chemical analysis and X-Ray diffraction studies of bore hole samples (chemical analysed at CGWB, Laboratory & X-Ray studies at IIT, Kanpur) from Birohi exploratory well, Nadia district have been conducted to study the source of arsenic, and it is observed that Source of Arsenic is in clay & sand. Arsenic concentration is more in clay than in sand.

vi) Water samples have been collected through vadose zone sampler (within 3m bgl) from 22 locations of Nadia and North 24 Parganas districts to study the arsenic concentration in Vadose zone water, and it is observed that arsenic is below detection limit (<0.001mg/l) in the vadose zone water.

vii) A collaborative programme with BARC, Trombay was taken up for studying the dynamics of groundwater, origin & age of groundwater in the arsenic infested area in parts of Murshidabad, Nadia, North and South 24 Parganas district of West Bengal using environmental stable isotopes (^{2}H, ^{18}O, ^{34}S) and radio isotopes (3_H, ^{14}C). The study shows that ground water from the shallow are mostly of modern recharge (< 50 years), whereas deep ground water are old (5000 to 13000 years).

viii) Arsenic content in food items (cereals, vegetables & fruits) have been studied in arsenic affected areas using arsenic contaminated water for irrigation and also in non arsenic area where irrigation is done through arsenic free water. The results indicate that the total arsenic in food crops, irrigated through arsenic water, in arsenic infested area (North 24 Parganas district), is present in the range of 0.3 to 7.088 mg/kg and is non detectable in food crop samples collected from non arsenic area (Medinipur district). This indicates that there is a possibility of arsenic intake through food items not only to the people residing in the arsenic affected areas but also to the other areas where these food items are marketed. However the form of the arsenic in food items(organic or inorganic) has not been studied in details. It may be indicated here that the inorganic arsenic from ground water while entering the food crops, may be converted into non toxic organic arsenic.

ix) A collaborative project between CGWB and United Nations Industrial Development Organization was conducted to explore the efficacy of arsenic removal units in arsenic infested areas of West Bengal. Ground Water quality of 16 community-based units comprising six technologies and 40 domestic units comprising four technologies were examined. The test of water quality as envisaged was in terms of determination of arsenic, iron and heavy metals along with other parameters of general chemistry for the water samples before and after it has undergone treatment process. The major finding of the project indicates that although, by and large the arsenic removal equipments are effective in bringing down the concentration of input water to less than 0.01 mg/L, there are instances, when the output water does contain noticeable arsenic concentration. The concentration of arsenic in the treated water above the permissible limit can mainly be attributed to poor maintenance and monitoring than any inherent weakness in the technology itself.

4. Options for Mitigation of Arsenic Menace:

The Hydrogeological and hydrochemical studies carried out in the areas having arsenic rich aquifers indicates that in majority of cases, arsenic contamination owes it origin to geological sources. In such a scenario mitigation in terms of controlling or regulating the contamination may not be feasible. Therefore, it is necessary to resort either to alternative source or to adopt suitable technological options, available for supplying arsenic free water in the arsenic affected area. The options available can broadly be grouped as under:

(i) Using Surface water Sources
(ii) Exploring and harnessing alternative arsenic free aquifer, if available.

(iii) Removal of Arsenic from ground water using Arsenic treatment plants/filters
(iv) Rain Water harvesting.

(i) Supply of Surface Water

Surface water based schemes are also safe options and these schemes have also reduced the stress on ground regime. But availability of such sources is a problem and thus can not be implemented everywhere.

Supply of water for drinking purposes from ponds, rivers etc. through pipe net work after purification by conventional method of treatment viz. coagulation, flocculation, rapid sand filtration and disinfections, have been considered wherever easily accessible. Horizontal roughing filter with slow sand filter have also been adopted using pond water.

(ii) Tapping Alternative Aquifer for Arsenic Free Ground Water

Groundwater with arsenic contamination has been found mainly in the shallow aquifers. Deep aquifers when separated by a thick clay layer of appropriate composition & thickness, sealing off the upper arseniferous aquifer by cement, prevents percolation of arsenic contaminated ground water from the top aquifer. It was inferred from the isotopic studies carried out in West Bengal that in alluvial formations, there is no hydraulic connection between shallow and deep aquifers (they belong to different age group) they , when separated by an appropriate impervious layer. Central Ground Water Board, while carrying out extensive work on this aspect, has deciphered and delineated deep arsenic free aquifers at number of places in the states of West Bengal. Deep arsenic free aquifers, potential enough to yield adequate water to meet the water requirement in the domestic sector, are available in most of the arsenic affected blocks of the state, where CGWB has carried out ground water exploration. Only in the south western part of the district Malda, where deep aquifers (generally below 70-90mts) are constituted by hard consolidated rocks, the prospect of getting arsenic free water from such aquifers, is yet to be explored.

(iii) Treatment and Removal of Arsenic from ground water

While the first two options are being adopted wherever possible not withstanding the huge financial requirement for the piped water scheme, the treatment of tube well water for removal of arsenic has also been applied in a big way, specially in the state of West Bengal. The removal of arsenic depends upon its chemical state in which it occurs in the water, viz. Trivalent Arsenic (As III) and Pentavalent Arsenic (As V). As (III) is much more prevalent in ground water and it is difficult to remove because it exists predominately in the non ionic form. Where as Arsenic (V) exists in monovalent state and when water contains iron in higher concentration, it is easier to remove As V as it co precipitates with iron. Therefore, the oxidation of As(III) to As(V) improves the effectiveness of arsenic removal technology. The oxidizing agent used for this conversion are, Oxygen, powdered active carbon, .UV irradiation, free chlorine, hypochlorite, Potassium permanganate, Ozone and also sunlight.
Some of the adopted removal techniques are:

1. Coagulation-flocculation-Sedimentation and Filtration using Alum, Ferric alum lime etc.
2. Ion exchange Resins.
3. Adsorption using activated alumina, Granulated ferric hydroxide, iron coated sand, activated carbon, laterites etc.
4. Membrane Techniques using Reverse Osmosis or Electrodialysis
5. Biological method using Phyto-remediation and Bacterial removal and
6. Adsorption of arsenic by colloidal media suspended in water and application of membrane

based separation technique using ceramic micro – filtration membrane.

(iv) Rain Water Harvesting

Rain water harvesting may be adopted if appropriate conservation structure is available to facilitate collection. Water conserved in such a way needs to undergo filtration, and disinfections before it is put to use for public supply. This will provide an option and the use of treated arsenic contaminated water, may be dispensed with. Artificial recharge of rain water into the aquifer through recharging structures may also be considered wherever hydrogeological condition is found feasible to dilute the concentration of arsenic in ground water and thereby making its arsenic content within the permissible limit.

5. Mitigation Initiatives Taken up by CGWB:

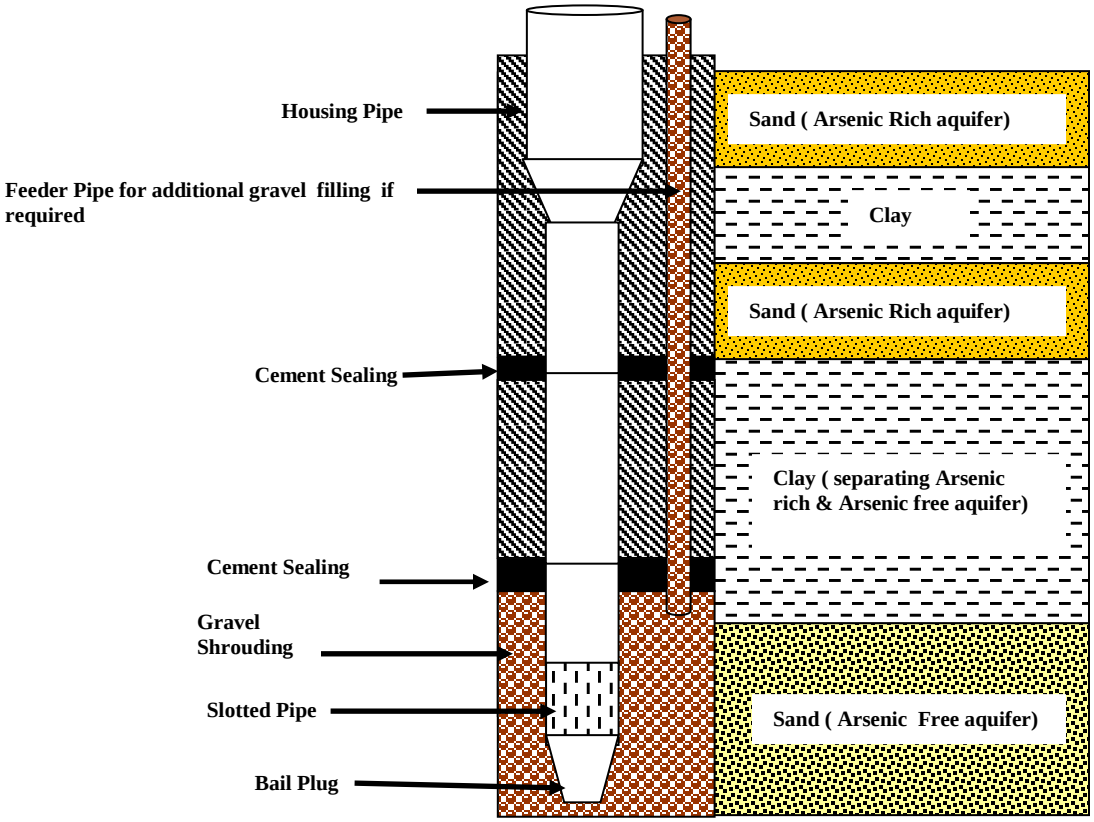
CGWB is carrying out ground water exploration in the arsenic affected districts of the State down to the depth of 350 m bgl (maximum) to mitigate the arsenic menace of West Bengal. Till March'09, 122 exploratory wells have been constructed in West Bengal, most of the production wells have either been handed over to the State Govt. department, Academic Institutions and the local Panchayats or the wells are in the process of being handed over.

The findings of Ground Water exploration in the State of West Bengal are as under:

1. Three aquifer systems have been identified within 100 mbgl, 120 – 160 mbgl and 200 –250 mbgl.
2. The top aquifer within 100 m bgl is mostly arseniferous, whereas both deeper aquifers which are separated by a thick clay (>10 m) from the overlying aquifers, are arsenic free. The thickness of clay layer (10-20 m), which acts as a barrier to arrest the transport of arsenic, is another significant factor in effectively separating shallow arseniferous aquifer from the deep arsenic free aquifer.
3. The deeper arsenic free aquifer was screened in the exploratory wells constructed by CGWB using special design adopting cement sealing techniques (fig 1). Proper design of the well which screens only the desired aquifer of appropriate length, and the cement sealing technique which has been adopted, plays a key role in safe withdrawal of water from the deeper aquifer preventing arsenic rich water from the upper contaminated aquifer to percolate down to the deeper aquifer.
4. Arsenic free deeper aquifers (below 100 mbgl) are potential with a capacity to yield 5 to 20 liter per second and can cater to the need of both rural and urban water supply. The demand for potable water vis-à-vis availability of arsenic free ground water from the deeper aquifer, has been calculated as a test case, for **some of the blocks**(7)of North 24 Parganas district for drinking and cooking purpose only. Considering the average yield of the arsenic free water from each constructed tube well, (projecting the demand as 10 liters per capita per day for the drinking & cooking purposes only), it has been observed that water from a total of 48 tube wells in North 24 Parganas district can meet the supply of safe arsenic free water among the population living in the risk zone of seven arsenic infested blocks. (Table-1).

Fig 1

DESIGN OF DEEP EXPLORATORY WELL
(Using cement sealing techniques)



Block	Average expected yield of Arsenic free in litre per sec	Supply of arsenic free water by running 8 hrs of pump /day	Population in risk zone	Water required for drinking purposes in 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

Table 1

Similarly, arsenic problem in rest of the district can be met by constructing optimum number of deep tube wells, using proper design and cement sealing technique.

6. Mitigation Measures undertaken in West Bengal by the State Government:

Public Health Engineering Department, Government of West Bengal has taken up different measures for supplying arsenic free water to the affected habitations through the construction of ring wells (500-600 population get benefited by each well), Hand pump fitted tube wells tapping deeper arsenic free aquifers (about 1000-1200 population get benefited by each well), Piped water supply scheme in big diameter tube well tapping deeper arsenic free aquifers (about 10000 population get benefited by each well), Surface water based piped water supply schemes (like Malda Water Supply Scheme supplying 75 MLD for 14.31 lakh population, South 24 Parganas Water Supply Scheme supplying 145.31 MLD for 29.51 lakh population, North 24 Parganas Water Supply Scheme supplying 34 MLD for 7.51 lakh population, Mahyampur Water Supply Scheme, Murshidabad district, supplying 3.95 MLD for 68,975 populations, Balupur Water Supply Scheme, Malda district, supplying 5.23 MLD for 72,883 populations etc). Apart from these Arsenic Removal Plant has been installed in the existing Piped Water Supply Scheme and about 15000 populations are being benefited by each scheme. About 2396 Arsenic Treatment Units have been fitted with existing hand pumps and about 600-800 population have benefitted from each hand pump.

7. Important Milestones Achieved in Arsenic Mitigation in West Bengal, Hurdles ahead and Suggestions:

While working in the field of arsenic related problems in the state, Government and Non Government organizations delivered their findings in terms of conceiving, devising, and demonstrating some of the encouraging results that were put to practice and were successfully implemented. The important milestones achieved in such studies are as follows:

1. The sincerity with which, the Government of West Bengal, prioritized the problem of arsenic contamination in ground water in the state, is projected in the constitution of 'Arsenic Task Force', comprising technical experts from different discipline, working in the state.
2. A 'Master Plan', has been prepared for the entire state under the guidance of the 'Arsenic Task Force for providing arsenic free water to the affected villages, both with surface and ground water based schemes with the provision of Arsenic Treatment Unit, wherever necessary.
3. Public Health Engineering Department, Government of West Bengal, has established district level chemical laboratories for the determination of arsenic content in ground water with trained man power and equipments.
4. CGWB, Government of India, has identified arsenic free aquifers in the depth zone of 120 to 160 m bgl & 200 to 250 m below ground level, where tube wells have been constructed with suitable design to get arsenic free water. It is observed that properly designed tube well harnessing the deeper arsenic free aquifer yields arsenic free water. Similar scenario occurs in the coastal areas where fresh deeper aquifer is separated from upper saline/brackish water by a thick clay layer and numbers of well constructed using cement sealing techniques yields for a very long period fresh and only fresh water. Sometimes it is reported that some of the deep tube wells are contaminated with arsenic, this may be attributed to the following reasons :
   (a) Tube wells constructed earlier were not properly designed with cement sealing techniques
   (b) Tube wells screen both the upper contaminated & deeper arsenic free aquifers to get higher discharge
   (c) Tube wells constructed with cement sealing techniques but not constructed properly (i.e. cement sealing was not done properly against the thick clay layers, quality of Cement used & its thickness were not up to the desired standard etc.)
5. Trace elements other than arsenic have been analyzed in high arsenic water and have been found to be within the permissible range of drinking water standard.
6. Age of ground water has been detected which indicates that arsenic rich younger water from shallow aquifer has no hydraulic connection with the arsenic free old water from the deeper aquifer.
7. Arsenic treatment units which are community based and can cater to the needs of 200 persons, have been installed in different arsenic infested areas to provide arsenic free water to the people.
8. Most of the Arsenic Treatment Units work effectively, provided they are monitored and maintained effectively.
9. Surface water based schemes, have also been put into operation successfully, where river water is supplied for public distribution after required chemical treatment. Generally villagers are habitually adopted in using ground water for drinking uses and they are not usually habituated in drinking treated surface water (specially chlorinated water & its smell). This needs some time for their acceptance of surface water instead of ground water.

   However before implementation of surface water based schemes the following factors need to be carefully examined :

a) Availability of surface water sources which can be harnessed are not omnipresent and therefore can not be utilized everywhere.
b) Periodical maintenance of water treatment units installed at various sites, requires close monitoring.
c) The transportation of surface water from intake point/ treatment unit to the delivery point

10. Arsenic content in some of the food items have been determined. However, whether the arsenic is in organic or inorganic form and whether there is any adverse impact of these arsenic containing food items on human health or not, is yet to be established.
11. Physical manifestations of arsenic poisoning among the people in the arsenic infested areas, are not always diagnosed and registered in a cogent manner. Therefore the entire population of the administrative unit which is recognized as arsenic infested, is considered to be the population under the potential threat of arsenic poisoning who stay there at a risk. Epidemiological study need to be conducted in the Arsenic affected areas to study different aspects of health impact including dose response, water use pattern ecological and environmental aspects etc. The role of the Ministry of Health assumes special significance, to ascertain the number of persons actually suffering from arsenic diseases as they have the trained manpower (mainly doctors, well acquainted with the symptoms of the disease) to certify and verify the seriousness of the menace which is often blown out of proportion by the non qualified agencies.
12 Study needs to be carried out to assess how arsenic is entering into the food chain and also to assess the extent and magnitude of the problem. It needs to be established that the arsenic content of ground water when applied for irrigation, gets totally converted into organic arsenic after entering the crops, grown with the contaminated water. That would negate the apprehension that the food item which are transported to distant places, do not carry the poison along as organic arsenic is considered to be harmless for human consumption.
13. Health linked awareness and motivation campaign involving Panchayat Raj Institutions, NGOs etc. need to be initiated. People need to be made aware that early symptoms of arsenocosis can easily be identified and measures to get rid of the disease are quite simple.
14. The collection of water samples and its quality analyses (especially arsenic) should be done in a systematic manner and using sophisticated instruments with a common method of analysis approved by all the agencies working in arsenic field. A water quality database will be developed to store all Arsenic and other water quality data collected.