Environment

Water Community

Solution Exchange for the Water Community Consolidated Reply

Query: Mitigation of Arsenic Contamination in Groundwater - Experiences

Compiled by Nitya Jacob, Resource Person and Ramya Gopalan, Research Associate

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From Arunabha Majumder, All India Institute of Public Health and Hygiene (AIIHPH), Kolkata

Posted 20 February 2008

I am a Professor, Department of Sanitary Engineering, All India Institute of Public Hygiene and Health in West Bengal and have worked extensively on arsenic contamination of groundwater.

Arsenic contamination was detected in West Bengal in the beginning of the 1980s. Today it has spread to 8 districts, 79 blocks, 11 municipal areas and 18 non-municipal areas in West Bengal. It is also found in Bihar, Jharkhand, Chhattisharh, Uttar Pradesh and Assam. Arsenic is a slow poisoning metalloid that causes skin lesion, keratosis, melanosis, liver and intestinal disorders, nausea, coughs, colds and influenza, nervous system disorders, urinary and kidney problems, lung and cardio-vascular problem. Acute arsenic poisoning causes cancer of the skin, lever, kidney and lung. Many villagers in these states are affected with arsenicosis. Poor villagers who already have a heavy burden of malnutrition are generally the victim of arsenicosis in the affected areas.

Mitigation measures include the following:

- Intensive water quality monitoring (100%sources on regular basis)
- Supply of arsenic free or arsenic-safe drinking water in the affected areas. This can be achieved by purified surface water supply, installing deep bore wells or tube wells to draw water from arsenic safe aquifers, rain water harvesting and removal of arsenic (domestic or community)
- Diagnosis and treatment of patients
- Awareness and motivation
- Conducting epidemiological studies in the arsenic affected areas
- Conducting hydro-geological study to assess dynamic mechanism of leaching of arsenic in ground water
- Providing nutritional support to the villagers
- Conducting Training programmes
- Development of IEC materials

Given the inter-state nature of the problem, I would like to recommend setting up a Centre of Excellence on Arsenic Problem Mitigation. This will pull together resources and expertise from different sources,

provide advice, develop appropriate technical solutions to the problem of arsenic contamination, act as a referral centre for people from arsenic-affected areas, conduct epidemiological and other studies and develop IEC material. It will also develop simple methods to test water in arsenic contaminated areas. The centre will act as a resource for all states from where arsenic contamination is being reported.

I therefore request members to share:

- Experiences on reducing arsenic in drinking water and its impact on human health as well as case studies where these have been implemented.

Based on your experiences, members are requested to provide further information to guide the establishment of the Centre of Excellence on Arsenic Problem Mitigation:

- Must the Ownership of the Centre be with the PRIs, State government or Central Government, or be outside the government machinery
- Suggestions with regard to mandate and structure for the Centre.

Look forward to your inputs

Responses were received on the Solution Exchange Water Community, with thanks, from

1. **R. Srikanth, WaterAid, New Delhi (Response 1; Response 2)**
2. **Krishan Khanna, iWatch, Mumbai**
3. **Nupur Bose, A.N. College, Patna (Response 1; Response 2)**
4. **Sushant K. Singh, A.N. College, Patna**
5. **Vijay Dhasmana, Arambh Society, Dehradun**
6. **Chandi Charan Dey, Ramakrishna Mission Lokasiksha Parishad, Kolkata**
7. **Anshuman, The Energy and Resources Institute (TERI), New Delhi**
8. **R. Seenivasan, DHAN Foundation, Madurai, Tamil Nadu**
9. **Ashok Ghosh, Department of Environment and Water Management, A.N. College, Patna**
10. **Ramesha C., Karnataka State Pollution Control Board, Bangalore**
11. **Braja Mishra, The Livelihood School, Hyderabad**
12. **Tomojeet Chakraborty, Globalnewsnet, Kolkata**
13. **Abhishek Mendiratta, Consultant, New Delhi**
14. **S. Vishwanath, Arghyam and Rainwater Club, Bangalore**
15. **Jasveen Jairath, CapnetSA, Hyderabad**
16. **S. D. Limaye, Ground Water Institute, Pune**
17. **N. Lakshmi Narayana, Dakshinya Institutes, Guntur, Andhra Pradesh**
18. **P.S. Yadav, Haryana Institute of Rural Development and Department of Development and Panchayats, Haryana**

Responses were received on the Yahoo Groups - WaterWatch, with thanks, from

1. **C. Udaya Shankar***
2. **Prosun Bhattacharya, KTH-International Groundwater Arsenic Research Group, Stockholm, Sweden***
3. **Rohit Pathania***
4. **Gautam Jayprakash***
5. **Sureshwar Sinha, Paani Morcha (Response 1; Response 2)***
6. **Gunnar Jacks, Land & Water Resources Engineering, KTH, Stockholm, Sweden***
7. **Mukul Mahant (Response 1; Response 2)***
8. **Tom Spalding***
9. **Ramesh N. Athavale***

10. S. K. Acharyya, Jadavpur University, Kolkata*

** Offline Contributions*

Further contributions are welcome!

Summary of Responses

The query on arsenic generated a rich debate around the need for a Centre of Excellence in Arsenic mitigation, measures to eliminate arsenic in drinking water and the permissible standards of arsenic in drinking water. The members suggested setting up the Centre would help focus national efforts to mitigate arsenic contamination, and suggested the terms of reference for the Centre. They also offered their support for the initiative.

On permissible standards of arsenic in drinking water, members felt current Indian standards were too lax and needed to be considerably tightened. Further, process of blocking wells that yield arsenic-contaminated water had to be more rigorous. Testing for the presence of arsenic must be more systematic and widespread given the peculiar characteristics of this contaminant.

Participants suggested various mitigation measures, ranging from filters to storage and use of surface and rain water, in arsenic-affected areas of India. They provided pros and cons of each solution and it emerged that a certain type of household filter would be best suited to Indian conditions, if adequate and safe surface water was unavailable.

The Centre of Excellence on Arsenic Problem Mitigation, said some participants, must function as an autonomous institution under the Union Government, called the National Institute of Drinking Water Management/All India Institute of Drinking Water Management and felt it would be appropriate for DDWS to consider setting up the Centre, with four regional centres, in arsenic-affected areas.

However, others felt the Centre must be independent of the government, staffed by professionals and field practitioners. They suggested the government, international NGOs and other players support, help develop and run the Centre. Participants also recommended the inclusion of local community representatives and corporate sector as stakeholders in the Centre.

Regarding its terms of reference, the Centre must pool expertise from different sources to provide advice, develop appropriate technical solutions, act as a referral centre for people from arsenic-affected areas, conduct epidemiological studies and develop IEC material. Importantly, members recommended development of simple methods to test water in arsenic contaminated areas. The Centre must act as a resource for States, which report arsenic contamination.

The following activities were suggested:

- **Hydro-geochemical studies** for sources of arsenic contamination
- **Microbial and Plant studies** for bio- and phyto- remediation
- **Epidemiological studies** for assessing arsenicosis and its follow-up treatment
- **Socio-Economic studies** of the vulnerable population to facilitate cost-effective mitigation

- And, based upon above findings, a **Technical Centre** for building viable mitigation techniques, suitable for specific environments of arsenic hotspots

Some members shared experiences of similar institutes and said adding a Technical Centre will shift the focus to laboratory-based R&D activities rather than aiding in the solution of field-level problems. It is therefore critical the Centre focuses on field-level issues to assess the spread and impact of arsenic-contaminated through a multi-dimensional approach.

The move to set up the Centre is a commendable initiative. Communications is the key for which the Centre can work closely with district-level health and administration officials to ensure IEC material was distributed in the district. The Centre must also bridge the global and the local.

Members suggested the Centre address failures of mitigation activities in different parts of India, such as **Bihar**, by distilling what worked in other states such as **Karnataka,** which used rainwater harvesting systems successfully documented by videos, with respect to providing safe drinking water in arsenic-affected areas. An experience from **Uttarakhand** showed community education was needed to ensure appropriate use of roof rainwater harvesting techniques. Members also examined the **Bangladesh** Government's arsenic response strategy.

Members highlighted the WHO guidelines and noted that US-EPA raised the permissible arsenic limit in drinking water to 10ppb while other developed countries were planning on setting it at 5 ppb. However, in India, the limit is 50 ppb, which members felt was too high. This high limit was set based on health concerns and economic considerations. However, deliberations are underway for a *desirable* limit of 10 ppb because arsenicosis affects the poor the most. Its effects, said participants, are exacerbated by the deficient diets of the poor and the higher intake of contaminated fluids, given the hotter weather in the country. Participants strongly felt the guidelines/standards on arsenic fluoride must be revisited given differences in weather patterns and dietary and water intake.

A new perspective is needed on the problem, said participants, given the spatial spread of arsenic contaminated ground water sources in densely populated Indo-Gangetic plains. A lot more is needed to understand and manage the problem comprehensively to implement appropriate mitigation measures.

Respondents provided details of technologies for arsenic removal as well as reference of Organizations engaged in their development. In developed countries, members noted the use permissible reactive barriers to stop and prevent spreading of groundwater pollution and further reported that while the principle is simple the implementation is costly. In India, NEERI in Nagpur developed very inexpensive methods to remove arsenic from water using Alum and small doses of Chorine. Onsite safe production of Chlorine can be done through electrolysis of common salt using Modern Electrochlorinators.

Another removal method was the Bio-sand filter with an add on, promoted by CAWST Worldwide and Dhan Foundation in India. One innovation in **Nepal** involves the use of rusted iron nails or iron dust in combination with the Biosand filter. Sono Arsenic Filters were another cost-effective solution, and methods like Coprecipitation and Ion Exchange for mass purification methods could be implemented at Municipality and Panchayat levels. Members suggested capacity building for implementing these and other treatment techniques. Respondents also recommended Information Bases for details of equipments and list of resources on the subject and until the establishment of the Centre, such simple affordable technologies can be extended as a relief to Communities, suggested members.

Costs of all identification, awareness, treatment and mitigation activities must be shared between communities and PRIs in the ratio of 90:10 for accountability. This would maximize community ownership and acceptability of measures, felt members. The strategy must be based on field studies to assess ground realities, including socio-economic and geographic conditions. The effects of arsenic can also be

mitigated by improving diets of vulnerable people through a subsidized market system for access to nutrient rich food.

Awareness leads to policy intervention, felt members and reiterated the urgent need to highlight the issue of arsenic contamination at the national level ensuring accountability from the pollution control boards and involving Panchayats to spread awareness and facilitate mitigation. Despite the operation of several mitigation programmes relief is missing in many affected areas which thus signifies the need to understand the reasons for failure together with ensuring strong community participation and beneficiary ownership of mitigation structures.

Comparative Experiences

Bihar

Significance of Community Ownership and Government Accountability, Semariya Ojhapatti Village, Bhojpur District *(from Nupur Bose, A.N. College, Patna; response 1)*
Mitigation strategies in arsenic affected river belt districts, adopted by the government include construction of overhead tanks, rainwater harvesting units, revival of open wells, and provision of piped water. However, no initiative has worked and villagers continue to drink arsenic affected water, due to the lack of community participation, no accountability by state government officials, and subsequent lack of linkage between authorities and villagers. Recent newspaper reports highlight this point.

Ground Realities of Arsenic Affected Villages, Maner and Bhagalpur Villages, Patna District *(from Ashok Ghosh, Department of Environment and Water Management, A.N.College, Patna)*
The rural population is aware their water is arsenic contaminated, but are forced to drink it, because there are no alternative despite promises from groups. This has left the community feeling angry and that they are "subjects" of academic research. Installed rainwater harvesting units are now redundant and water stored in tanks stinks, and due to lack of maintenance, the open wells have bacterial contamination. Arsenic filters, would solve the problem, but are too expensive for the community.

Karnataka

Sachetana Programme *(from S. Vishwanath, Arghyam and Rainwater Club, Bangalore)*
In 60 villages BIRD-K built rooftop rainwater harvesting tanks with capacities of 5,000-10,000 litres, which filters and provides 20 litres per day of fluoride-free water to families for drinking and cooking. The tanks are all underground tanks with a robust filter, located inside the house below the room or kitchen floor and the water is regularly tested for potability using the H2S strip. Community members maintain the tanks and as a result have noticed a difference in their health after drinking rainwater.

Uttarakhand

Misuse of Arsenic Free Water from Rainwater Harvesting Systems *(from P.S. Yadav, Haryana Institute of Rural Development & Department of Development and Panchayats, Haryana)*
Many households installed roof rainwater harvesting systems. However the systems are not used for drinking. The arsenic free water is used for watering cattle, washing clothes and bathing. Storage tanks were found exposed to the sun and air and the rainwater was therefore neither protected nor kept covered.

International

Bangladesh

Evolution of Government's Arsenic Response Strategy *(from Abhishek Mendiratta, Consultant, New Delhi)*
Phase I conducted a random testing to establish the contamination pattern and found 29% of wells affected. The 5 *upazila* (sub-district) project *tested* 105,000 wells, found 800 patients. Phase III expanded to 15 more upazilas, testing 300,000, identified 2,700 patients. Thus, mitigation efforts were launched- rainwater collection, surface water treatment systems and arsenic free dugwells. Phase IV added 25 more upazilas and completed testing of 500,000 wells by end 2002.

Related Resources

Recommended Documentation

From S. Vishwanath, Arghyam and Rainwater Club, Bangalore

Rooftop Rainwater Harvesting – Fluoride Free Water and Filter
Video; BIRD-K; YouTube; Karnataka
Available at http://www.youtube.com/v/7qiY011J6uI (Size: 14 MB)
Explains in Kanada the rooftop rainwater harvesting system built by household and BIRD-K in Laghumuddepalli village, this film can be used to explain the system in affected villages

Rooftop Rainwater Harvesting – Fluoride Free Water for Homes
Video; BIRD-K; YouTube; Karnataka
Available at http://www.youtube.com/v/cvmNNdauJqw (Size: 14 MB)
Explains in Kanada the rooftop rainwater harvesting system built by household and BIRD-K in Laghumuddepalli village, this film can be used to explain the system in affected villages

Bangladesh's Arsenic Poisoning: Who is to Blame? *(from Tom Spalding)*
Article; by Fred Pearce; UNESCO; Courier; 2001
Available at http://www.unesco.org/courier/2001_01/uk/planet.htm
Discusses the origin, causes and status of arsenic contamination in the water sources of villages in Bangladesh

Water Harvesting and Sustainable Supply in India *(from Ramesh N. Athavale)*
Book; by R.N. Athavale; Centre for Science and Environment (CSE); 2003; Permission Required: Yes, paid publication. Ordering details available at https://www.vedamsbooks.com/no29992.htm
Presents scientific, perspective and technical information required for traditional and recent water harvesting practices, discusses arsenic in groundwater and use of dugwells

From Ramya Gopalan, Research Associate

Arsenic Drinking Water Regulations in Developing Countries with Extensive Exposure
Paper; by Allan H. Smith, *et al*; Toxicology; Elsevier Ireland Ltd; 2004
Available at http://socrates.berkeley.edu/~asrg/04SmithAsDWRegulations.pdf (PDF Size: 204 KB)
Discusses the complexity in choosing an appropriate regulatory response in developing countries with large populations and higher concentrations of arsenic in drinking water,

Contamination of Drinking-Water by Arsenic in Bangladesh: A Public Health Emergency
Paper; by Allan H. Smith *et al*; Bulletin of the World Health Organization; 2000
Available at http://socrates.berkeley.edu/~asrg/00SmithContamDWBngldsh.pdf (PDF Size: 862 KB)
Describes the history of the discovery of arsenic in drinking-water in Bangladesh and recommends intervention strategies.

Arsenic in Drinking Water
Factsheet; World Health Organization (WHO); May 2001
Available at http://www.who.int/mediacentre/factsheets/fs210/en/

Details source, effects, measurement and prevention and control of arsenic in water together with the global situation and WHO's activities in addressing the same

Study on Arsenic Level in Ground Water of Delhi using Hydride Generator Accessory Coupled with Atomic Absorption Spectrophotometer
Paper; by Sanjeev Lalwani; Indian Journal of Clinical Biochemistry; India Water Portal; 2004
Available at http://www.indiawaterportal.org/tt/gwm/res/iaft04i2p135.pdf (PDF Size: 102 KB)

Reports arsenic containing sediments and chemicals into the soil due to dumping of garbage rich in chemicals into open landfills as possible source of arsenic in ground water

Arsenic – India's Health Crisis Attracting Global Attention
News Article; by Samuel Taylor Coleridge; Current Science, Vol. 88, No. 5, 10 ; March 2005
Available at http://www.iisc.ernet.in/currsci/mar102005/683.pdf (PDF Size: 24 KB)

Details the evolution and spread of arsenic contamination in ground water and suggests solutions for alleviating the arsenic problem

Recommended Organizations and Programmes

From Krishan Khanna, iWatch, Mumbai

National Environmental Engineering Research Institute (NEERI), Nagpur
Nehru Marg, Nagpur-440020; Tel: +91-712-2249885-88/2249970-72; Fax: +91-712-2249900; http://www.neeri.res.in/

Developed low cost methods to remove Arsenic from water which requires inputs of Alum and small doses of Chorine to completely remove all traces of Arsenic and make it safe

Titanor Components Limited, Goa
Plot Nos.184, 185 & 189, Kundaim Industrial Estate, Kundaim-403115; Tel: +91-832-3981100; Fax: +91-832-3981101; titanor@denora.com; http://www.titanor.com/

Recommended for details of arsenic treatment equipment such as modern electrochlorinators etc.

From R. Seenivasan, DHAN Foundation, Madurai, Tamil Nadu

Centre for Affordable Water & Sanitation Technology (CAWST), Canada
Bay 12, 2916 5th Avenue NE, Calgary, Alberta, Canada-T2A 6K4; Tel: +1-403-243-3285; Fax: +1-403-243-6199; cawst@cawst.org; http://www.cawst.org/

Promotes biosand filter in many parts of the world including India and adds on an arsenic removal component to the conventional biosand filter to serve for arsenic removal

DHAN Foundation, Tamil Nadu
18, Pillaiyar Koil Street, S.S. Colony, Madurai-625016; Tel: +91-452-2610794/2610805; Fax: +91-452-2602247 dhantank@gmail.com; http://www.dhan.org/

Promotes the biosand water filters for arsenic removal and conducts training programmes on biosand filter technology

The Bio-Sand Filter
http://www.biosandfilter.org/biosandfilter/index.php/item/229

Discusses the effectiveness of slow sand filtration as a treatment of contaminants like arsenic in water

BAIF Institute For Rural Development-Karnataka (BIRD-K), Karnataka *(from S. Vishwanath, Arghyam and Rainwater Club, Bangalore)*
"Kamadhenu", P.B. No 3, BAIF Campus, Tiptur Hassan Road, Sharadanagara, Tiptur-572202; Tel: +91-8134-50659/43755; Fax: +91-8134-51337 baif@bgl.vsnl.net.in; http://mpcpdb.frlht.org.in/BIRDK.htm; Contact Dr. G. N. S. Reddy and Mr. Dyasa; birdksachetana@gmail.com

Promotes rainwater harvesting systems in fluoride and arsenic affected villages

Environment and Public Health Organization (ENPHO), Nepal *(from Prosun Bhattacharya, KTH-International Groundwater Arsenic Research Group, Stockholm, Sweden)*
110/25 Adarsa Marg-1, Thapagaon, New Baneshwor, G.P.O Box No.: 4102, Kathmandu (East); Tel: +977-1-4468641/4493188; Fax: +977-1-4491376 enpho@mail.com.np; http://www.enpho.org/drinking_water_quality.htm

Conducts research and implementation for identifying or developing effective and user-friendly arsenic removal best options suitable to local conditions

Recommended Portals and Information Bases

Arsenic in Drinking Water, US-Environmental Protection Agency (US-EPA), Washington DC, U.S.A *(from Nupur Bose, A.N. College, Patna; response 2)*
http://www.epa.gov/safewater/arsenic/index.html

Provides details of EPA's arsenic standard, notes on arsenic in drinking water and guidance materials for American states and water systems to comply with the standard

Arsenic in Drinking Water, Water, Sanitation and Health, World Health Organization (WHO), Geneva, Switzerland *(from Krishan Khanna, iWatch, Mumbai)*
http://www.who.int/water_sanitation_health/dwq/arsenic/en/

Reviews arsenic in drinking water, includes a discussion paper on health effects, fact sheet on arsenic contamination and WHO Guidelines for Drinking Water Quality (2003)

From R. Seenivasan, DHAN Foundation, Madurai, Tamil Nadu

Clearinghouse for Low-Cost Household Water Treatment Technologies, Jalmandir
http://www.jalmandir.com/arsenic/arsenic-mitigation.html

Lists appropriate arsenic mitigation technologies includes Kanchan and Shapla Arsenic Filter, Bucket Treatment Unit (BTU), Rainwater Harvesting, 3-Pitcher, SORAS & STAR

Arsenic Remediation Technologies, Massachusetts Institute of Technology (MIT), Massachusetts, U.S.A
http://web.mit.edu/murcott/www/arsenic/details.htm

Details 9 categories of remediation processes for arsenic removal includes oxidation, co-precipitation, sedimentation, filtration, absorption, ion exchange, reverse osmosis etc.

Recommended Tools and Technologies

Sono Arsenic Filter *(from Tomojeet Chakraborty, Globalnewsnet, Kolkata)*
Treatment Technology; Invented by Abul Hussam, George Mason University (GMU), Fairfax, Virginia. Information available at http://en.wikipedia.org/wiki/Sono_arsenic_filter

Contains 20 pounds of shards of porous iron, which bonds chemically with arsenic, includes charcoal, sand and bits of brick and filters most of the arsenic from well water

Related Consolidated Replies

Arsenic Levels and Drinking Water Quality, from Nupur Bose, A.N. College, Patna (Advice). Water Community,
Issued 8 September 2005. Available at http://www.solutionexchange-un.net.in/environment/cr/cr-se-wes-08090501.pdf (PDF, Size: 100 KB)

Discusses arsenic contamination and the levels of arsenic contamination that are considered permissible

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Responses in Full

R. Srikanth, WaterAid, New Delhi *(response 1)*

I agree with Majumder's view. It is not only Arsenic, we need to setup center of excellence on Fluoride, microbial contamination as well . Today fluorosis has emerged as number one public health disaster in India and China. There are certain concerns that can also be addressed by resource center.

1. Uniformity on IEC material: This would avoid duplication
2. Consensus on technological options : At present the opinion is divided among practitioners including NGOs and government
3. Research in linking WQ and health : This will help us identifying and prioritizing contaminants in community based approach
4. Establishing national drinking water standards based on scientific oversight rather than adopting WHO guidelines
5. Linking center for excellence with grassroots organizations/communities in rural India is a big
6. Response_det, xxx, xxxchallenge. Institutions are developed in urban centers but benefits seldom percolate into remote villages affected by fluorosis
7. Center of excellence should not end up like our CSIR institutions. The center should be organically linked to the affected rural population.

Krishan Khanna, iWatch, Mumbai

NEERI in Nagpur has developed very low cost methods to remove Arsenic from water. I believe it requires inputs of Alum and small doses of Chorine to completely remove all traces of Arsenic and make it safe for Human Consumption.

For on-site generation of Chlorine, in a safe mode, using only common salt and electricity as raw materials, use of Modern Electrochlorinators is recommended, as they produce Chlorine in the form of Sodium Hypo with 8000ppm of Free Chlorine content. These can also be used for "Drinking Water Disinfection".

As per W.H.O, only 1 to 2ppm free Chlorine usage, with max of 0.50 ppm residual Chlorine in water is sufficient to remove harmful effects of all diseases.

For details of these equipments, which are made in India, please see http://www.titanor.com/

Nupur Bose, A.N. College, Patna *(response 1)*

PROJECT ARSENIC is a research initiative of the Department of Environment and Water Management, A.N.College, Patna, which has completed a UNICEF-sponsored project on Study of Arsenic Contaminated Aquifers in Patna, Bhojpur, Vaishali and Bhagalpur Districts, Bihar. At present, it is conducting researches

on microbes to facilitate bioremediation of arsenic contamination; on arsenic infiltration into the foodchain in Patna hotspots; and on alternative arsenic filters.

In Bihar, mitigation strategies in the arsenic affected river belt districts, adopted by the govt. include construction of overhead tanks, rainwater harvesting units, revival of open wells, and provision of piped water. However, none of the initiatives are working, and villagers are back to drinking arsenic affected water. This lack of linkage between the authorities and villagers stems mainly due to lack of community participation and state govt.'s accountability. This point has also been highlighted in recent newspaper reports, especially in the case of Semariya Ojhapatti village of Bhojpur district.

It is also found that after our submission of detailed report on arsenic levels in each hand pump of our study area, no other comprehensive study [hydro-geological and epidemiological] has been conducted. Our initial findings indicate that in north Bihar, Holocene sediments bear arseniferous aquifers, while in south Bihar, it is the Pleistocene deposits.

This study group is conducting a mitigation experiment by using a gravity-based arsenic filter, which is cost-effective and does not use power resource [a scarce commodity in Bihar].

We welcome your proposal of setting up a Centre of Excellence on Arsenic Problem Mitigation, as we feel that the dimensions of the arsenic problem can be best assessed and confronted with multi-disciplinary research.

In view of increasing geographical areas under arsenic contaminated ground water, a few suggestions for its establishment is being made hereunder -

A. **Stakeholders** – Research Institutions, Govt. representatives, local community representatives, corporate sector.
B. This center can have five sectors to work upon, in order to avoid fragmented, repetitive research-
    - **Hydro-geochemical studies** for sources of arsenic
    - **Microbial and Plant studies** for bio- and phyto- remediation
    - **Epidemiological studies** for assessing arsenicosis for follow-up treatment
    - **Socio-Economic studies** of the vulnerable population to facilitate cost-effective mitigation
    - and, based upon findings of above, a **Technical Centre** for building viable mitigation techniques, suitable for specific environments of arsenic hotspots

C. Maintenance & operation of the Centre by arsenic affected community members
D. This has to be central database unit to which all reports are to be submitted. In view of humanitarian aspects, information is to be accessible to all stakeholders
E. International and national research bodies to liaison in this organization

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Nupur Bose, A.N. College, Patna *(response 2)*

The relentless spatial spread of arsenic contaminated ground water sources in the densely populated river plains of India demands a new perspective on this problem. As increased incidence of arsenic-associated skin lesions, lung and bladder cancer are being perceived, and the US-EPA has marked a permissible arsenic limit at 10 ppb in drinking water as "critical deadline and requirement".

In other developed economies, efforts are on to bring the figure down to 5 ppb. In India, it has been indicated that, taking into consideration the economic factors, the permissible limit of 50 ppb has been adopted in the concerned states. Our country is also talking in terms of a *desirable* limit of 10 ppb. Clearly, the bases for adopting varying levels of permissible limit of arsenic in drinking water range from direct health concerns in developed societies to economic permutation and combinations in my country.

It is also to be noted that human resistance to arsenicosis has a strong positive correlation to a nutritious diet.

In the given Indian scenario, wherein the poorest of the poor are becoming victims of arsenicosis, environmentalists and social engineers in India are faced with the ethical question of whether to consider 10 ppb or 50 ppb as the defining permissible limit of arsenic in drinking water. The answer has to take into consideration human inequities and deprivations and the promotion of the same in the name of economic concerns and logistical issues.

Sushant K. Singh, A.N. College, Patna

We are researching these topics in the Department of Environment and Water Management, A N College, Patna, with a focus on the effects of arsenic on the food chain. The most important factor to monitor arsenic levels is screening of all drinking and irrigation water at least twice a year. The process of mitigating arsenic contamination needs 100% community ownership for acceptability and sustainability, and this can be achieved by suitably designed IEC material. We have found the participation of the community and the Panchayati Raj Institutions should be in the ratio of 90:10 for the maximum accountability.

The strategy is to be developed based on field studies to assess the ground realities, including the socio-economic and geographical conditions. We have found sanitary wells to be a good source of arsenic-free drinking water, and other surface water supply systems can also serve the purpose. Open wells also work, but the water may need further treatment to be potable (reduce the bacteria count, smell, etc).

The effects of arsenic can also be mitigated by enhancing the diets of people through setting up a subsidized market system so that people have access to nutrient-rich food, proteins and other sulphur-containing food.

Vijay Dhasmana, Arambh Society, Dehradun

It has been a very intense and learning discussion. I just wanted to add a couple of points.

Awareness leads to policy intervention. There is an urgent need to highlight the issue of arsenic contamination at national level and demand accountability from the pollution control boards. Panchayats have to be roped in to spread awareness and facilitate mitigation. We have to stop pollution at the root, that will reduce the mitigation expenses. Further, as happens in cases of groundwater contamination, the pollution is not restricted to the directly affected area, but is transported to distant areas through food, water, air, soil etc., and is one area of study by the institute.

Chandi Charan Dey, Ramakrishna Mission Lokasiksha Parishad, Kolkata

Prof Majumder has rightly initiated the idea of an Institute of Excellence in Arsenic mitigation that can extend technical and managerial support to different actors working in solving the arsenic mitigation problem. The institute can be independent of the government, with participation of technical/professional people and field practitioners. The government, international NGOs as well as other players can extend support to develop and run the institute.

As the mitigation of arsenic has to be tackled in a multi-dimensional manner that includes technical, medical and social aspects, the institute will have to adopt a multi-dimensional approach. Arsenic is a vast and multi-dimensional issue that was initially identified in West Bengal but in recent years, it has spread to Bihar, Uttar Pradesh and Assam. The institute will also help to integrate mitigation efforts in different states.

However, attaching the institute with another technical organization will make laboratory-based R&D activities the focus that may not help in solving field-level problems. This has been the experience with regard to other similar institutes. It is critical that the institute tackles field-level issues to assess the spread and impact of arsenic-contaminated water. Identification of the location of the problem and its mitigation measures are really very complicated tasks.

I do strongly consider that the Water Community Solution Exchange has a great role in advocating and pursuing this issue.

Anshuman, The Energy and Resources Institute (TERI), New Delhi

Presence of arsenic in the ground waters of different parts of the country has been well established. While a number of studies have probed its quantification and spread in a localized manner, a lot needs to be done to understand the problem more closely/holistically to be able to envisage and execute effective mitigation plan. While on one hand action is warranted at communities/stakeholder level through awareness along with mitigative and treatment solutions but equally important is the need to understand the origin and behavior of the problem underground.

Ground/surface water modeling tools combined with strategic water quality evaluation program are effective tools for studying the origin and flow of contaminant in the groundwater. It is the warrant of time for widespread use of such tools in consonance with strategic & more intense groundwater monitoring and water quality testing in each of the arsenic affected region to understand the basic origin and dynamic behavior of the contaminant (rather than localized source information) to be able to appropriately implement effective mitigation program. I strongly feel that a center to study the arsenic problem must at first have such advanced tools to unravel the problem in totality to be able to make a difference in addressing the menace.

I appreciate Prof. Majumder's idea and would be more than happy to contribute in addressing arsenic related issues.

R. Seenivasan, DHAN Foundation, Madurai, Tamil Nadu

There are agencies in Nepal working with Arsenic removal from the available water at the household level. One such innovation is that to use rusted iron nails or iron dust being used in combination with the Biosand filter for removal of arsenic.

The Biosand filter is promoted by a Canadian NGO named **Centre for Affordable Water and Sanitation Technology (CAWST)** http://www.cawst.org/ in many parts of the world including India. However arsenic removal is an add on to a conventional biosand filter to serve arsenic removal.

There are enough resources available on the current and completed research on the subject in MIT civil engineering department's website. Also a list of resources are available on this subject at the following link:
Clearing House for Low Cost Household Water Treatment Technologies
http://www.jalmandir.com/arsenic/kanchan/kanchan-arsenic-filter.html

The idea of setting up an exclusive institution is welcome and meanwhile such simple affordable technologies can be extended as a relief to communities till they get pure water.

In India, the biosand water filters are promoted by DHAN Foundation and members interested in the subject can contact dhantank@gmail.com

Ashok Ghosh, Department of Environment and Water Management, A.N. College, Patna

It is good to see so many responses to the query related to arsenic mitigation. My research group is working in Bihar on arsenic issue since 2004 and identified many arsenic hotspots along the river Ganges. Money has been spent in crores for mitigation by Bihar Govt. and other National and International agencies, but unfortunately majority of exposed population are drinking arsenic laced water even today. This indicates the failure of the mitigation strategy. I visited Maner in Patna District and Bhagalpur after the initiation of the present query to know the ground realities. The picture was pathetic. The response of the rural population was that they have become subjects of academic research only. They are aware of the problem but angry because they have to drink the arsenic contaminated water as there is no alternative even after may promises by many groups. The rainwater-harvesting units installed have become redundant and water stored in the tank stinks. The open wells are not sanitized and has excessive bacterial contamination due to lack of maintenance. The Arsenic filters are expensive, beyond the reach of the poor rural population.

I am strongly convinced that mitigation will not succeed only by spending money. There has to be strong community participation and the ownership of mitigation structure must go to the beneficiaries. No doubt, Ground/surface water modeling tools combined with strategic water quality evaluation program are effective tools for studying the origin and flow of contaminant in the groundwater, and I will welcome any such initiative. But at the same time only the scientific studies will not solve the problem. Already we have thousands of scientific data from Bangladesh, West Bengal, Bihar, Assam, Uttar Pradesh, Nepal and other places about the arsenic contamination in ground water. But despite that the relief is missing in many affected areas. We have to find out the reasons behind the failure of mitigation programmes and find a practical solution.

My research group will support such initiative.

Ramesha C, Karnataka State Pollution Control Board, Bangalore

Permissible reactive barriers, has been used in developed countries for stopping and spreading of ground water pollution. The principle is simple. A deep trench is dug across pollution source in the direction of pollution with material, which has capability to react with pollutant and reduce ground water pollution. But implementation is costly due to required efforts in construction of trenches. In current case bore well/wells can be drilled near drinking ground water source and can be filled with adsorbants/reacting granules.

Braja Mishra, The Livelihood School, Hyderabad

Dear Arunabha, this is a really commendable initiative by your esteemed institute! But the message has very limited reach out as many organisations/people working in health, water and sanitation programmes in the interior parts of the country are not the members of solution exchange community nor do they have access to internet. Reaching out to this mass is really challenging. I do not know, apart from sharing your idea on net what other efforts you are making to reach out this masses! I think the District Collectors/Magistrates and Chief District Medical Officers of the affected districts can also be communicated in hard copies about the initiative and they in turn shall transmit the same down the line for widespread publicity about your efforts.

R. Srikanth, WaterAid, New Delhi *(response 2)*

The standard on Arsenic fluoride need to be revisited because of following reasons:

a. The standards and guidelines developed by western countries (US-EPA;WHO) are based on temperate climate where climate is mild that facilitate low intake of water and these standards are based on healthy individual in predominantly urban context.
b. While in India it is the rural population who belong to farming community are affected by arsenic and fluoride. This population consume on an average 3-5 lt of water during most part of the year in the drier parts of the country where these disaster often strikes and suffer from malnutrition and other deprivation. Habitual Indian diet is often semisolid and contains more water than those consumed in west.
c. Unfortunately no research is done on at what level these toxic compounds affects individual at different geographical regions and populations in India which should ideally form the basis of fixing standards
d. Ideally the standards need to be lowered in Indian context taking into consideration of above facts and this need and not economic factors
e. National drinking water standards need to consider local issues and not blindly adopting western standards

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Tomojeet Chakraborty, Globalnewsnet, Kolkata

It is a worthy proposal. Some suggestions in this regard:

Our approach should be a three pronged one:

i. **Identification of Arsenic affected areas and spread awareness in such areas as to that diseases like arsenicosis or hyperkeratosis or cardiovascular ailments originally stem from the deadly allosteric regulator**. Probably Bangladesh and Ganges Plains in West Bengal are the hardest hit regions .Specially Bangladesh bore the brunt since 1970s the efforts to eradicate sanitation and diarrheal problems saw millions of deep tube well being sunk to supply clean potable water. This tube wells <approx 8 million> dug out water naturally contaminated with Arsenic. Also 19 districts in WB are suffering from Arsenic contamination. **So in this and other regions, like Rajnandgaon, M.P etc., sampling should be done and all such tubewells be identified and sealed.** Probably this would require a close and active involvement Of **PRIs** and **Municipality's with NGOs and Aid Agencies.**
    - At the Grassroots level we can then have a structure at Block Level with an Arsenic Committee set up at Block Level having representatives from Panchayat Samity, GPs, NGOs, Aid Agencies. They will be running the show with a team working at GP level. We can have youths under NREGS working under this committee.
    - At District Level another committee will be there comprising of Zilla Parishad Engineers, Elected representatives as well as Subject experts.
    - The Center of Studies will be working at the apex level of this structure.

ii. **Water Treatment: Sono Arsenic Filters** are cost effective solutions to the problem. For mass purification methods like **Coprecipitation, Ion Exchange** might be implemented for Municipality, GP level.

iii. **Capacity Building: Proper Training** needs to be disseminated to the Team taking care of the Identification, Awareness and Sono Arsenic Filter deployment part. This workforce can be effectively trained under the **Vocational Institutions and the Vocational Council** can award certificates to the successful candidates. I feel we can achieve our goals through this.

Probably I am being too optimistic but this is a structure I could have thought of.

Abhishek Mendiratta, Consultant, New Delhi

Arsenic contamination was first detected in West Bengal in India in 1987 when medical researchers, finding serious skin lesions in some patients, suspected a form of arsenic poisoning. Subsequent surveys showed dangerous levels of arsenic in tube-wells tested along the West Bengal border. In 1994 the World Health Organization (WHO) notified that arsenic contamination was suspected in certain districts along the West Bengal border with Bangladesh.

It was not until 1997, after a considerable amount of testing by the Department of Public Health Engineering (DPHE) that it became clear that arsenic contamination was a widespread problem but some experts continued to believe that arsenic was not naturally occurring and instead the contamination was coming from pesticides and treated telephone poles. The Government of Bangladesh is currently in the fourth phase of its arsenic response strategy. The evolution of the programme is given below.

Phase I, 1998-1999: Random, national testing of 51,000 tube-wells which established the overall pattern of contamination (29% of all wells affected above the national standard).
Phase II: 1999-2000: In the 5 upazila (sub-district) project, a four part approach was developed: i) communication for raising awareness through a multi-media campaign; ii) testing of all wells, iii) identification and management of patients, and iv) provision of alternative water sources in line with the national government policy on rural water supply and sanitation. During this phase, 105,000 wells were tested in the 5 upazilas, and 800 patients identified.

Phase III: 2001-2002: The same activities were expanded to another 15 upazilas and 300,000 wells were tested, of which 68% were affected with arsenic and identified 2,700 patients. Mitigation activities (alternative water supplies) were launched with an emphasis on arsenic avoidance. Household rainwater collection and community-level surface water treatment systems were demonstrated, and arsenic-free dug wells rehabilitated.

Phase IV: 2002-2003: Another 25 more upazilas were added. This is 10% of all upazilas in the country, and 20% of the most heavily affected ones. The testing of approximately 500,000 wells was completed by December 31, 2002.

Testing: By December 2002, as many as 900,000 tube-wells were tested.

Alternative Water Systems: This included supporting setting up model rainwater harvesting systems, pond sand filtration and dug wells and testing adsorbent systems with local and imported media.

Communication: An extensive multi-media communication strategy was launched in December 1999 focussing on arsenic's effects, the need to use and properly maintain alternative sources of safe water, sharing water, and how to care for people who have been affected by arsenic. Information material was designed for health workers, doctors, agricultural extension workers, tube-well mechanics and students and pictorial booklets produced for illiterate people.

Health Training, Management and Surveillance: the Ministry of Health trained 16,000 doctors, health workers nation wide, and helped develop the institutional capacity to diagnose and manage patients.

Testing process: Highly accurate testing can be done in laboratories, but doing all testing in labs is expensive and logistically impossible. The contamination levels in wells change during the day and by season so these are accurate for a specific time. Further, it is important that the community sees and trusts the test being carried out.

Most testing was done at the field level using specially-designed arsenic field test-kits, that are cost-effective and can be done rapidly on a large scale, as well as give results to the community on site in a matter of minutes. A scientific procedure was followed by sampling carried up authorized labs. Maps showing the demographics and the geographic boundaries were prepared, that show the village names,

etc., to guide the process. The maps and GPS used during the surveys achieved an accuracy of 5-8 metres. The survey sampled public handpumps in working condition and were marked for subsequent identification.

Arsenic mitigation strategy. This includes policy support to government to develop a comprehensive plan, and developing a water quality testing protocol for arsenic. Further, for public awareness, a media and community mobilization campaign through NGOs and CBOs is needed. Development of low cost systems for drinking water such as rainwater harvesting, pond sand filtration and surface water treatment by local institutions is another part of the strategy. Communities have to be provided support for health training, identifying patients and their management.

S. Vishwanath, Arghyam and Rainwater Club, Bangalore

The community has provided excellent answers ranging from domestic to community methods for removing arsenic from water, to rainwater harvesting and to shift to open well and surface water sources, which may not have arsenic contamination.

An example was also quoted regarding rainwater harvesting as a solution which has NOT worked in the Patna and Bhagalpur districts and the rainwater tank has 'stinking water'. Obviously, the question has to be asked as to why the community and individuals see themselves as being experimented upon and why the rainwater tanks do not work. I want to share an experience from Karnataka concerning 5400 flouride-affected villages.

BIRD-K works in 4 districts of the state, which have a high level of fluoride in groundwater. In 60 villages under the Sachetana programme of the Government of Karnataka, rooftop rainwater harvesting tanks are being built with capacities of 5,000-10,000 litres. This water is filtered and 20 litres per day of this fluoride-free water is provided to families for drinking and cooking. This has received an excellent response from the community, which is taking care of the rainwater tanks and in three months have found a difference in their health after drinking rainwater.

The tanks are all underground tanks with a robust filter. Some are located inside the house below the room floor or the kitchen floor and hence occupy no outside space. The water is regularly tested for potability using the H2S strip test and maintenance issues are resolved with the community. I am sure many lessons can be learnt from the Sachetana project and transferred to other Fluoride and Arsenic affected villages in India and overseas.

BIRD-K would be happy to share its experiences concerning the project. Their emails are birdksachetana@gmail.com and birktpr@gmail.com and Dr GNS Reddy and Mr Dyasa would respectively have more details of the project. In addition, for those interested I have a small booklet could be posted on the Sachetana project.

I embed 2 films on this system and the household explaining (in Kannada) the rooftop rainwater harvesting system that they have in their home in the village Laghumuddepalli in Bagepalli Taluk of Karnataka. The system was built by the household and BIRD-K. These films are downloadable by any NGO/Government organisation/individuals and can be taken and played in any of the fluoride affected villages to explain what the system actually does.

Rooftop rainwater harvesting – fluoride free water and filter
http://www.youtube.com/v/7qiY011J6uI (Size: 14 MB)
Rooftop Rainwater harvesting – fluoride free water for homes
http://www.youtube.com/v/cvmNNdauJqw (Size: 14 MB)

Jasveen Jairath, CapnetSA, Hyderabad

It was interesting to read how rainwater harvesting had been used in Patna and other parts of Bihar, but people were not using the water because the water in the tanks stank. Can you share the reasons so we can become aware of the possible pitfalls.

S. D. Limaye, Ground Water Institute (NGO), Pune

I have gone through the YouTube videos with great interest. The household scale solution seems to be quite successful. If the villages in the area have percolation tanks formed by building earthen bunds across local streams, it may possible to get arsenic free water in dug wells located the downstream of such bunds. Dug wells located by the side of old village tanks are also low in F & As. These have been tried in Rajasthan and can be replicated in Karnataka.

N. Lakshmi Narayana, Dakshinya Institutes, Guntur, Andhra Pradesh

The first step towards arsenic mitigation is determining the problem spread and intensity. This can be done through reviews of existing data, maps and impacts. The next step is to pinpoint sources using hydrogeological and chemical studies. I can provide more information on the hydrogeological studies.

P.S. Yadav, Haryana Institute of Rural Development and Department of Development and Panchayats, Haryana

The Department of Drinking Water Supply (DDWS), Government of India launched the Accelerated Rural Water Supply Programme (AWRSP) to supply safe drinking water to the rural areas, under which several crore have been spent. Water quality monitoring and surveillance are an integral part of the programme and kits for testing water quality have been distributed. Communication and Capacity Development Units (CCDU) have been set up in almost all the states for awareness creation among various stakeholders regarding use of safe drinking water.

It is appropriate that DDWS consider setting up a Centre of Excellence, given the seriousness and size of the problem of arsenic contamination of groundwater, along with four regional centres in problem areas. The Centre can be called the National Institute of Drinking Water Management/All India Institute of Drinking Water Management. The Ministry will fund this institute and its ownership will rest with the Central Government.

Regarding the terms of reference, it is suggested that the institute coordinate expertise from different sources, provide advice, develop appropriate technical solutions to the problem of arsenic contamination (and other kind of water quality problems), act as a referral centre for people from arsenic-affected areas, conduct epidemiological and other studies and develop IEC material. It must develop simple methods to test water in arsenic contaminated areas. The centre will act as a resource for all states from where arsenic contamination is being reported, as suggested by Prof. Arunabha Majumder. Further, the institute will research drinking water-related problems and provide technological solutions/guidance, that will go a long way in solving the problem of water quality.

I feel communities need to be educated about the appropriate rain roof water harvesting techniques, as per the suggestion made by Mr. Vishwanath to resort to rain roof water harvesting to tackle the arsenic and fluoride problems. This is necessary because in Uttarakhand, I noticed during a visit many households had rain roof water harvesting systems in place but they do not use it for drinking. Instead, they use the water for cattle, washing and bathing. The storage tanks were open to air and sun, even though harvested rain water needs to be protected and kept covered.

C. Udaya Shankar*

The ulcerative syndrome (US) affecting the fishes in the Brahmaputra river is probably also due to Arsenic in the sediments carried down by the river's waters. Fish also algae that is similarly contaminated with arsenic.

Bangladesh developed a cheaper filter called "SONA" filter for removing Arsenic from ground water for drinking and cooking purposes. More details about this filter would be welcome.

Prosun Bhattacharya, KTH-International Groundwater Arsenic Research Group, Dept. of Land and Water Resources Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden*

The SONO Filter was developed in USA by the scientists of Bangladeshis origin, Prof. M. Alauddin and Prof. Abul Hussam. There is another one called the Kanchan Filter of Nepal (http://www.enpho.org/).

I request Dr. M. Jakariya from the NGO Forum for Drinking Water Supply and Sanitation for evaluation of this filter at the grassroot levels in Bangladesh so that they can enlighten the group.

Rohit Pathania*

With regards to arsenic contamination, a paper was published in the Denmark Technical University in 2005 wherein it was shown that red mud neutralized by seawater (red mud is a waste generated during the Bayer's cycle of alumina extraction from bauxite) can be used to remove arsenic from water. This paper is available online as well and this is a viable alternative.

I feel the contamination problem is actually due to overdrawing of groundwater and due to industrial pollution of surface water. Arsenic has even entered the food chain, with rice impregnated with arsenic being reported now.

Finally, arsenic in any concentration is dangerous, as it is a bio-accumulator.

Gautam Jayprakash*

Would you be kind enough to throw some light on how this arsenic contamination works? I think it has to do something with the excessive exploitation of ground water. Your inputs will surely help spreading awareness to areas that are next in line.

Sureshwar Sinha, Paani Morcha *(response 1)**

There are international and national standards that give the concentration of arsenic in water that is acceptable. The figures have been furnished by me to the Honourable Supreme Court of India, in my case {WPC 537/92} pending before the Court.

Gunnar Jacks, Land & Water Resources Engineering, KTH, Stockholm, Sweden*

Arsenic is mobilized from sediments under reducing/anaerobic conditions when ferric hydroxides are reduced to soluble ferrous iron. Ferric hydroxides are very good adsorbents for arsenic. We have in

Sweden found concentrations of 0.5 % of arsenic in ferric precipitates in streams where we have arsenic rich sediments around. However, in the Bengal delta the sediments do not contain that much arsenic, possibly a little above the global background. The specific condition for arsenic is that the content in groundwater can be high even if the redox conditions are unfavorable, irrespective of the content in the sediments.

There are other mechanisms for mobilization of arsenic elsewhere, such as the oxidation of sulphides and release from sediments at high pH levels, when the sediment "looses grip" on the arsenic.

Mukul Mahant *(response 1)**

Is there a review of existing knowledge on Arsenic in groundwater and how it impacts humans/livestock/biosphere. Based on this, how can arsenic that has been removed be prevented from re-entering the water cycle.

Tom Spalding*

There seems to be sufficient studies of the aquifer system and it seems deep wells or safe surface water supplies may able to provide water for people. Here is a link to an article about the source of the pollutant: http://www.unesco.org/courier/2001_01/uk/planet.htm, which says: The arsenic probably originates in the Himalayan headwaters of the Ganges and Brahmaputra rivers, and has lain undisturbed beneath the surface of the region's deltas for thousands of years in thick layers of fine alluvial mud smeared across the area by the rivers.

According to David Kinniburgh of the British Geological Survey, who has recently completed a detailed study of the arsenic's route into millions of tubewells, the arsenic concentration in the mud is not extraordinary. Time is the culprit. The mud in Bangladesh lies thicker, wider and flatter than almost anywhere on Earth. It can take hundreds or thousands of years for underground water to percolate through the mud before reaching the sea. All the while it is absorbing arsenic. This, says Kinniburgh, helps explain the diverse pattern of arsenic concentrations in tubewell waters. The contaminated wells almost all take water from a depth of 20 to 100 metres. Shallower wells are clean because they contain mostly recent rainwater or water flowing swiftly through the sediments. Deeper wells tap water in older sediments which have by now been flushed clean of arsenic. It will take thousands of years, says Kinniburgh, before the rest of the arsenic will wash away into the Indian Ocean. Many underground water sources around the world contain arsenic. Parts of Taiwan, Argentina, Chile and China have all suffered epidemics of skin diseases, gangrene and cancer as a result. Smith's analysis of the Taiwan epidemic in particular helped set the WHO arsenic standards for water and is the basis for his current predictions. Bangladesh, he says, is quite unprecedented."

As an alternative water source, I offer the following. In Kentucky, there has been study of cisterns as a farm water supply. This link is fairly comprehensive on the topic.

http://www.ca.uky.edu/agc/pubs/ip/ip4/ip4.htm

Ramesh N. Athavale*

A dug well/open well is a very common source of water in most of India, but in West Bengal and in Bangladesh, surface water, in the form of perennial rivers and ponds (*pukurs*) is plentiful and dug wells are rarely used. The phreatic (unconfined) aquifer in this area – which can form the source for dug wells - is practically free from Arsenic. The dug well water is also comparatively more hygienic (free from

organic contamination) than the surface water, which is free of Arsenic, but likely to have organic contamination. Dug wells should be constructed and used in place of tube wells in West Bengal and Bangladesh, at least for domestic Arsenic free water supply.

I have devoted several pages to the topic of Arsenic in ground water and also given design details for a dug well, protected from anthropogenic organic contamination, in my book 'Water Harvesting and Sustainable Supply in India', published jointly by the Center for Environment Education, Ahmedabad and Rawat Brothers, Delhi, in 2003.

The first mention of this dug well solution can be found in the following reference: "Dug wells, a solution to the Arsenic menace?" in Catch Water, a periodical published by the Center for Science and Environment, Delhi, Vol 2, no. 1,pp1-2, year 2000.

Mukul Mahant *(response 2)**

The State Public Health Engineering Department has to monitor all water sources for arsenic levels regularly. Arsenic-free water can be supplied in arsenic-affected areas by purifying surface water by installing deep bore wells or tube wells to draw water from aquifers not contaminated by arsenic, rainwater harvesting and removal of arsenic through filters. The PHED can diagnose and treat monitoring of patients. The government has to conduct awareness and motivation programmes and epidemiological studies in arsenic affected areas. The state geology/mining department should study the mechanism of how arsenic enters groundwater. The state health insurance corporation can provide nutritional support to villagers to mitigate the health effects of arsenic.

Sureshwar Sinha, Paani Morcha *(response 2)**

I think we are overlooking the fact that restrictions in rivers' flows (due to mis-conceived projects) has reduced ground water recharge, thereby reducing the dilution of arsenic contents with fresh water, and also creating the dangerous levels of arsenic content in ground water. The solution lies in increased flows in rivers, which recharge ground water in a natural manner.

S. K. Acharyya, Jadavpur University, Kolkata*

Release of arsenic to groundwater is not directly related to recharging of groundwater, but may have indirect effect. Release of arsenic to groundwater is mainly caused by organic matter induced reductive dissolution of ferric oxyhydroxide that is mainly present as coatings on sediment grains. Recharge of groundwater from biomass enriched water bodies in alluvial belt may mobilise dissolved organic carbon to the aquifer thereby enhancing the reduction process and thus aiding arsenic release to groundwater.

** Responses received on the Yahoo Groups WaterWatch, with thanks.*

Many thanks to all who contributed to this query!

If you have further information to share on this topic, please send it to Solution Exchange for the Water Community in India at se-wes@solutionexchange-un.net.in with the subject heading "Re: [se-watr] Query: Mitigation of Arsenic Contamination in Groundwater - Experiences. Additional Reply."

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