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Million Dollar Arsenic Removal Plants in West Bengal, India: Useful or Not?

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The effectiveness of arsenic removal plants (ARPs) to provide safe water was evaluated based on a study of 577 ARPs out of 1900 installed in 5 arsenic-affected districts of West Bengal, India. Out of 577, 145 (25.1%) were found in defunct condition. Both raw and filtered water from 305 ARPs were analyzed for total arsenic concentration. Forty-eight ARPs were installed despite raw water arsenic concentrations below the Indian standard (50 µg/L) and in 22 cases even below the WHO guideline value (10 µg/L). Among the 264 ARPs having raw water arsenic above 50 µg/L, 140 (53.1%) and 73 (27.7%) failed to remove arsenic below the WHO guideline value and Indian standard, respectively. The highest arsenic concentration in treated water was 705 µg/L. Analysis of 217 treated water samples for iron showed that 175 (80.6%) failed to remove iron below 300 µg/L. The treated water became coloured on standing 6 to 8 h, for 191 (44.2%) ARPs and 25 (5.8%) produced bad-odoured water. Overall, the study showed that 475 (82.3%) of the ARPs were not useful. The reasons for ineffectiveness and poor performance of these ARPs include improper maintenance, sand gushing problems, a lack of user-friendliness and absence of community participation. A comparative study of ARPs in two different blocks (Domkol in Murshidabad district and Swarupnagar in North 24 Parganas) showed that 39 (80%) and 38 (95%) ARPs, respectively, were not useful. Further study in Gram Panchayet Kolsur, Deganga block, North 24 Parganas, showed that 14 (87.5%) ARPs were not useful. Proper watershed management with active participation from the villagers is urgently required for successful mitigation.

Key words: **arsenic removal plant, chemical and acceptability aspects, maintenance, alternate options, watershed management**

Introduction

Before 2000, three major incidents of groundwater arsenic contamination were reported from the Asian countries of Bangladesh; West Bengal, India (Chakraborti et al. 2002) and China (Xia 2004). In the following four years additional instances were revealed from different Asian countries including locations in China, Lao People's Democratic Republic, Cambodia, Myanmar and Pakistan (China Inter-regional Conference on Water Quality-Arsenic Mitigation 2004), Nepal (Shrestha et al. 2003), Kurdistan province of Iran (Mosaferi et al. 2003) and Vietnam (Berg et al. 2001). Studies by the School of Environmental Studies, Jadavpur University, India, over the past 18 years indicate that a significant portion of the Ganga-Meghna-Brahamaputra (GMB) plain in India and Bangladesh, encompassing an area of 569,749 km^2 with a population of over 500 million, is at risk from arsenic contamination of groundwater (Chakraborti et al. 2004).

Since 1997, the governments of India and Bangladesh, the World Bank, United Nations Children's Fund (UNICEF), the World Health Organization (WHO) and other international aid agencies along with national non-governmental organizations (NGOs) have launched a biphasic program in West Bengal, India, and Bangladesh to control the arsenic crisis. The first phase involved screening of the contaminated tubewells and the second was to provide safe drinking water to the affected villagers.

In the arsenic-affected regions tubewells were painted green or red according to arsenic concentrations below or above 50 µg/L, respectively, and field arsenic test kits were used to measure the arsenic concentration. The poor reliability and effectiveness of these field-testing kits and dependence of field kit results on skill and training of the operators was discussed in earlier publications (Rahman et al. 2002). Other researchers also dealt with ineffectiveness of the arsenic field test kits

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(Erickson 2003). This poor performance was largely to blame for often jeopardizing the proper screening of the tubewells in arsenic-affected regions. UNICEF stopped using these kits in West Bengal after evaluating them independently (Hossain et al. 2005). Notably, the South East Asia Regional Director of WHO commented, "We are now at a stage to support the development of standardized laboratory testing of arsenic" (WHO 2003), but the debate continues (Van Geen et al. 2005; Mukherjee et al. 2005).

The second phase was to ensure a supply of arsenic-safe drinking water in the affected areas. One of the possible arsenic mitigation strategies was installation of arsenic removal plants (ARPs). The ARPs are mainly based on adsorption, co-precipitation, ion exchange and membrane techniques. The operational mechanism of different devices employed in arsenic-affected regions of West Bengal is discussed elsewhere (Hossain et al. 2005).

Like proliferating "business" of field kits, many national and international business organizations from various countries are now taking a keen interest in promoting the ARPs in India, Bangladesh and many other arsenic-affected Asian countries. The total market for household water treatment in India alone is estimated at US$200 million (Jamwal 2004). Installation of ARPs in West Bengal, India, started at the end of 1998 (Hossain et al. 2005). The West Bengal government and other organizations have already invested about US$3 million in installing ARPs purchased from both national and international manufacturers (1900 ARPs were set up at an average price of US$1500 each) in mainly 5 out of 9 arsenic-affected districts of West Bengal, India.

Starting in late 1998, we evaluated the efficiency of 577 ARPs in the districts of North 24 Parganas, Murshidabad, and Nadia of West Bengal, and the reports were submitted to the Government of West Bengal, ARP manufacturers and other concerned NGOs for their information and follow-up action. A two-year-long systematic study showed ineffectiveness and poor reliability of 19 ARPs from 11 different national and international manufacturers installed in Baruipur block of South 24 Parganas district under a project titled "Technology Park Project" (Hossain et al. 2005).

Based on field study from 1998 to present in different arsenic-affected areas of West Bengal, this paper discusses the reasons behind the poor performance of ARPs, users' opinion about the effectiveness and user-friendliness of ARPs and probable solutions and alternate options for safe drinking water. A study of one cluster of villages, i.e., Gram Panchayet (Kolsur) of North 24 Parganas district, is presented here to investigate effectiveness and applicability of ARPs. A comparison between performances of all of the ARPs installed in the Domkol block of Murshidabad district and the Swarupnagar block of North 24 Parganas district, is also presented.

Description of a Typical ARP System

A schematic diagram of a typical ARP widely used in West Bengal is presented in Fig. 1. An ARP, connected to a hand tubewell, consists of a gravel filter followed by an adsorption tower filled with granular ferric hydroxide (trade name AdsorpAs). The raw water enters the first filter at the top and flows down the gravel bed to be freed from suspended particles in groundwater. The water exits at the bottom of the gravel filter and enters the adsorption tower at the top, where it flows downward through the AdsorpAs bed to be freed from arsenic concentration for potable use.

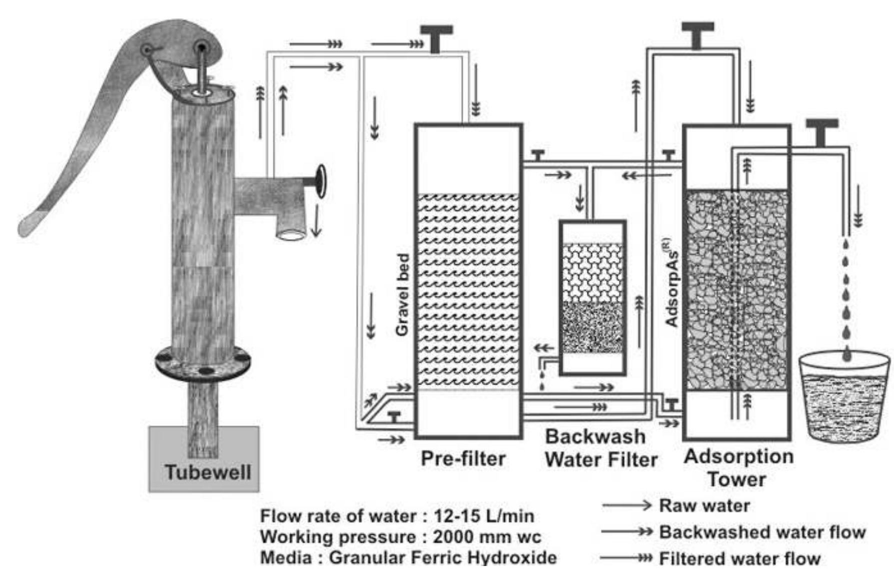

Fig. 1. Schematic diagram of a typical arsenic removal plant widely used in West Bengal, India.

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The gravel filter and AdsorpAs of the ARP need to be backwashed regularly and the frequency of backwashing depends on both quality and quantity of the water treated. In order to backwash the gravel bed and AdsorpAs, tubewell water is pumped through the filter bed by closing the normal operation valves and opening the backwash valves. The backwashed water from the gravel filter and AdsorpAs, containing arsenic and iron, is discharged into a bucket.

Materials and Methods

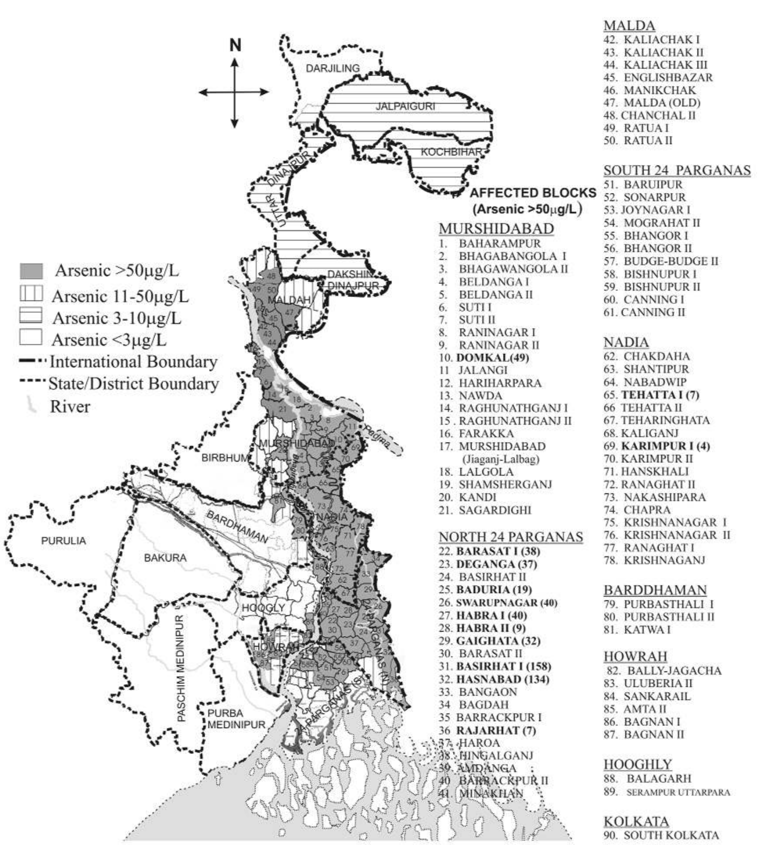
Study Area

West Bengal, one of the 29 states of India, is made up of 19 districts. Each district is further divided into several blocks and each block is composed of several clusters of villages known as a Gram Panchayet (GP). The present study area was comprised of the Tehatta I and Karimpur I blocks of the Nadia district, the Domkol block of the Murshidabad district and 10 blocks of the North 24 Parganas district including Swarupnagar. Figure 2 shows the present status of arsenic contamination in West Bengal and the ARP study areas.

Sample Size

Five hundred and seventy-seven ARPs in different time periods were investigated, and the views and opinions of the users regarding the efficiency, usefulness and the problems of most of the ARPs were collected. Among them 145 were found in "not working" condition. To judge the chemical performance of the ARPs, both raw and filtered water samples from 305 ARPs were collected and analyzed for arsenic; 213 of them were analyzed for both arsenic and iron. Water samples from some of the ARPs could not be collected because of jammed valves and due to resistance by some ARP users to collect water. In a few places, the users were so dissatisfied with the ARPs that they physically assaulted the field survey team, mistaking them for a manufacturing/maintenance party. The analytical results from the remaining ARPs could not be obtained because of missing samples and mislabeled samples. A total of 1731 (3×577) ARP users was selected at random and interviewed regarding performance of the ARPs.

For further study all of the 16 ARPs in Kolsur GP of North 24 Parganas were investigated. For comparative study, all of the 49 ARPs from the Domkol block of



(Our studied blocks are highlighted. Figures in the parenthesis indicate number of ARPs investigated)

Fig. 2. Map of West Bengal, India, showing present groundwater arsenic contamination status along with the location of the study blocks for ARPs.

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Murshidabad district and 40 from the Swarupnagar block of south 24 Parganas district were investigated.

Instrumentation and Analysis

A flow injection hydride generation atomic absorption spectrometer (FI-HG-AAS) and UV spectrophotometer were used for the arsenic and iron analyses, respectively, as described in earlier publications (Chatterjee et al. 1995). Water samples from each of the ARPs before and after treatment were analyzed for arsenic using FI-HG-AAS. The modes of water sample collection and analytical procedures were as reported earlier (Chatterjee et al. 1995).

Quality Assurance and Quality Control Program

Raw water samples were collected from 16 hand tubewells for interlaboratory comparison. After analyzing the samples for arsenic in the laboratory by the FI-HG-AAS method, aliquots of the samples were sent to the Intronics Technology Centre (ITC), Dhaka, Bangladesh, and the Central Food Laboratory (CFL), Kolkata, India, for analysis. In both of the laboratories, arsenic analysis was conducted by FI-HG-AAS after reduction.

Aliquots of 11 samples were also sent to Intronics Technology Centre (ITC) and NGO Forum Laboratory, Dhaka, Bangladesh, for analysis of iron by spectrophotometry. The same samples were analyzed in the laboratory by spectrophotometry. No significant differences were observed in arsenic and iron concentration levels in the water samples among the various laboratories (Hossain et al. 2005).

Statistical Analysis

Standard statistical techniques were applied to analyze and present the data. Both univariate and bivariate approaches of data analysis were adopted. Descriptive statistics like arithmetic mean and standard deviation as a measure of central tendency and dispersion were used for arsenic and iron concentration for both raw and filtered water. Associations between dichotomous variables were tested from a 2 × 2 contingency table using χ^2 statistics. The observed χ^2 value was compared with tabulated values with specific degrees of freedom (d.f.). The larger the value of observed χ^2, the stronger the association between the concerned variables.

Results and Discussion

The seven-year-long study demonstrated that although the ARPs were installed to supply treated arsenic-safe water to the affected people, this venture failed in most cases. The stakeholders are: (a) the government, (b) international aid agencies sometimes along with national NGOs (such as the India Canada Environment Facility [ICEF] venture in Baruipur, South 24 Parganas, setting up 19 treatment plants in the "Technology park area," a joint venture between the governments of India and Canada and an NGO), (c) manufacturers, (d) persons responsible for maintenance, possibly an NGO or manufacturers or in few cases the users themselves, and (e) the users. The responsibility for the success or failure of the program ideally should be borne by each of them.

Based on seven-year-long field experience on installed ARPs, many factors, as described below, should be taken into consideration to evaluate efficacy of these plants.

Site Selection for the ARPs

The areas with high arsenic concentrations (>50 µg/L, Indian standard for arsenic in drinking water) with no alternate safe drinking water resources nearby should have been chosen for setting up the ARPs. Analysis (Table 1), however, showed that 48 ARPs (15.8%) were set up where arsenic concentration in the raw water was below this limit, and for 22 cases (7.3%) below 10 µg/L, the WHO guideline value.

We observed few places that had numerous sources of arsenic-safe drinking water all in operating conditions viz. deep tubewell, supply water along with the ARPs. Some ARPs were installed in office campuses (e.g., Bock Development Office, police stations) where common people had limited access, thus costly ARPs mostly remained unused. During field surveys we noticed factors other than the arsenic concentration became important in determining the site.

Performances of the ARPs with Regard to Chemical Parameters of the Filtered Water

Performance of ARPs with regard to arsenic removal. Most of the ARP manufacturers claimed their device could remove arsenic up to the WHO guideline value (10 µg/L) (SOFR 2001). Since the Indian standard is 50 µg/L of arsenic in drinking water, we expect that all ARPs should remove arsenic at least up to this level. Analysis, however, showed that out of 264 ARPs where raw arsenic was above 50 µg/L, 140 (53.1%) failed to maintain WHO guideline values (10 µg/L) while 73 (27.7%) even failed to maintain Indian standards (50 µg/L) (Table 1). The mean arsenic concentration in raw water among the operational ARPs was 185 µg/L with standard deviation of 165 µg/L, while that for filtered water was 44 µg/L with standard deviation of 87 µg/L. The highest arsenic concentration in filtered water was 705 µg/L.

Performance of ARPs with regard to iron removal. Most of the ARP manufacturers claimed to be able to remove Fe below 300 µg/L. Though no health-based guideline value for iron in drinking water is proposed by WHO, taste is usually unacceptable at iron concentra-

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TABLE 1. District-wise distribution of arsenic concentration in raw and filtered water

Arsenic concentration range (μg/L)	Number of ARPs							
	Raw water				Filter water[a,b]			
	Murshidabad	North 24 Parganas	Nadia	Total[c]	Murshidabad	North 24 Parganas	Nadia	Total[c]
≤3	5	8	—	13 (4.3)	13	56	1	70 (26.5)
4–10	1	8	—	9 (3.0)	—	54	—	54 (20.5)
11–50	8	18	—	26 (8.5)	6	60	1	67 (25.4)
51–100	6	32	1	39 (12.8)	—	34	3	37 (14.0)
101–200	10	105	2	117 (38.4)	1	16	—	17 (6.4)
201–300	3	53	1	56 (18.4)	—	11	—	11 (4.2)
301–400	—	20	1	21 (6.9)	—	3	—	3 (1.1)
401–500	1	6	1	8 (2.6)	—	2	—	2 (0.8)
501–700	—	12	—	12 (3.9)	—	2	—	2 (0.8)
>700	—	4	—	4 (1.3)	—	1	—	1 (0.4)
Total	34	266	5	305	20	239	5	264

[a]Those with raw arsenic above 50 μg/L.
[b]Seven raw waters could not be collected because of a jam in the valve.
[c]Figures in the parentheses indicate percentage.

tions above 300 μg/L (WHO 2004), and we used it as the limiting value for evaluation of ARPs. The analysis of raw water samples for iron from 213 ARPs showed that raw water of 210 ARPs had above 300 μg/L. Only 39 (19.4%) ARPs could reduce iron below 300 μg/L (Table 2). Mean and standard deviation of iron concentration in raw water were 4493 and 3596 μg/L, and for filtered water were 2630 and 4590 μg/L, respectively.

Performance of ARPs with regard to appearance, odour and taste in filtered water. Taste and odour can originate from natural inorganic and organic chemical contaminants and biological sources or processes (e.g., aquatic microorganisms), from contamination by synthetic chemicals, from corrosion or as a result of water treatment (e.g., chlorination) (WHO 2004). During treatment of raw water for removing arsenic and/or iron by the ARPs, the process may yield unacceptable taste and odour of the filtered water.

Colour, cloudiness, particulate matter and visible organisms may also be noticed by users and may create concerns about the quality and acceptability of the drinking water supply. ARP users were interviewed regarding colour and odour of the treated water during field surveys. According to them, 44.2% of the ARP treated water turned a yellow/red/reddish-brown colour after some time of collection, 5.8% produced bad odour, thus making the treated water unacceptable (Table 3).

Association between acceptability factors and usage of ARPs. A statistical analysis was performed to find out if there is any possible association between colour, odour,

TABLE 2. District-wise distribution of iron concentration in raw and filtered water

Concentration range (μg/L)	Number of ARPs					
	Raw water			Filter water[a,b]		
	Murshidabad	North 24 Parganas	Total[c]	Murshidabad	North 24 Parganas	Total[c]
≤300	—	3	3 (1.4)	3	39	42 (19.4)
301–1000	1	11	12 (5.6)	21	51	72 (33.2)
1001–2000	11	27	38 (17.8)	4	23	27 (12.4)
2001–3000	8	26	34 (16.0)	2	21	23 (10.6)
3001–4000	4	21	25 (11.7)	1	13	14 (6.5)
4001–5000	4	29	33 (15.5)	1	5	6 (2.8)
5001–7000	4	28	32 (15.0)	2	8	10 (4.6)
7001–10,000	1	23	24 (11.3)	—	11	11 (5.1)
>10,000	1	11	12 (5.6)	—	12	12 (5.5)
Total	34	179	213	34	183	217

[a]Those with raw iron above 300 μg/L.
[b]Seven raw waters could not be collected because of a jam in the valve.
[c]Figures in the parentheses indicate percentage.

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TABLE 3. Association between acceptability criteria and use of the ARP treated water

		Villagers use the ARP treated water?			
		Yes	*No*	*Total*	*χ2 Value*
Filter water safe?	Yes	147	44	191	
	No	49	24	73	2.67
	Total	193	68	264	
Water gets colour on standing	Yes	76	115	191	
	No	216	25	241	120.81
	Total	292	140	432	
Water smells bad?	Yes	3	22	25	
	No	289	118	407	37.44
	Total	292	140	432	
		Water smells bad?			
		Yes	*No*	*Total*	
Water gets colour on standing?	Yes	18	173	191	
	No	7	234	241	8.31
	Total	25	407	432	

arsenic contamination status of filtered water and the users' decision to use (for their drinking and cooking purpose) the same. Table 3 shows the result of binary analysis of the data indicating association and/or non-association of different acceptability criteria. According to the arsenic concentration levels in filtered water, the ARPs were divided into two classes: "Safe" if filter water arsenic is below 50 µg/L and "Unsafe" if otherwise. The acceptability aspects like colour and odour of the filtered water were found to be significantly influencing the choice (χ^2 = 120.81 and 37.44). A significant association between colour and odour of the treated water was also observed (χ^2 = 8.31), indicating their interdependence.

Interestingly no association (χ^2 = 2.67) was observed between arsenic concentration in the treated water and whether the ARP is used or not, while the arsenic concentration in the treated water should be the prime judging criterion for usability. As the users were unaware about the arsenic concentration level of the ARP treated water, their decision depended on minor criteria like acceptability aspects of the treated water.

Maintenance of the ARPs

Backwashing and disposal of backwashed sludge. Backwashing is a critical step for consistent and efficient performance of the ARPs (SOFR 2003). Unfortunately, neither the installing nor the maintaining authority (in case they are different) had any clear idea regarding frequency of backwashing. They also did not know about the amount of forward washing needed to get arsenic-safe water after the backwash was complete.

Based on the information collected from the users regarding regularity and frequency of backwashing it was observed that only 131 (30%) out of the 432 operational ARPs received regular backwashing. Backwashing twice a week is necessary for efficient performance of the ARPs (Hossain et al. 2005), but only 10 out of 131 regularly backwashed ARPs were being backwashed twice a week. The frequency of backwash ranged from more than once in a week to once in two months.

Information regarding the disposal process of highly arsenic-contaminated backwash sludge was collected for 175 ARPs. The backwashings from 80% of the ARPs were disposed on the open field.

Clogging of ARPs due to sand gushing. Another problem often encountered in running the ARPs is clogging, which happens due to silvery colloidal sand coming in with the water and choking the tubewell and the filter media of the ARPs. Most of the ARPs are attached to the pressure pumps, and sand gushing becomes an unavoidable problem in arsenic-affected areas of West Bengal situated in recent alluvial depositional areas. The ARP manufacturers and the installing authority did not consider this aspect before installation. As a result, many ARPs faced this problem. Each ARP has a fixed media life and after that the media needs to be changed for consistent performance. It was often observed (SOFR 2001) that many ARPs required changing their media (as mentioned by their respective manufacturers) well before adsorptive capacity due to clogging.

Low user-friendliness of the ARPs. As the ARPs are attached to existing tubewells, the attachment involves some changes in the tubewell at their mouth and head (Fig. 1). The tubewells and the ARPs belonged to different manufacturers, and the matching was often poor. While the mouth valve of the tubewell is closed, treated arsenic-safe water can be obtained and when it is open,

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arsenic-contaminated raw water comes out which can be used for domestic purposes other than drinking and cooking. When the mouth valves get jammed, the villagers use treated arsenic-safe water (supposing the plant is capable of producing that) for all purposes including bathing. If the valve attached to ARP gets jammed the users receive only contaminated water.

The packing at the head of the tubewells to facilitate flow of water to the plant from the tubewell was often inadequate. Water erupted on pumping from the head of the tubewell and drenched the user. Sometimes high pressure caused the tubewell handle to spring up injuring the user in the process. It usually took more time to collect the same amount of water from tubewells attached to ARPs than from those which were not. Damages to the washer of the tubewell were more frequent in case of tubewells attached with ARPs.

Effectiveness of the ARPs: A Survey in Kolsur GP in North 24 Parganas

Kolsur is one of the 13 GPs of the Deganga blocks of the North 24 Parganas district. There are approximately 2400 hand tubewells in the GP and 2184 (91%) wells were analyzed for arsenic; 67.6% of the tested tubewells had arsenic contamination above 50 µg/L. A total of 16 ARPs were installed here. Though the plant-wise numbers of users were not fixed, on average 200 to 250 users per plant was estimated.

The performance of the ARPs based on different parameters is shown in Table 4. Considering all these factors, it was found that 87.5% of the ARPs were not useful. Most of the ARPs had no particular authority to take care of them. A few plants were observed to be running successfully through active participation from all groups of people.

Effectiveness of the ARPs: A Comparative Study between ARPs in Swarupnagar Block in North 24 Parganas and Domkol Block of Murshidabad District

From the Swarupnagar and Domkol blocks 3366 and 1401 tubewells were analyzed for arsenic, respectively. Analytical results showed that in Domkol 35.1% of the tubewells had arsenic more than 50 µg/L. Similarly, in Swarupnagar 51.7% of the tubewells were contaminated above 50 µg/L arsenic. There were 49 ARPs in Domkol and 40 in Swarupnagar. The performance of these ARPs is shown in Table 4. Summing up the results, in Swarupnagar 95% of the ARPs were not useful to the villagers while in Domkol it was 80%.

Usefulness of the 577 ARPs

Table 5 shows the salient features of the 577 ARPs surveyed from three arsenic-affected districts at a glance. During the survey period 145 were found in "non-working" condition. Since this was a cross-sectional sur-

TABLE 4. Comparative situation of the ARPs installed in Swarupnagar block and Kolsur GP of North 24 Parganas district and in Domkol block of Murshidabad district

		No. of ARPs		
Sl. no.[a]	*Criteria*	*Domkol Block*	*Swarupnagar Block*	*Kolsur GP*
1.	Total no. of ARPs investigated	49	40	16
2.	Total no. of defunct ARPs	15	19	1
3.	Total no. of ARPs which are supplying water to the villagers (good or bad)	34	21	15
4.	Total no. of ARPs producing yellow/red/reddish-brown water	19	12	7
5.	Total no. of ARPs producing bad-odoured water	4	1	2
6.	Total no. of ARPs for which both raw and filtered water arsenic analysis was done	34	21	15
7.	Total no. of ARPs with raw water arsenic concentration below 10 µg/L	6	0	2
8.	Total no. of ARPs with raw water arsenic concentration below 50 µg/L	14	0	2
9.	Total no. of ARPs with filtered water arsenic concentration above 10 µg/L	7	17	11
10.	Total no. of ARPs with filtered water arsenic concentration above 50 µg/L	1	16	7
11.	Total no. of ARPs producing non-acceptable water (coloured and odoured water together) but raw arsenic above 50 µg/L and filter arsenic below 50 µg/L	6	3	3
12.	Total no. of ARPs where service persons come regularly for backwashing	0	0	6
13.	Total no. of ARPs for which both raw and filtered water iron analysis was done	34	20	15
14.	Total no. of ARPs with raw water iron concentration below 300 µg/L	0	0	0
15.	Total no. of ARPs with filtered water iron concentration above 300 µg/L	31	20	8
16.	Total no. of ARPs in operation, produce acceptable water and can remove arsenic from raw water below 50 µg/L but people do not use the treated water	3	0	1
17.	Total no. of ARPs that were found useful	10	2	2
% of the ARPs that were found not useful to the villagers		80	95	87.5

[a]The factors with Sl. no. 2, 8, 10, 11 and 16 were considered to calculate number of ARPs useful/not useful to the villagers.

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vey, some defunct ARPs became operational afterwards and some working ones might have become defunct. Figure 3 shows a defunct ARP in South 24 Parganas which became a toy for children.

From Table 5 we observe that among the ARPs 82.3% were not useful. Indiscriminate installation of ARPs without proper preparatory steps, coupled with ill maintenance, gross mismanagement and a sense of disowning on the part of the users have resulted in utter misuse of these costly plants and the treated water.

The Role of Community Involvement

Table 5 shows that in most of the cases ARPs failed miserably as a successful means for arsenic removal in the affected regions. It was noticed that arsenic remediation through ARPs in the laboratory may be successful to achieve 90% removal but when it goes to the field level it fails. ARPs in the field can be viewed broadly as a social project. The concept of community participation through a new paradigm is now becoming an integral part of any successful social venture. A proper initiation exercise should have preceded the installations. The users need to be properly educated about:

a. the danger of arsenic in drinking water
b. the necessity of arsenic removal
c. the options at hand and the importance of ARPs as a viable option
d. how the process works (explained in a simple manner) with the help of diagrams and without technical jargon
e. the importance of maintaining the ARPs and periodical checking of treated water for arsenic, and
f. the importance of keeping updated on the quality of treated water in terms of arsenic and other contaminants as found from periodical testing. The results of periodical testing may be displayed near the ARP.

Fig. 3. A defunct ARP which became a plaything for children.

TABLE 5. Situation of the investigated 577 ARPs at a glance

Sl. no.[a]	*Criteria*	*Number of ARPs*
1.	Total no. of ARPs investigated	577
2.	Total no. of defunct ARPs	145
3.	Total no. of ARPs which are supplying water to the villagers (good or bad)	432
4.	Total no. of ARPs producing yellow/red/reddish-brown water	191
5.	Total no. of ARPs producing bad-odoured water	25
6.	Total no. of ARPs where service persons come regularly for backwashing	131
7.	Total no. of ARPs for which both raw and filtered water arsenic analysis was done	305[b]
8.	Total no. of ARPs with raw water arsenic concentration below 10 μg/L	22
9.	Total no. of ARPs with raw water arsenic concentration below 50 μg/L	48
10.	Total no. of ARPs with filtered water arsenic concentration above 10 μg/L	140
11.	Total no. of ARPs with filtered water arsenic concentration above 50 μg/L	73
12.	Total no. of ARPs producing non-acceptable water (coloured and odoured water together) but raw arsenic above 50 μg/L and filter arsenic below 50 μg/L	198
13.	Total no. of ARPs for which both raw and filtered water iron analysis was done	213[b]
14.	Total no. of ARPs with raw water iron concentration below 300 μg/L	3
15.	Total no. of ARPs with filtered water iron concentration above 300 μg/L	175
16.	Total no. of ARPs in operation, produce acceptable water and can remove arsenic from raw water below 50 μg/L but people do not use the treated water	11
17.	Total no. of ARPs that were found useful	102
% of the ARPs were found not useful to the villagers		82.3

[a]The factors with Sl. no. 2, 9, 11, 12 and 16 were considered to calculate number of ARPs useful/not useful to the villagers.
[b]For 7 ARPs raw water could not be collected due to a valve jam and only filtered water was collected.

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Lack of awareness and relevant information is one of the major hurdles in any arsenic mitigation program. In very few cases the users were able to recognize the ARPs as an asset for the community and maintain them properly. Without cost sharing it is difficult to instill in users' minds a sense of ownership. Three examples of plants where community participation was able to successfully run the ARPs are cited: two ARPs belonged to BE College (Village Parpatna, GP Chakla, Block Deganga, District North 24 Parganas and Village Sangrampur paschimpara, GP Sangrampur Sibhati, Block Bashirhat I, District North 24 Parganas) and the other one belonged to Pal Trockner (near Ichhapur Ayurbedic Hospital, GP Ichapur 1, Block Gaighata, District North 24 Parganas).

Additional Options for Arsenic Mitigation other than ARPs

There are other less costly ways to combat the arsenic calamity:

Deep tubewells. It is well established that in the Gangetic plain arsenic contamination in hand tubewells has been observed to decrease after a certain depth (Roychowdhury et al. 1999) but in unconfined aquifers there appears to be no depth guarantee, even if the construction of the tubewell is done properly. Some arsenic contamination (Chakraborti et al. 1999) in even deep (depth range 100–200 m) tubewells in Bangladesh was reported. In West Bengal many tubewells that were safe (As <10 ppb) became contaminated (above 50 ppb) over time (Rahman et al. 2001). No doubt, a deep tubewell (depth more than 300 m) is usually a source of arsenic-safe water and the possibility of arsenic contamination is less if the deep tubewell construction is done properly, the aquifer tapped is underneath a thick clay barrier, and periodical testing is done to check the water quality.

Dugwells. The use of dugwells in Asia was known even during the Mahenjodaro and Harappa civilization more than 4000 years ago. The culture of the dugwell, however, died down due to induction of tubewells, which proved more convenient as far as bacterial contamination is concerned. So far, around 700 dugwells in Bangladesh and West Bengal were surveyed for arsenic and bacteria. Ninety percent were found safe with respect to arsenic (<3–35 µg/L, average 15 µg/L). There are few areas where arsenic contamination above 50 µg/L (maximum 330 µg/L) was found. With the advent of technology, the bacterial problem in dugwells is no longer a serious problem.

Rainwater harvesting. In many states of India and southern parts of Bangladesh, the harvesting of rainwater is still a common practice. In the present scenario, if rainwater is harvested through clean rooftop collection into storage tanks, and precautions are taken against bacterial contamination, the stored rainwater can be used for at least 4 to 5 months per year. In arsenic-affected areas of Thailand this is a common practice.

Proper watershed management Up to the early 20th century the main sources of drinking water in West Bengal and Bangladesh were ponds, lakes, etc., and people would drink untreated water. However, at that time proper technology was not available to treat water but there were separate ponds for drinking water and washing and bathing purposes. Proper treatment against bacterial and other contamination and proper management of available surface water may hold the key to safe potable water for Bangladesh and West Bengal where per capita available surface water in the form of wetlands, oxbow lakes and flooded river basins is enormous (11,000 m^3 in Bangladesh and about 7000 m^3 in West Bengal), average annual rainfall in these regions is about 2000 mm and the land known as "land of rivers."

Conclusion

Out of 577 ARPs investigated, 145 (25.1%) were found in non-working condition. Both raw and filtered water from 305 ARPs were analyzed for total arsenic concentration. Among the 264 ARPs having raw water arsenic above 50 µg/L, 140 (53.1%) and 73 (27.7%) failed to remove arsenic below the WHO guideline value (10 µg/L) and Indian standard (50 µg/L), respectively. The treated water became coloured mainly due to excessive iron in the treated water on standing 6 to 8 h, for 191 (44.2%) ARPs and 25 (5.8%) were producing bad-odoured water. Strong dependence on usage of the ARPs on colour and odour of the treated water was supported by 2 X 2 contingency analysis. Overall, the study showed that 475 (82.3%) of the ARPs installed in the arsenic-affected areas were not useful. The reasons for ineffectiveness and poor performance of these ARPs include improper maintenance, sand gushing problems, lack of user-friendliness and absence of community participation. A comparative study of ARPs in two different blocks (Domkol in Murshidabad district and Swarupnagar in North 24 Parganas) showed that 39 (80%) and 38 (95%) ARPs, respectively, were not useful. Further study in Gram Panchayet Kolsur, Deganga block, North 24 Parganas showed that 14 (87.5%) ARPs were not useful. Proper watershed management with active participation from the villagers is urgently required.

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