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Arsenic Management Strategies for Ground Water Irrigation in Murshidabad District

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Abstract : Soluble inorganic arsenic found in ground water is poisonous. It pollutes water, land and crops, ultimately affecting human health. The most dangerous aspect for human is, when arsenic releases into ground water from sediments through natural, chemical and biochemical processes like oxidation of arsenic rich sulphide compounds and the reduction of arsenic containing iron oxides. Irrigation with arsenical ground water leads to elevated level of arsenic in soils, which may lead to increased concentration of arsenic in plants. Irrigated wetland rice is most vulnerable to arsenic in the irrigation water-soil system in India as it grows under anaerobic soil condition, which makes arsenic mobile and bio-available.

Over the last three decades, huge numbers of tube wells have been installed throughout the state of West Bengal, India. Due to heavy ground water withdrawal, underground aquifer becomes aerated and oxygen causes degradation of arsenic rich sources mainly, in eastern part of Bhagirathi River in the state. To date, only limited attention has been paid to the risks of using arsenical ground water for irrigation. Ground water under eighty one numbers of blocks in eight numbers of districts in West Bengal is declared as arsenic infested by the State Water Investigation Directorate (SWID),Government of West Bengal. Murshidabad is one of these eight districts in West Bengal, where ground water in shallow aquifers of eighteen numbers of blocks covered with younger alluvium got affected byarsenic. It has been brought into notice during post-monsoon'09 and pre-monsoon'10 that ground water in deeper aquifers is affected with arsenic having maximum concentration of 0.005 to 1.50 mg/l. In Murshidabad district, 1, 91,768 ha (91% of total actual area irrigated) is irrigated by using ground water only (Third Minor Irrigation Census in West Bengal 2000-2001). *Summer paddy* (Boro) cultivations, which depend heavily on irrigation with ground water, have been practiced in 91% Boro cultivation area in the district, which led declining of water table rapidly because of over-extraction. Long-term use of arsenical irrigation water could result in food chain contamination in Murshidabad district.

Several water-soil-crop management techniques like reduction of quantum of irrigation water without any yield losses, summer paddy cultivation on raised beds, shifting to dry-land crops like wheat, maize etc. and rotational crop cultivation may be experimented to reduce the arsenic load on the soils, crops as well as the food chain in younger alluvial plains of Murshidabad district.

Key words: arsenic, contamination, ground water, irrigation, management.

INTRODUCTION

Arsenic in ground water is a major problem, not only in India but also in twenty countries throughout the world. This problem is much more severe in Bangladesh, followed by West Bengal, India. Genesis of arsenic in ground water in India is broadly geogenic (Kunar et al., 2009). Due to intake of arsenic either through drinking water and/ or through irrigation water via food for a consecutive year, people may suffer from abdominal pains, vomiting and coma. The most pronounced effect of arsenic is hyperpigmentation on skin and hyperkeratosis on palms of hands and feet, which may turn into malignant dermatosis (cancer) (Sarkar et al. 1999). The safe limit of arsenic for drinking water as per World Health Organisation (WHO) standard is 0.01mg/l and the permissible limit of Arsenic for irrigation water as per Food and Agricuture Organisation (FAO) standard is 0.10 mg/l.

Study areaMurshidabad district with total geographical area (TGA) of 5,324 square kilometer (sq km) is bounded by the latitude 24°50'20" N to 23°43'30" N and longitudes 88°46'00" E to 87°49'17" E. It has five sub-divisions consisting of 26 numbers of blocks with 2210 numbers of villages. The total populations (as on 2001 Census) is 58,66,569 and the density of population is 1102 per sq km.

PHYSIOGRAPHY AND DRAINAGE

The river Bhagirathi has distinctly divided Murshidabad district into two separate zones viz. "RARH" and "BAGRI". The western side of Bhagirathi river in the district is known as "RARH", which is substantially a continuation of the sub-Vindhyan region of laterite clay and calcareous nodules of older alluvium. The land is slightly undulating having a gentle slope from west to east with the elevation from 15 to 35 metre (m) above mean sea level (msl). On the other hand, the eastern part of Bhagirathi known as "BAGRI" is mainly composed of riverine tract of Bhagirathi river having younger alluvial soil with comparatively light texture. The area is generally flat with surface elevations ranging from 8 to 15 m above msl and has gently slopes from north to south.

The main drainage of the district is controlled by tributaries and distributaries of the Ganga-Padma river system. The Bhagirathi emanates from the Ganga at a place near Jangipur and finally leaves the district in the south. The Padma acts as the north-eastern boundary of the district. Jalangi and Bhirab are two channels within the interfluve region of Padma and Bhagirathi. Dwarka, Mayurakshi, Dehula and Babla are the rivers of the western part of the district. These rivers originate from the north-western uplands of Rajmahal and fall into the Bhagirathi. The Farakka feeder canal diverts some water from the Ganga and drains it into the Bhagirathi during lean period. The drainage has reached the base level of erosion, with the result that the rivers have lost much of their activities.

CLIMATE

Murshidabad district belongs to the sub-humid sub-tropical zone of Indian peninsula. It is a prominent playground of the south-east monsoon, which sets in the second half of June and withdraws by the first week of October, generally. About 75% of rain occurs during monsoon. The average annual rainfall according to Indian Meteorological Department (IMD) is 1389 millimeter (mm) and the normal annual rainfall is about 1477 mm. The Isohytes in the district reveal that the central part of the district receives maximum rainfall, whereas the western part experiences comparatively less rainfall. According to IMD data, the maximum and minimum average daily temperature in the district is 31 degree centigrade (°C) and 20.8°C, respectively. The maximum temperature during summer is often as high as 43°C, when the minimum temperature during winter becomes as low as 6.5°C. The maximum and minimum humidity in the district according to IMD data is 73 % and 62%, respectively. The total annual potential evapotranspiration rate in the district is 1333 mm.

AGRICULTURE

Murshidabad is one of the agricultural potential districts in the upper gangetic delta of West Bengal, where diversified crops are grown throughout the year. The main crops in "RARH" zone are paddy, potato, oilseeds and vegetables. The diversified crops in "BAGRI" zone viz. paddy, jute, wheat, oil-seeds, pulses, sugarcane, vegetables, different spices and fruit crops like mango, litchi, jack fruit, banana, papaya, guava etc. are grown in this zone.

IRRIGATION

The economy of the Murshidabad district is basically rests on agriculture as around 80% of the population is directly depends upon it. The cultivable land in the district is fixed or rather in declining trend due to various reasons of soil erosion along the River Padma. To meet up the demand of agricultural production with fixed cultivable land, extension of irrigation facility is essential for enhancement of Cropping Intensity (CI) through mulltiple cropping with assured irrigation facility.

Out of 3,65,000 hectare (ha) Net Cultivable Area (NCA) (i.e. 68.6% of TGA), 2,26,300 ha cultivable lands (62% of NCA) receive assured irrigation of which 86% is covered by Minor Irrigation and 14% is covered by Major Irrigation (Canal). Nine blocks viz. Suti-I, Raghunathganj-I, Sagardighi, Nabagram, Khargram, Kandi, Burwan, Bharatpur-I and Bharatpur-II in the "RARH" zone of the district partially fall under Mayurakshi Canal Command and receive Canal Irrigation during Kharif season only. According to Minor Irrigation Census 2000-2001, out of 1,95,535 ha Culturable Command Area (CCA) in Minor Irrigation sector 87% CCA is covered by Ground Water Irrigation (GWI) and 13% CCA is covered by Surface Water Irrigation (SWI). In Murshidabad district 91% area under boro cultivation covers with GWI and 9% covers with SWI.

HYDROGEOLOGY

The alluvium deposited by the river system is the source of ground water. The sand and gravel formations of different textures constitute the main aquifers down between depth from 40 to 350 m below ground level (bgl) in the eastern part of the Bhagirathi river and upto 150 m bgl towards westerns flank of the district.

Ground water in the eastern part of the district i.e. "BAGRI" zone generally occurs under water table condition except in some blocks like Beldanga-II, Jalangi, Murshidabad-Jiaganj, Berhampore, where confining clay beds of 6 to 10 m thick had separated the upper unconfined aquifer from deeper confined aquifer. The pre-monsoon depth to water level in this zone ranges from 5 to 10 m bgl except in parts of Jalangi, Domkol(east), Raninagar-II(east) and Beldanga-I(south-east) blocks, where the same is in the range of 2 to 5 m bgl. A small area in north-western part of Raghunathganj-II block shows water level below 10 m. The post-monsoon depth to water level in this zone ranges from 2 to 5 m bgl except in parts of Domkol (north), Raninagar-I (south) and Berhampore (east) blocks, where the same is in the range of 5 to 10 m bgl. In parts of Berhampore (west), Kandi (east), Bharatpur-I (east) Beldanga-I and Beldanga II (north-west) block show water level within 2 m bgl.

Ground water in the western part of the district i.e "RARH" zone generally occurs under water table and confining condition in older alluvial deposits. Confining conditions formed by a thick clay bed attaining a thickness upto 20 m from the surface are observed in Kandi, Burwan, Nabagram, Sagardighi and Raghunathganj-I blocks resulting in artesian conditions. Seasonal artesian conditions are found during August to January moth in tube wells near Mirzapur, Jarur (Raghunathganj-I block), Bilol (Nabagram block) and Dhalsa (Sagardighi block) in topographic depressions. Rests of the area in this zone are unconfined in nature. The pre-monsoon depth to water level in this zone ranges from 5 to 10 m bgl except in part of Kandi (north) block, where the same is in the range of 2 to 5 m bgl. A small area in central part of Sagardighi block shows water level 10 m bgl. The post-monsoon depth to water level in this zone ranges from 2 to 5 m bgl except in parts of Farakka (west), Samserganj (west), Suti-I, Suti-II and Burwan (south-west) blocks, where the same is in the range of 5 to 10 m bgl. A small patch in central part of Sagardighi block shows water level 10 m bgl.

Ground water level shows declining trend during both pre and post-monsoon in southern part of "RARH" zone i.e. Barwan, Bharatpur-I, Bharatpur-II, Kandi, Khargram, Nabagram blocks and in western part of "BAGRI" zone i.e Bhagwangola-

I, Bhagwangola-II, Berhampore and Beldanga-I blocks. The declining trend of pre and post-monsoon water level indicates that the recharge through rain fall infiltration is not enough to regain the original levels i.e. diminishing of dynamic ground water resources.

HYDRO-GEOCHEMISTRY

The ground water in Murshidabad district is of Calcium-Magnesium-Bicarbonate (Ca-Mg-HCO_3) type. The chloride content in ground water is low as 7.00 to 430.00 milligram/litre (mg/l). The ground water is mainly alkaline in nature and its pH value ranges between7.35 to 8.85. The total hardness as Calcium Carbonate ($CaCO_3$) of ground water ranges from 32 to 578mg/l. Generally, Iron (Fe) content ranges from 0.10 to 0.55 mg/l, but in few places it is found of the order of 11mg/l (Raninagar-II block). The low content of sulphate in ground water possibly explains the absence of Sulfate + Bicarbonate (SO_4+HCO_3) and Sulfate + Chloride (SO_4+Cl) facies.

In general the ground water both in shallow and deeper aquifer are good except in eighteen numbers of blocks, where sporadic occurrence of arsenic beyond 0.01 mg/l is found in shallow aquifer system, which is not used for drinking purpose but for irrigation purpose.

Also, it has been noticed that Iron content is high in arsenic contaminated ground water. The overall hydro-geochemical assessments indicate that the arsenic affected ground water in Murshidabad district is associated with high bicarbonate (HCO_3), iron (Fe) and low sulphate (SO_4) and chloride (Cl).

ARSENIC OCCURRENCE IN GROUND WATER

In West Bengal (W.B.), arsenic infested areas in upper delta of Bengal basin are covered by unconsolidated allocthonous Quaternary sediments. This delta is characterised by a series of abandoned river channels formed under varying hydrodynamic conditions in a fluvial regime. The sediments of this delta consist of several sequences of clay, sand, silt and conglomerate. Interaction of arsenic bearing sediments with ground water under different sub-surface environmental conditions plays an important role in controlling retention and mobilization of arsenic in this delta region (Shivanna et al., 2000).

Arsenic occurrence in ground water within shallow aquifer (up to 80 m below ground level) and deeper aquifer (100 to 160 m below ground level) is observed in eighteen blocks sporadically in Murshidabad district as declared by the State Water Investigation Directorate (SWID), Government of West Bengal already (Table 1).

[N- No Rising/Falling trend of decadal depth to ground water level; R- Rising trend of decadal depth to ground water level; F- Falling trend of decadal depth to ground water level @d" 20cm/ year; SF- Significantly Falling trend of decadal depth to ground water level @> 20cm/ year. *Arsenic and Iron concentrations in ground water during the period of post-monsoon 2009 and pre-monsoon 2010 have been considered.]

Generally, the maximum concentration of arsenic is found in clay horizons and fine grained sandy layers within depth range of 20-80 m bgl. The concentration of arsenic in acid leachate (pH-2.0) and alkali leachate (pH-12) is highest in clay followed by sandy clay and lowest in sand. Recently it is observed that arsenic has been migrated into first deeper aquifer (semi-confined) within depth range of 100-160 m bgl containing a mixture of old and young water. The elevated arsenic concentration in ground water of Murshidabad district is possibly released from the sediment under anoxic condition in the aquifer. But the second deeper aquifer (confined) within depth range of 200-220 m bgl is still free from arsenic. Besides these eighteen numbers of arsenic infested blocks, arsenic is also detected in ground water of shallow as well as deeper aquifer in a few localized pockets of the following five

Table 1. Maximum *Arsenic* and *Iron* concentration in ground water vis-à-vis ground water development in eighteen numbers of arsenic infested blocks (as declared) in Murshidabad district (West Bengal)

Sl. No.	Block	Zone of Soil	*Max. **Iron** concentration in ground water of **shallow aquifer** (mg/l)	*Max. **Arsenic** concentration in ground water of **shallow aquifer** (mg/l)	*Max. **Arsenic** concentration in ground water of **deeper aquifer** (mg/l)	Stage of ground water development (March'04) (%)	Decadal depth to ground water level trend		Area under Summer Paddy (Boro) ('08-'09) (ha)
							Pre-monsoon	Post-monsoon	
1	Farakka	**RARH**	7.40	**0.07**	**0.07**	18.50	**F**	**F**	-
2	Samserganj	-do-	9.50	**0.08**	**0.08**	47.34	R	**F**	382
3	Suti-I	-do-	3.50	**0.07**	**0.07**	75.89	**N**	**N**	1383
4	Suti-II	-do-	10.90	**0.07**	0.40	113.53	**N**	**F**	482
5	Raghunathganj-II	**BAGRI**	4.60	**0.08**	**0.08**	48.41	**F**	**F**	-
6	Lalgola	-do-	5.20	**0.05**	**0.05**	145.36	**N**	**F**	2805
7	Bhagwangola-I	-do-	6.00	**0.04**	**0.05**	100.57	**F**	**F**	1363
8	Bhagwangola-II	-do-	4.00	0.20	**0.10**	113.86	**F**	SF	2442
9	Murshidabad-Jiaganj	-do-	4.80	1.00	1.00	109.96	**F**	**F**	4359
10	Raninagar-I	-do-	6.50	**0.07**	1.00	116.30	**F**	**F**	2791
11	Raninagar-II	-do-	-	1.12	1.00	87.50	**F**	**F**	2465
12	Jalangi	-do-	8.70	0.30	0.20	148.10	**F**	**F**	1637
13	Domkal	-do-	5.70	0.50	0.50	141.87	**F**	**F**	3181
14	Hariharpara	-do-	12.40	**0.07**	**0.10**	110.41	**F**	SF	1611
15	Berhampore	-do-	5.40	0.40	0.20	114.63	**F**	SF	12170
16	Beldanga-I	-do-	15.4	**0.08**	1.50	84.90	**F**	**F**	3110
17	Bedanga-II	-do-	6.70	**0.07**	**0.10**	81.01	**F**	**F**	6405
18	Nowda	-do-	15.80	0.30	0.20	111.05	**F**	SF	4766

numbers of blocks in central and southern part of "RARH" zone (Table 2).

It can be predicted that arsenic in ground water may be migrated upto Sagardighi block in centre and upto Bharatpur-II block in extreme south of "RARH" zone in future.

The observations by SWID regarding occurrence of arsenic in ground water of shallow aquifer in

Table 2. Maximum *Arsenic* and *Iron* concentration in ground water vis-à-vis ground water development in five numbers of blocks in Murshidabad district (West Bengal)

Sl. No.	Block	Zone of Soil	*Max. **Iron** concentration in ground water of **shallow aquifer** (mg/l)	*Max. **Arsenic** concentration in ground water of **shallow aquifer** (mg/l)	*Max. **Arsenic** concentration in ground water of **deeper aquifer** (mg/l)	Stage of ground water development (March'04) (%)	Decadal depth to ground water level trend		Area under Summer paddy (Boro) ('08-'09) (ha)
							Pre-monsoon	Post-monsoon	
1	Nabagram	**RARH**	**4.60**	**0.025**	NIL	78.12	**F**	SF	13406
2	Kandi	-do-	**3.70**	**0.05**	**0.05**	44.65	SF	**F**	12221
3	Khargram	-do-	**2.80**	NIL	**0.005**	27.79	SF	**F**	15173
4	Barwan	-do-	**11.60**	NIL	**0.01**	56.60	SF	SF	12477
5	Bharatpur-I	-do-	**4.20**	**0.05**	**0.10**	45.84	SF	SF	8698

Murshidabad district during post-monsoon 2009 (November 2009) and pre-monsoon 2010 (April 2010) are shown in Figure1.

In Murshidabad district, first deeper aquifer (100-160 m bgl) is vulnerable to arsenic occurrence as shallow and first deeper aquifers are interconnected, which was studied by Shivanna et al. in 1999 that depleted stable isotopic content of high Tritium and ^{14}C contents in ground water of deeper aquifer indicating the possibility of interconnection between shallow and deeper aquifer. Even though arsenic concentration in shallow aquifer is high, the spatial distribution of arsenic concentrations mainly depends on nature of sediment, ground water flow condition and geochemical conditions. The hydro-chemical analysis of ground water in arsenic infested areas of this district shows that much of the arsenic (beyond FAO's permissible limit of irrigation water i.e. 0.10 mg/l) is in younger alluvium deposited in eastern part of Bhagirathi River ("BAGRI"). In the western and south-western part of Bhagirathi River ("RARH"), arsenic concentrations are within FAO's permissible limit of irrigation water.

Most likely, the arsenic, which is in the parent rock might have separated due to weathering and drained towards Bengal basin and at the time of sedimentation, arsenic might have co-precipitated/ adsorbed on fine sand and clay along with iron oxide. The elevated arsenic concentration in shallow ground waters is possibly due to its release, when arsenic rich iron oxy-hydroxides is reduced in anoxic environment in the aquifer. In addition, it might be caused by oxidation of pyrite and arsenopyrite that are present in aquifer sediments, by atmospheric oxygen, which enters the ground water due to lowering of the water table caused by excessive ground water abstraction.

MECHANISM OF ARSENIC DISSOLUTION IN GROUND WATER

Arsenic one of the member of nitrogen family is an odourless and tasteless semi-metal that occurs

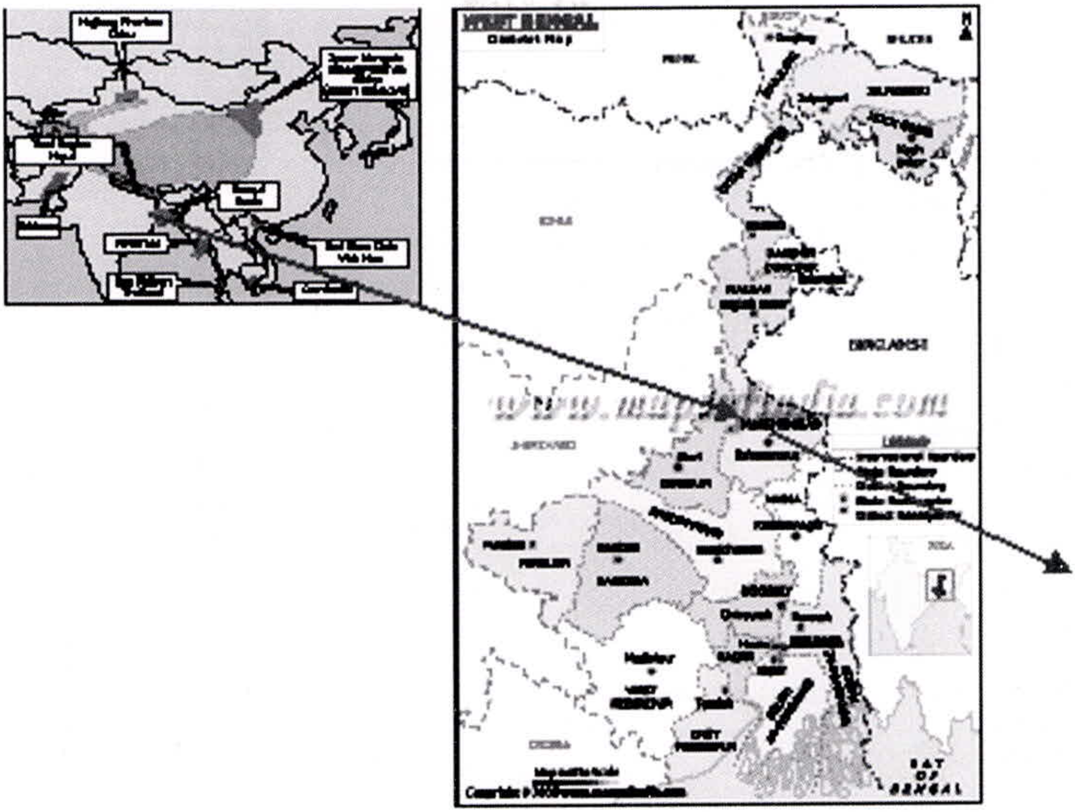

Fig. 1. Arsenic occurrence in shallow aquifers of Murshidabad district (W.B.)

naturally in rock and soil. It can combine with other elements to form organic and inorganic arsenicals, the latter being generally more toxic and more prevalent in water. The natural presence of organic arsenic is low compared to inorganic arsenic. Inorganic arsenic is far more toxic to humans than organic arsenic. A well-balanced evaluation of arsenic in foods should thus be based on inorganic arsenic and not on total arsenic to avoid an overestimation of the human health risks. However, the methodology to assess arsenic speciation in plant and animal tissue is complicated. To date, the methodology is not yet standardised and certified reference materials for inorganic arsenic are not available.

There are two geochemical mechanisms on occurrence of arsenic in ground water of Bengal Basin:

- Oxidation of Arsenopyrite: It is caused by oxidation of pyrite and arsenopyrite that are present in aquifer sediments, by atmospheric oxygen, which enters the ground water due to lowering of the water table caused by excessive ground water abstraction.
- Reductive dissolution of ferric-oxy hydroxide (FeOOH): It is caused in alluvial aquifers by reductive dissolution of ferric-oxy hydroxide that contains sorbed arsenic.

Plants are effectively exposed to arsenite (As^{3+}) not to arsenate (As^{5+}) because of reducing soil condition. Thus As^{3+} is more toxic than As^{5+}. Speciation of inorganic arsenic in the soil is largely controlled by reduction and oxidation processes (redox). Under aerobic (oxidizing) conditions As^{5+} predominates, whereas As^{3+} predominates under anaerobic (reducing) conditions. As^{5+} and As^{3+} adsorb mainly to FeOOH present in the soil and As^{5+} bound strongest. The behaviour of FeOOH is highly dependent on Redox conditions. Under anaerobic conditions FeOOH readily dissolves and arsenic is released into the soil solution, where arsenic presents mainly as As^{3+}. Under aerobic conditions FeOOH is relatively insoluble and serves as a sink for arsenic. Iron and arsenic behaviour is thus dynamic and closely related in lowland paddy fields. FeOOH is mainly present in clay size soil fraction (<2ìm) and clayey soils therefore, generally have a higher arsenic content compared to more sandy soils.

When a paddy field is flooded, the rhizosphere (the micro-environment around the roots) can still be aerobic as rice plants can transport oxygen from leaves to the roots. The oxidized conditions can result in the precipitation of FeOOH around the roots, also known as Iron-plaque. Iron-plaque has been reported frequently on roots of wetland plants including rice. It may influence arsenic speciation, bioavailability and uptake. As^{5+} adsorption decreases with increasing pH, in particular pH>8.5, whereas the opposite occurs for As^{3+}. A number of vegetables, namely cauliflower, tomato, bitter gourd are also noted to accumulate arsenic in their economic produce (Sanyal, 2010).

IRRIGATION MANAGEMENT WITH ARSENICAL WATER

It is clear that Minor Irrigation plays an important role towards development of irrigation by exploitation of ground water and surface water through installation of different types of Minor Irrigation structures like Shallow Tube Wells (STW), Deep Tube Wells (DTW), Surface Water Lift (River Lift and Tank Lift) Irrigation schemes in public and private sector. But more and more withdrawal of ground water led to declining ground water table regionally and also causes occurrence of arsenic in different areas, mainly confined to old river meander belt i.e. eastern part of the Bhagirathi River in the district. Therefore, management of irrigation water in the district is become essential with respect to the present arsenic vulnerability and non-recoverable dynamic ground water resources scenario in regional aquifer regime.

Alternate source of ground water for irrigation

Historically though this district possesses sufficient numbers of water bodies and tanks, many of it has lost its potential due to siltation. The district gets about 1000 mm rainfall during June to October and major quantity of Surface Run Off (SRO) remains unutilized. To accumulate this SRO and harvesting rain water in order to provide alternate source for irrigation, which is free from arsenic the idea of "Repairs, Renovation and Restoration (RRR) of water bodies directly linked to agriculture" would be very useful in irrigated agriculture.

Modified design for Irrigation tube wells

Installation of Irrigation STWs within depth range 20 to 80 m below ground level must be discarded in the arsenic affected blocks in the Murshidabad district immediately. Irrigation DTWs should be designed adopting cement sealing techniques along impervious clay layers separating deeper aquifer from arsenic infested shallow aquifer in order to avoid vertical leakage from arsenic infested upper aquifer to the fresh water aquifer down below (Figure 2). Bentonite and neat cement are widely used as sealing material. Neat cement is often disadvantageous as it does not stick with PVC made casing surface and tends to shrink away from the casing after curing and enhances possibility of cracks over time. But Bentonite

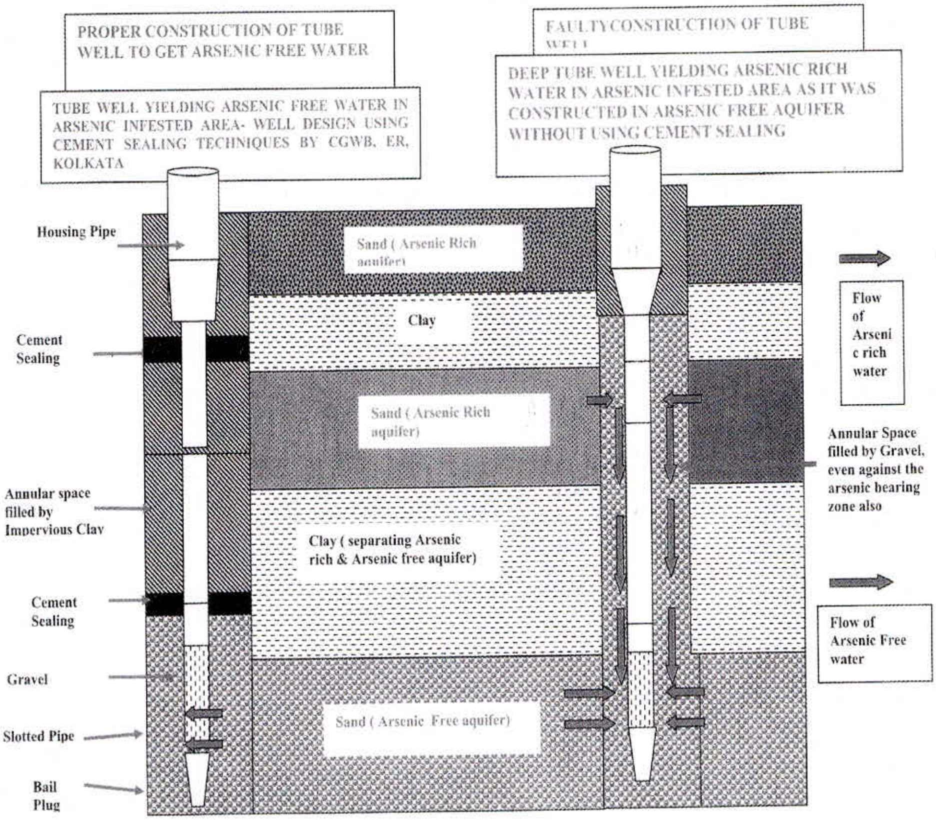

Fig. 2. Designed tube well in arsenic infested area (Talukdar et al., 2009)

swells and remains on PVC and fretains its original low permeability when exposed to water. For placement of seal "Clay Basket" packer may be used suitably. The actual sealing depth must be determined through borehole logging, especially gamma logging technique (Sarkar and Ray, 1999).

Alternate cropping pattern and management of irrigation practice

Over the last three decades, millions of STWs have been installed throughout the state of West Bengal. This has significantly contributed to access groundwater resources, which has been a major contributor to the green revolution in West Bengal. At present, agricultural production is under pressure from multiple factors including arsenic in the state.

The mid-1970s saw a large scale exploitation of ground water resources for irrigation purposes as a consequence of exodus of millions people from Bangladesh to the border district Murshidabad. Adverse health effects due to the consumption of ground water with excess arsenic content manifested in the population within time span of 8-10 years. In spite of the reported occurrence of high arsenic in ground water, the people of Murshidabad district are solely dependent on the ground water resources.

However, to date, only limited attention has been paid to the risks of using arsenical ground water for irrigation. Due to heavy groundwater withdrawal, underground aquifer becomes aerated and Oxygen causes degradation of arsenic rich sources. Irrigation water with high level arsenic may result in food chain contamination. Long-term use of arsenical irrigation water could result in arsenic accumulation in the soil. The continuous addition of arsenic to the topsoil may pose additional risks to soil quality and if absorbed by the crops, this may lead add substantially to dietary arsenic intake, thus poisoning additional human health risks. Over time, arsenic accumulation in the soil could reach soil concentrations toxic to crops, thus reducing yields. Boro rice contained significantly more arsenic than Aman Rice as Aman rice is mainly rainfed and Boro rice irrigated with arsenic-rich ground water. Boro rice production depends heavily on irrigation with water from the shallow aquifer, but the water table is declining rapidly at many locations in Murshidabad district because of over-extraction.

Measures to reduce arsenic into soil and crops:

- Ground water irrigation can be reduced in Rice (*Oryza sativa* L.) cultivation, which will reduce arsenic input: A major option is to optimize irrigation water use in rice cultivation. The Bangladesh Rice Research Institute (BRRI) estimates that farmers could apply up to 40% less irrigation water without any yield losses. Once the arsenic input is reduced, naturally present removal mechanisms may be sufficient to avoid a buildup of arsenic in the topsoil. If water input can be reduced so that the soil conditions become more aerobic, the solubility of arsenic and therefore, its uptake would be minimised as well.

- Less ground water demanding cropping pattern can be introduced: Another option is to promote cropping patterns that require less irrigation water such wheat, maize etc. by replacing *Boro rice*.

- Select arsenic tolerant rice cultivation: Plant breeding should also focus on rice cultivars that are tolerant to arsenic and have a limited uptake. Rice cultivars show variation in their response to arsenic exposure but only a limited number of cultivars have been screened so far. A systematic screening is urgently needed to identify differences in arsenic uptake, tolerance and translocation.

- Food and Agriculture Organisation (FAO) system to save rice from arsenic: Use of arsenical irrigation water ultimately leads to issues of food security, food safety and environmental degradation. A new report by the FAO of the United Nations showed that high levels of arsenic in rice grains can be greatly reduced by applying improved irrigation management practices. Cultivating paddy on raised beds, rather than in flooded fields, will help reduce arsenic contamination of rice and cut water use.

A study conducted by FAO in cooperation with the Cornell University revealed that planting rice in raised beds, around 15 cm above the ground, and not in conventional flooded fields, counteracted yield losses and resulted in lower arsenic levels in both crops and soil. Raised rice bed was also found to lessen the effects of drought and flooding, therefore serving as an adaptation to climate change. The study was conducted in Bangladesh, where the highest occurrence of arsenic in ground water has been recorded.

FUTURE NEEDS IN IRRIGATION MANAGEMENT WITH ARSENICAL WATER

- The extent of using arsenical ground water resources for irrigation should be quantified using the relationship between arsenic in water, soil and plants.

- The scale of arsenic accumulation in top-soils and scale of land degradation through arsenical irrigation water is required to be measured.
- Factors determining arsenic accumulation in soils must be understood sufficiently and quantified.
- Management options to prevent and mitigate arsenic-contamination of agricultural land must be developed.
- Uptake and toxicity of arsenic in crops is to be predicted. Only limited data on inorganic arsenic in rice, vegetables and other foods are available.
- Policies concerning the use of arsenical ground water for irrigation should be adopted immediately.
- The uptake efficiency/bioavailability of arsenic in rice and other foods after consumption is largely unknown.
- Globally, except for China, no food safety standards for inorganic arsenic in foods have been found.
- A reliable and representative human health risk assessment for arsenic in foods cannot be made at this stage.
- Exploratory studies are needed to assess the potential risks of arsenic in the environment to livestock and fisheries.
- Periodic monitoring of arsenic concentration in ground water at different depth.
- Hydro-geological tests on arseniferous aquifer and monitoring of arsenic concentration in ground water consequent of pumping.
- The behavior of soil moisture zone or vadose zone both litho samples and water samples in connection with the arsenic mobilization should be studied.
- Study the effect of arsenical pesticides on arsenic contamination, if any.
- Construction of artificial recharge structures in arsenic affected areas and study the impact of artificial recharging in shallow arseniferous aquifers in connection with dilution of arsenic in ground water.

CONCLUSIONS

It would require in-depth understanding of arsenic levels in irrigation water, soil and crops, the behaviour of arsenic in soil, uptake and toxicity in crops in the relevant agro-ecosystems, the influence of agricultural practices including irrigation water management on arsenic and the establishment of safe level for arsenic in irrigation water, soil and crops. This information would result in an evaluation of the current situation and would serve as a baseline for the future irrigation practices using arsenical water. Further, it will be of great importance to develop an effective and efficient water/soil/crop quality monitoring system for long-term monitoring of land degradation in agro-ecosystems. This system should include both arsenic and other physical, chemical and biological parameters that together determine the quality of agro-ecosystems.

The integrated approach to address the issue of using arsenical ground water resources for irrigation offers substantial opportunities to assess the overall status of land degradation in agro-ecosystems, develop a system to monitor future trends in land degradation and assist governments and development partners in developing policies and setting priorities. Depending on the outcome of the initial evaluation, management options to prevent or mitigate arsenic input to the agricultural system can be developed.

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REFERENCES

Arsenic Mitigation in Bangladesh (2002). The Local Government Division, Ministry of Local Government Rural Development & Cooperatives Government of the People's Republic of Bangladesh. ISBN 984-32-0349-6.

Bhattacharya P., Samal A. C., Majumdar J. and Santra S. C. (2009). Transfer of Arsenic from Groundwater and Paddy Soil to Rice Plant (Oryza sativa L.): a Micro Level Study in West Bengal, India. World Journal of Agricultural Sciences 5 (4): 425-431, 2009. ISSN 1817-3047 @ IDOSI Publications, 2009.

FAO (2008). FAO system to save rice from arsenic contamination http://www.financialexpress.com/news/FAO-system-to-save-rice-from-arsenic-contamintaion

Hydrogeology and Ground Water Potential of Murshidabad District, West Bengal (2008). Technical report Series 'D' No.: 210. Central Ground Water Board (Eastern Region), Ministry of Water Resources, Government of India.

IRRI-CIMMYT (2007). Arsenic Toxicity http://www.knowledgebank.cimmyt.org

Kunar S., Jain S. K., Shekhar S. and Sharma V. (2009). Arsenic in ground water in India: An overview, Central Ground Water Board, Ministry of Water Resources, Government of India, Bhu-Jal News, Vol. 24, No. 2 & 3, April-Sept. 2009.

Report on Third Minor Irrigation Census in West Bengal (2000-2001) (2003). Water Resources Investigation and Development Department, Government of West Bengal.

Ray T. (2010). Status of arsenic contamination in groundwater of West Bengal. Workshop on Migration of Arsenic in Aquifers of West Bengal – organized by Indian Institute of Social Welfare and Business Management (IISWBM), Kolkata, India.

Shivanna K., Sharma S., Sinha U. K., Nair A.R., Navada S. V., Ray A., Talukdar T., Mehta B. B. and Ghosh A. K. (1999). Arsenic pollution in ground water of West Bengal. Workshop on Ground Water Pollution and its Protection with Special reference to Arsenic Contamination, Central Ground Water Board (Eastern Region), Kolkata, India.

Sarkar S. C., Roy Chowdhury S. and Chatterjee D. (1999). Studies on the source of arsenic-pollution in ground water at some places of West Bengal: progress, problems and a few suggestions. Workshop on Ground Water Pollution and its Protection with Special reference to Arsenic Contamination, Central Ground Water Board (Eastern Region), Kolkata, India.

Shivanna K., Sinha U. K., Joseph T. B., Sharma S. and Navada S. V. (2000). Isotope hydrological investigation in arsenic infested areas of West Bengal, India. ICIWRM-2000, Proceedings of International Conference on Integrated Water Resources Management for Sustainable Development, 19-21 December, 2000, New Delhi, India.

Sarkar A. K. and Ray J. (1999). Construction of tube wells in arsenic affected areas borehole grouting with "Clay Basket" packer. Workshop on Ground Water Pollution and its Protection with Special reference to Arsenic Contamination, Central Ground Water Board (Eastern Region), Kolkata, India.

Sanyal S. (2010). Arsenic Contamination in Groundwater in the Bengal Delta: Implications in Agricultural Systems and Strategies Ahead. Workshop on Migration of Arsenic in Aquifers of West Bengal – organized by Indian Institute of

Social Welfare and Business Management (IISWBM), Kolkata, India.

Talukdar T., Ghosh A. K. and Srivastava K. K. (2009). Arsenic in ground water of North 24 Parganas District, West Bengal, Central Ground Water Board, Ministry of Water Resources, Government of India, Bhu-Jal News, Vol. 24, No. 2 & 3, April-Sept. 2009.