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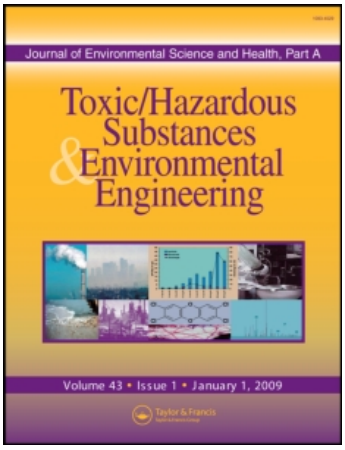

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A Dugwell Program to Provide Arsenic-Safe Water in West Bengal, India: Preliminary Results

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ABSTRACT

In 1982, Dr. K. C. Saha, a dermatologist of Calcutta, West Bengal, identified patients with skin lesions from the district of 24 Parganas, leading him and others to search for a cause. The cause was soon identified to be arsenic in drinking water, but even today, 20 years later, large number of people continue to drink arsenic contaminated water and patients are increasing in number. Project Well is a program chosen for implementation in some villages of North 24 Parganas. Arsenic safe drinking water is provided for adopted villages by constructing shallow, concrete dugwells designed to tap the water of the unconfined aquifer, 20–30 feet below ground level, that contains low levels (<0.05 mg/L) of arsenic in the target region. The traditional dugwell design is modified by use of tube well hand pumps to withdraw water. The project includes community involvement,

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programs to increase awareness of the need to drink arsenic safe water, and training in monitoring of dugwell water for arsenic and harmful pathogens. Disinfecting of the water and regulating the water hazard diagram are also included in the training program. The plan is to make the system sustainable at the village level using indigenous labor and materials.

Key Words: Dugwell; Arsenic mitigation; Water hazard; Village adoption.

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INTRODUCTION

In 1982, Dr. K. C. Saha, a dermatologist of Calcutta, West Bengal, saw patients with skin lesions, which led him to the search for a cause. In 1983 the first arsenical dermatosis was suspected in a patient from the village Gangapur in the district of 24 Parganas. The disease was related to the arsenic contaminated tube wells, the primary source of drinking water. A study was carried out in six villages that revealed 197 patients in 48 families with skin lesions caused by arsenic.[1] In some families all the members were victims. Soon it was discovered that six out of the sixteen districts of West Bengal had arsenic contaminated tube wells.[2,3] In 1989, a few residents of southwest Calcutta were diagnosed with diseases caused by arsenic. It was found that the patients consumed water from shallow tube wells of about 60–90 feet (24–36 m) deep. The water was contaminated by discharge from a chemical factory that manufactured the insecticide containing copper acetoarsenite (Paris-green).[4] However, apart from this finding in Calcutta, the contamination of tube wells throughout West Bengal has resulted from natural sources.

By 1992, the combination of evidences from Taiwan and elsewhere was sufficient to conclude that ingested inorganic arsenic in drinking water could cause bladder, kidney, lung and liver cancer.[5] At about the same time it was estimated that the cancer mortality risk from drinking water containing 0.05 mg/L of arsenic could be as high as 1 in 100 exposed people.[6] However, the earliest sign of exposure involves skin lesions.

In 1996, the number of victims in West Bengal who were suffering from skin changes caused by arsenic in drinking water was estimated to be about 200,000.[7,8] By year 2000 it was discovered that the groundwater of nine districts out of the 18 districts of West Bengal (the number of districts had increased to 18 after divisions creating two new districts) had tube wells contaminated with arsenic.[9] A recent study showed that the number of affected villages has increased to 2600 in 74 blocks, and that the population at risk of exposure in the region was 42.7 million.[10] This study also found that 25% of the total (101,934) number of tube wells that have been analyzed contained arsenic concentrations more than 0.05 mg/L, while 52% contained above 0.01 mg/L.

There is no effective treatment for arsenic-caused disease, but the urgent need for the affected people, and those exposed but not yet apparently affected, is to get an alternative supply of arsenic-free water.[11] To provide arsenic free water, different methods need to be considered depending on the local economic, hydro-geological and geographical conditions. An analysis suggests the most cost-effective method

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suitable for some villages of North 24 Parganas would be shallow, concrete, dugwells.[12]

GEOLOGY OF THE STUDY AREA

Arsenic is naturally occurring in the shallow aquifers of a major tract of land lying within the Bhagirathi–Padma interfluve.[13] The problem of arsenic in ground water is prevalent in most of the areas of southern West Bengal and Bangladesh falling within the Ganga Brahmaputra delta. The deltaic sediments belonging to the quaternary period have been classified into three morpho-tectonic units. In the decreasing order of antiquity are: (a) Older Deltaic Plain deposits; (b) Younger Deltaic Plain (YDP) deposits and (c) Recent Fluvial deposits.[14] The arsenic contaminated ground water aquifers are confined to the YDP sediments. This unit can be further classified by depth into three broad stratigraphic horizons. Most of the arsenic contaminated tube wells tap the aquifers in the intermediate horizons, which are dominantly made up of fine sand and clay. This horizon occurs at very shallow depths in northern parts of the Bengal delta but dips towards the south at a very shallow angle.[15] Under certain geochemical conditions, not yet fully understood, the stable pentavalent arsenic in the sediment is converted to water-soluble trivalent arsenic and is released into the surrounding ground water. The geological formation in the project area is comprised of loose, unconsolidated sediments consisting of a wide-ranging proportion of sand, silt and clay. The sediments belong to the YDP formation of the quaternary period, which spans one million years.

METHOD AND MATERIALS

In the district of North 24 Parganas there are 19 blocks identified to have shallow tube wells contaminated with arsenic. A model community-based program provide arsenic safe drinking water was started in the village of Simulpur of North 24 Parganas, in 2001. It involved providing funding and technical know-how for construction of dugwells using methods that is inexpensive, adaptable, and sustainable. The dugwells tap water of the near-surface unconfined aquifer within the oxidized zone, where the arsenic concentrations is well below 0.05 mg/L. Under this scheme, the user community of each well is trained in well maintenance, including disinfecting and periodic sampling of water for monitoring of arsenic and bacterial concentrations. The scheme involves only indigenous raw material and labor.

The main criteria to adopt a village and select a site for digging dugwells are:

1. The first priority is being given to villages with arsenic patients;
2. Arsenic contaminated tube wells are present in the village;
3. Absence of any other source of arsenic free drinking water within a distance of about 200 m of their homes;

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4. A potential user population of about 200 inhabitants;
5. A dugwell location higher than the surrounding area with no toilet or agricultural field within a distance of about 100 feet to reduce the potential for contamination by coliform bacteria and pesticides respectively.

The Dugwell Design

One of us (TH) provided the design of the dugwell (Fig. 1). The plan is to construct dug wells with coarse sand in the annular space between the formation wall and the concrete rings. The coarse sand creates a highly permeable zone around the well that can function as a natural filter. In addition, the coarse sand layer provides an additional storage area from where water can easily move into the well during peak usage times (morning and evening). Solid concrete rings are commonly used in dugwells. However, they prevent groundwater infiltration through the sidewalls of the well and allow water to enter only from the bottom thus creating turbulence that increases the quantity of finer materials in the well water. Hence, a second construction technique involves the use of perforated concrete rings. Lateral groundwater movement creates little or no turbulence with infiltration through the sidewalls. The sidewall perforations can be adjusted to restrict the passage of finer materials.

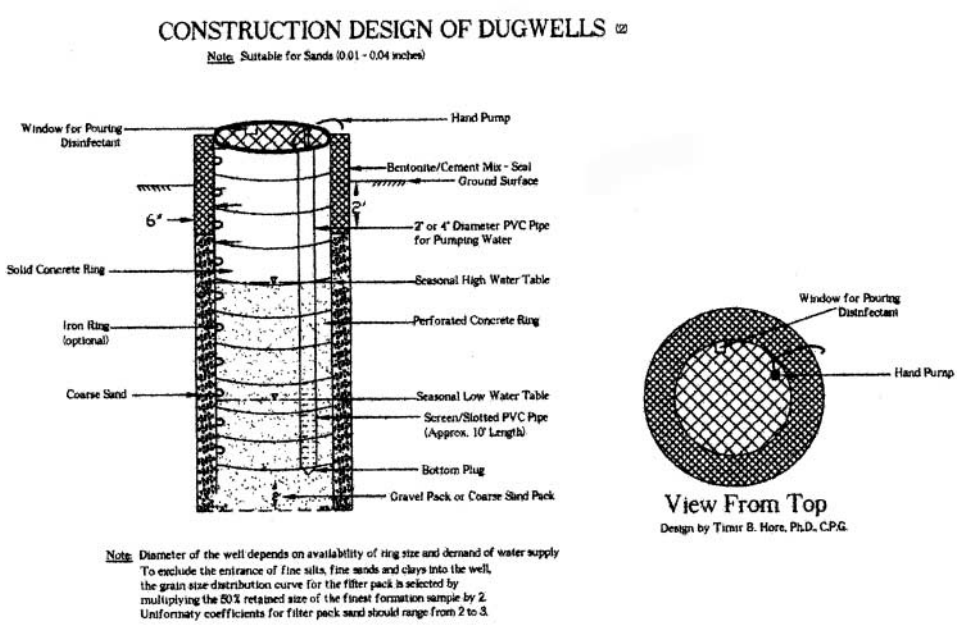

Figure 1. The interior design of the dugwell used by Project Well.

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Having the perforations in the rings smaller than approximately 70% grain size of the aquifer materials can accomplish this. Grain size distribution varies with landform units. However, if the formation materials consist of more than 60% clay, it is preferable to use a solid ring.

The appearance of the dugwell is not typical. The diameter is 3.3 feet and the depth is 22 feet. Solid rings of 12 inches height were used. The mouth of the dugwell is about 18 inches above the surface and is surrounded by a brick wall with a slanting roof, and is covered by a fine nylon net to avoid any external material from dropping into it, including insects. The roof is made of an undulating tin sheet that is locked to avoid any tampering. A hand pump is attached to the well to draw out the water, preventing contamination by human contact. The first such dug well was constructed and launched on 3rd June 2001 (Pictures and Reports are available on the web site: www.projectwellusa.org).

In West Bengal the average depth of the water level in the target areas of North 24 Parganas varies from 1.02 m to 6.36 m below ground level (bgl) for the month of January. In April, it is from 2.13 m to 7.85 m bgl, and in November from 0.67 m to 4.22 m bgl.[16] The months of May and June, before the onset of the monsoon, is the ideal time for construction of dugwells. Even then, pumps may need to be used during digging, depending on the level of the local water table that may vary from site to site.

Supervision of dugwell construction and maintenance is carried out through field staff from a local club that is involved in rural development. The field workers were trained to implement a beneficiary system. This includes formation of a committee from among the beneficiary families, creating a register of families, distributing information pamphlets (printed in Bengali, the regional language), collecting samples for water analysis, and carrying out a health survey. The health survey questionnaire includes basic information of name, address, age, sex, profession of all the family members of the household, information about the quantity of water consumed per day, and the occurrence of any gastrointestinal problems such as dysentery, diarrhea or indigestion.

The use of dugwell water in West Bengal was largely stopped about 30 years ago due to the incidence of gastrointestinal disorders. It is very important not to have such problems repeated in the villages. Hence the dug wells are being monitored for pathogens and periodically treated with potassium permanganate ($KMnO_4$). In general practice, $KMnO_4$ is primarily used to control the odor and taste of water, and it removes coloration and helps control bacteria, viruses, fungi and algae to some extent. There is no evidence of disinfection by-products from use of $KMnO_4$ as there is with chlorination of drinking water.[17] Use of $KMnO_4$ helps in maintaining the oxidizing state inside the well, which in turn allows the arsenic in the sediments comprising the walls of the well to remain in the pentavalent state, thereby precluding their leaching into the ground water inside the well. It is easily available in medicine shops in the village, is nontoxic and can be easily handled. Initially 100 g were used per 1000 L of water, but this was reduced to 50 g per 1000 L of water later to avoid obvious coloration. After treatment, the well is not used for 48 h, after which it is pumped out manually before general use starts again.

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For the measurement of arsenic, the dugwell water is collected in 500-mL bottle in which 30 drops of concentrated HCl is added. To detect the level of arsenic it is converted into arsine and absorbed in silver diethyl dithiocarbamate in chloroform containing morpholine. The resultant red color is measured in a spectrophotometer at 520 nm. (Method: ISO 6595-1982). Regarding other parameters the technical report[18] prepared by Central Ground Water Board states that the ground water in the district of North 24 Parganas with pH in the range of 7.3–8.7 is mildly alkaline in nature and the character has not changed over the years. The ground water also shows slight improvement in terms of specific conductance and chloride values which range between 396 to 1400 micromhos/cm at 25°C and between 14–335 mg/L, respectively, except at Barasat. Concentration of calcium, magnesium, bicarbonate and iron vary from 24–118, 13–52, 214–561, and <0.01–4.8 mg/L, respectively, showing bicarbonate type of water. There have not been noticeable changes in any of the significant constituents over the last 12 years, except for the seasonal or annual change within permissible limits in the northern and central parts of the district.

The maintenance of the dugwell and water quality is displayed on an indicator board prominently placed beside the dugwells. The Water Hazard Diagram (available on the web site) is a semicircle with four segments of different colors. Green indicates that the water is safe to drink; orange indicates that the water should be boiled before consuming; red indicates that it is unsafe to drink the water and white indicates that the well is dry. An arrow is manually operated by the field staff based on the monthly reports of the bacterial testing of the water.

RESULTS AND DISCUSSION

The geological log of the sediments prepared during the excavation of the first dugwell was as follows:

0–2 feet	Light grey, granular, sandy topsoil;
2–12 feet	Yellowish brown, silty clay with ferruginous concretions of 1 mm diameter;
Below 11.5 feet	The Vadose Zone (the zone of capillary moisture);
12–14 feet	Dark grey, extremely fine grained sandy silt with minute flakes of Mmica.

A few clots and stains of ferruginous oxides were also present. The arsenic level found in the soil was 5.04 mg/kg.

Initially, out of the total number of 40 beneficiary families listed in the register, almost all were taking water from the first dugwell for drinking and cooking. However the number of users dwindled after a few months. This was due to multiple reasons:

1. The distance was too far for some users, requiring more than 5 min walking;

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2. Preferred to get water from a deep tube well (this 400 feet deep tube well has recently been found to contain 0.05 mg/L arsenic) or from newly installed filter fitted tube wells;
3. The taste and odor was different from the customary tube well water;
4. Some also stopped drinking after the rumor was spread that a big insect was found in the water. This is not only unbelievable, it is impossible. The mouth of the dug well is well protected and the pipe fitted to the hand pump has a filter too.

Subsequently, two major problems occurred during the operation of the dugwell. After treating the water with $KMnO_4$ for 48 h, pumping out the tube well resulted in turbidity of the water, and the inflow of silt became sufficient to clog the delivery tube. Heavy rainfall was also considered to be an additional cause of turbidity. The pipe was cut shorter three times to get water from shallower depths during the rainy season as the well silted up more and more. In December, with the rapid fall of the water level, people were unable to withdraw water, and hence use of the well was discontinued until dredging was completed and the delivery pipe replaced.

From the above observations, the use of $KMnO_4$ has been considered to be no longer feasible. The use of theoline, chlorine based product, is being considered for use in the future. Monitoring will be done to assess the amount required to control coliform bacteria and also monitor the arsenic level in the water. By using theoline, pumping out the well water after treatment will not be necessary, thus reducing the inflow of silt.

Table 1 illustrates the result of the analysis of water for arsenic level and bacterial contamination. The arsenic level in the dugwell water was always below 0.05 mg/L, and was not detected at all in three tests with a detection limit of 0.01 mg/L (Method: ISO 6595-1982). Before the use of the disinfectant, the first total coliform count

Table 1. The arsenic levels and the coliform counts of the water analyzed during the period May 2001 to December 2001.

Dates	Dugwell Number	Arsenic Levels (mg/L)	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL
9 May 2001	PW9/SMP1	0.027	240	90
24 June		Treated with $KMnO_4$ (100 g/1000 L)		
17 July		<0.01	0	0
3 August		<0.01	124	NA
26 August		Treated with $KMnO_4$ (100 g/1000 L)		
1 October		<0.01	50	NA
4 October		Treated with $KMnO_4$ (50 g/1000 L)		
22 October		Treated with $KMnO_4$ (50 g/1000 L)		
18 December		<0.01	50	NA
20 December		Treated with $KMnO_4$ (50 g/1000 L)		

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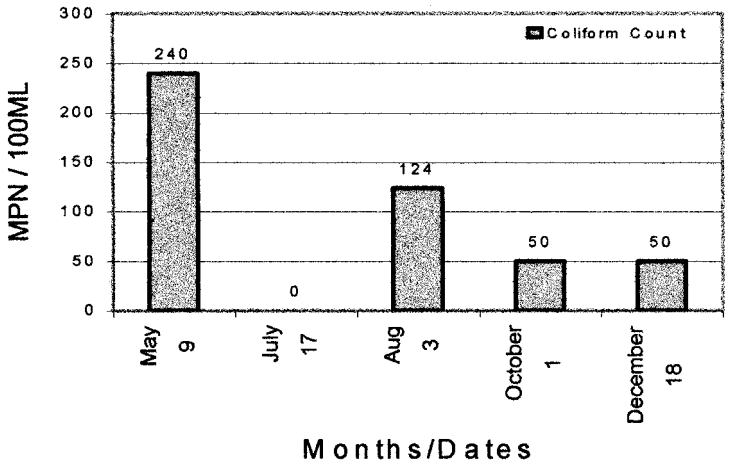

Figure 2. Bacterial count of the dugwell #PW9.

was 240/100 mL, and the fecal coliform count was 90/100 mL. The World Health Organization guideline for coliform organisms in unpiped water is 10/100 mL and for fecal coliform is 0/100 mL.[19]

The dugwell water was first treated with $KMnO_4$ (100 g/1000 L) in June 2001. The water analysis report, dated 17th July, showed both, total and fecal, counts to be 0. However, four weeks after the application of the disinfectant, the bacteria count increased to 124/100 mL. This can be attributed to the heavy rain during the monsoon season. In August, $KMnO_4$ was again applied. After more than a month the report dated 1st October showed the count to be 50/100 mL. Henceforth the dose was reduced to 50 g/1000 L to reduce the coloration of the water, but it was applied at intervals of two weeks. As seen in Fig. 2, during the period of October, November and December the coliform count did not exceed 50/100 mL. Based on questioning of participants, there is no suggestion of gastrointestinal effects, but it is hoped that the use of theoline will result in better control of bacterial contamination.

SUSTAINABILITY

One of the objectives of this kind of project is to create employment in the villages. It has been envisaged that 30 dugwells will be commissioned in the first phase, and each of them will supply water to 40 beneficiary families. To ensure proper functioning of such a large number of wells, three paid supervisors will be appointed. The monthly contributions of Rs 10.00 made by the beneficiary families will generate sufficient funds to provide a salary of Rs 1500 per month to each of the supervisors. These supervisors will be recruited locally and will be accountable to the beneficiary committees representing the dugwell users.

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CONCLUSION

The objective of the dugwell program is to develop a system for obtaining arsenic-free water sustainable at the village level using indigenous labor and materials. In the pilot program we found that dugwells could be installed at low cost, and the arsenic level was low, below 0.01 mg/L. Water testing showed increased counts of coliform bacteria, which was partly controlled by addition of $KMnO_4$ to the dugwell. Numerous problems have been encountered in the pilot program, which have led to revisions in plans for future dugwell installation. We believe these problems can be overcome, and that in appropriate settings dugwell can provide a solution to the arsenic problem. However, the goal of community participation and sustainability has so far been difficult to achieve mainly due to lack of sufficient educational and awareness programs.

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