Arsenic

Knowledge and Action Network

Photo courtesy: Arsenic Knowledge and Action Network

February 2018

Interventions for Safe Drinking Water

Case Studies addressing Arsenic Contamination

About the cover pictures

A rainwater harvesting filter being cleaned by local women during an exposure visit from Titabar to Majuli

Arsenic Knowledge and Action Network

SaciWATERs
B - 87, 3rd Avenue, Sainikpuri,
Secunderabad - 500 094,
Telangana, India
Email: info@saciwaters.org
Phone: +91 40 27116721
Website: www.arsenicnetwork.in www.saciwaters.org

Date of Publication: February 2018

Content editors: Anshika John and Manish Maskara

Publication designed by: Raju Kakkerla

Disclaimer

FOREWORD

The Arsenic Knowledge and Action Network (A-KAN) was established in 2013 with a mandate to bring together knowledge and action driven by a network of partner organizations and individual members, sharing a common vision of bringing systematic and structural changes in arsenic mitigation strategies across India. The network was seed funded by Arghyam, Bangalore and SaciWATERs, Hyderabad acts as its secretariat.

It brings us immense pride to share with you our case study booklet on interventions for safe drinking water. The booklet is a step in the direction of documenting and compiling the methods and solutions that individuals and organizations have adopted towards addressing arsenic contamination in water. It aims to look at the broad spectrum of the problem and solutions along with responses to it from the society. The booklet is an attempt to highlight the methodological understanding of different organisations in dealing with the issue of arsenic in water, and has brought forth a collection of case studies from the arsenic affected regions in India.

The booklet comprises of cases from West Bengal, Bihar and Uttar Pradesh that present various technologies that address the arsenic contamination in water. Apart from such technologies, the booklet even consists of institutional approaches that have proven successful such as the approach that makes women manage community based safe water filtration and supply programs.

The purpose of this booklet would be to serve as a source of ideas to address the challenges of arsenic contamination of water for policy makers, governments, implementing organizations or even communities. It would give the reader a broad idea of the various approaches and technologies that have worked and those that have failed and the reasons for the same. It aims to act as a repository of solutions that can be adapted and learnt from during future interventions towards addressing the challenge of arsenic contamination of water. Such an assimilated piece can lead to improvement in the learning curve and uptake of knowledge, identification of best practices, and translation of research to practice, greater visibility for practitioners working in this sphere, and progress towards sustainable solutions through mitigation and increased awareness.

Arsenic Knowledge and Action Network would like to thank the individuals and organisations who have contributed to the case study booklet.

We look forward to connecting with more contributors for future editions of the booklet.

Secretariat
Arsenic Knowledge and Action Network

Contents

Arsenic Knowledge and Action Network

Case Study One

Impact of Safe Water on Arsenicosis: A Case study

By *Kunal Kanti Majumdar*[1], *Aloke Ghose*[2], *Nilima Ghose*[3], *Anirban Biswas*[4], *D.N. Guha Mazumder*[5]

Description of the background

Arsenic pollution in groundwater used for drinking purposes has been envisaged as a problem of global concern. Arsenic contamination in drinking water has been reported from many countries, but the severity of this contamination in India and Bangladesh is unprecedented. In India, occurrences of arsenic in groundwater have also been reported from Bihar, Jharkhand, Chhattisgarh, Uttar Pradesh and Assam [1].

Over and above pigmentation, keratosis, arsenicosis produces protean manifestations like weakness, chronic respiratory disease, peripheral neuropathy, liver fibrosis, peripheral vascular disease etc [2,3]. Chronic arsenicosis leads to irreversible damage in several vital organs, and arsenic is an established carcinogen. Despite the magnitude of this potentially fatal toxicity, there is no effective therapy for this disease; patients once affected may not recover, even after remediation of the arsenic-contaminated water. The need for an effective therapy for chronic arsenicosis is obvious.

Chelating agents like meso-2,3-dimercaptosuccinic acid (DMSA), sodium 2,3-dimercapto-1-propane sulfonic acid (DMPS) and d-penicillamine have frequently been considered for treatment of chronic arsenic toxicity. However, their usefulness as a standard method of treatment is yet to be established [4,5]. Anti-oxidants and vitamins have also been tried by some workers for the treatment of arsenicosis [6]. But no authentic evidence on the basis of placebo controlled trial has been available substantiating the efficacy.

Limited information is available in the literature regarding the long-term effect of chronic arsenic toxicity after stoppage of consumption of arsenic-containing water. A decrement of clinical score of arsenicosis following drinking of arsenic safe water was reported in a hospital based study on 10 patients of arsenicosis who were also given high protein diet [4]. In a community based study intervention, by reducing supply of

[1]*Department of Community Medicine, KPC Medical College and Hospital, Jadavpur, Kolkata*

[2]*DNGM Research Foundation, Kolkata, India*

[3]*DNGM Research Foundation, Kolkata, India*

[4]*DNGM Research Foundation, Kolkata, India*

[5]*DNGM Research Foundation, Kolkata, India*

arsenic contaminated water in a Southern Thailand showed both regression and progression of skin lesion, though the majority of the subjects followed up remained the same [7].However, no objective evaluation of decrement of skin score on intake of arsenic safe water was done in that study. Further, no report is available with regard to change in systemic disease features following intake of arsenic safe water in an arsenic endemic population.

The current study was therefore done to assess the effect of drinking arsenic safe water (<50µg/L) on disease score in regard to dermatological and systemic disease manifestation in an objective way on a cohort of arsenicosis patients during the period of 2007 to 2011.The study was conducted in Nadia District of West Bengal, India which is an arsenic endemic District. (Figure 1). Nadia District is one among 19 Districts of West Bengal State. It is located 109 km South towards the state capital Kolkata. Nadia District population is 5168488. It is the 7th largest district in the state by population. All the 17 blocks of Nadia are arsenic endemic blocks.

Figure 1 Map of West Bengal with Nadia District (red colour)

source: IndiaGrowing.com

Intervention

Manifestations of various skin lesions and systemic diseases associated with chronic arsenic exposure was ascertained initially by carrying on baseline study on 208 participants in Nadia (Cohort-1, with skin lesion and Cohort- 2, without skin lesion) using a scoring system, as developed by us [4,8] and compared objectively at the end of each year for three year follow up period. There was no difference in regard to age and sex and BMI between the participants belonging to Cohort-I (arsenic exposed with skin lesion) and Cohort- II (arsenic exposed without skin lesion). There was also no difference between the peak and duration of arsenic exposure between the above two groups.

All the participants who had arsenic contaminated drinking water source in their houses were supplied with arsenic removal filters for getting arsenic free water during the follow up period. Continuous monitoring of arsenic level in drinking water source and their morning urine samples for arsenic was also done at the end of each year of study. Photographic recording of skin lesions of each participant at baseline and 1st and 2nd and 3rd year follow up study period was also done to objectively record the changes of skin score in time, if any.

Information from each recruit was collected on demographic and social characteristics and addiction to smoking, alcohol or chewing tobacco with betel nut. Weight and height were measured, and Body Mass Index (BMI) was calculated (Weight in Kg / Height in meter ^{2}). All the participants were clinically examined including examination for typical arsenical skin lesion of pigmentation and/or keratosis and recording of blood pressure was done. The patients were evaluated by an objective scoring system before and after every year of intake of arsenic safe water. Skin scoring and systemic scoring were done as per standardized protocol described earlier.[4,8] Briefly, though many symptomatic parameters recorded were subjective, the objective parameters included were pigmentation, keratosis, chest signs (rales and rhonchi), hepatomegaly and splenomegaly. Flushing of face, solid edema of legs and hands, ascites and absence deep reflexes for neuropathy were also included in the scoring system. Breathlessness at accustomed exertion, mild exertion, or at rest was defined as mild (1), moderate (2) and severe (3) respectively. Skin scoring was done based on mild, moderate and severe lesion of pigmentation and keratosis.

All exposed participants were questioned on lifetime history of water consumption using a structured questionnaire. Questions were asked as to sources of drinking and cooking water, and duration of water use from each source. Water samples were collected from present drinking and cooking water source of each participant and also from previous water sources when they were still available, in a polyethylene bottle from participants belonging to both the groups. Duration of intake of water from each water source was recorded.

First morning void urine sample was also collected from participants in a container. Both the water and urine samples were kept in ice box before shifting from the field and stored at -20°C. For collection of hair, a bunch of whole length hair sample was cut from the scalp of each participant by a stainless blade and kept in a plastic packet. All these samples were stored according to standard protocol of WHO (2005).[9] until further analysis.

Arsenic levels in urine, hair and water were measured using an atomic absorption spectrophotometer with a flow-injection hydride generation system as described by Das et al (1995).[10] The limit of detection determined at the 90% confidence level was 3μg/L. Hair samples were thoroughly cleaned and prepared in order to minimise the risk of surface contamination.

Approval of the study protocol was obtained from the Ethical committee of the Foundation, fulfilling the Helsinki criteria and recommendation of Indian Council of Medical Research, Govt. of India. All the participants gave their written consent for undergoing this study including taking photograph of their skin lesion.

Impacts

The mean peak (highest) arsenic level in drinking water of Cohort-I and Cohort-II participants was 250.56 ± 199.20 µg/L and 259.53 ± 161.49 µg/L respectively. The mean duration of peak arsenic exposure of Cohort-I and Cohort-II participants was 12.87 ± 7.32 and 10.96 ± 7.69 years respectively. The mean arsenic level in urine in Cohort-I, and Cohort-II participants was 123.24 ± 99.97 µg/L and 111.71 ± 88.57 µg/L respectively and in hair, 1.11±1.22 mg/Kg and 1.03 ± 0.64mg/Kg respectively. There was no difference between mean arsenic level in biomarkers like urine (p=0.3) and hair (p=0.6) among both the cohorts (Table-1).

Out of the 108 Cohort-I cases, arsenical pigmentation and keratosis were present in 107 and 67 cases respectively. According to total skin score arsenical skin lesions were mild (≤2) in 73 (67.6%), moderate (>2 & ≤4) in 32 (29.6%) and severe (>4 & ≤6) in 3 (2.8%) arsenicosis cases. (Table 1)

Though initial baseline study could be done on 108 participants of Cohort-1, the study could be repeated on 102 participants at the end of one year and on 100 participants at the end of 2nd year and 96 at the end of 3rd year. Out of 100 participants among Cohort-II in the baseline study, 98, 96 and 90 participants could be examined at the end if 1st,2nd and 3rd year follow up study in successive years. In participants belonging to Cohort–I significant (p=0.0097) improvement in skin score was observed 1 year after taking safe water (1.75±1.24) in comparison to baseline value (2.17±1.09). Further improvement in skin changes continued to occur in second (1.45±1.19, p=0.0000) and third year (1.23±1.17, p=0.0000) follow up study.

In participants belonging to Cohort –I the skin score was found to improve significantly at the end of each year and it was found to be reduced significantly from 2.17±1.09 to 1.23±1.17; p <0.001 at the end of 3 year's intervention study.

Fig.2. Improvement of mild skin lesion following drinking of arsenic safe water

However, there was less evidence of improvement of systemic disease score in both the Cohort-I and Cohort II study participants with intake of arsenic safe water. The systemic disease symptom score was also found to improve from 2.13±1.58 to 1.64±1.13,p<0.01 at the end of three years in Cohort -I and from 1.45±1.15 to 1.13±0.88;p<0.05 in Cohort-II participants respectively (Table-2).

Most important observation during the follow up study was persistence of severe symptoms of chronic lung disease and severe skin lesion including Bowens disease in spite of taking arsenic safe water in severe cases. Two participants died due to lung cancer and two due to severe lung disease associated with skin manifestations of arsenicosis during this period of follow up study.

Table –1.Baseline data of arsenic exposure through water and As level in urine and hair of study participants

	Skin Lesion	No Skin Lesion	p-value
	(N = 108)	(N = 100)	
As in tube well water			
Current As in tube well µg/L (mean ,range)	27 Range:BDL -150	74 Range:BDL -370	0.00
Highest known tubewell concentration, (peak, µg/L) (Mean ± S.D.)	250.56 ± 199.20	259.53 ± 161.49	0.721
Duration of Exposure to peak concentration (years) (Mean ± S.D.)	12.87 ± 7.32	10.96 ± 7.69	0.068
Urine: (Mean ± S.D.)	123.24 ± 99.97	111.71 ± 88.57	0.381
Hair: (Mean ± S.D.)	1.11 ± 1.22	1.03 ± 0.64	0.580
Arsenicosis Skin Score	No %		
Mild (≤ 2)	73	67.6	
Moderate (>2 to ≤4)	32	29.6	
Severe (> 4)	3	2.8	

Table 2. Change in clinical score of the cohort of study participants following drinking of arsenic safe water for three years

Clinical Score	Baseline	Follow up after 1 year	Follow up after 2 years	Follow up after 3 years	Remarks
Cohort I					
As Skin Score	N= 108 2.17±1.09	N= 102 1.75±1.24	N= 100 1.45±1.19	N= 96 1.23±1.17	1yr.p=0.0097 2yr.p=0.0000 3yr.p=0.0000
Systemic Score	N= 108 2.13±1.58	N= 101 1.87±1.21	N= 100 1.45±1.19	N= 96 1.64±1.13	1yr.p=0.1853 2yr.p=0.0006 3yr.p=0.0125
Cohort II					
Systemic Score	N= 100 1.45±1.15	N= 98 1.27±1.12	N= 94 1.29±1.06	N= 90 1.13±0.88	1yr.p=0.2660 2yr.p=0.3158 3yr.p=0.0340

Conclusions/Discussions/assessment & Way forward

This study describes demographic characteristics, clinical profile and impact of drinking safe water (As level <50 µg/L) on amelioration of symptoms of chronic arsenic toxicity in people living in one of the arsenic affected district of West Bengal. Significant chronic arsenic exposure was documented in the arsenic exposed people in two cohorts with and without skin lesions. Arsenic level in biomarkers like urine and hair was also elevated similarly in both the study cohorts. Participants of both the cohorts were evenly matched in regard to age and sex, smoking habit and BMI.

In participants belonging to Cohort-I the skin score was found to improve significantly at the end of each year and it was found to be reduced significantly from 2.17±1.09 to 1.23±1.17; p <0.001 at the end of 3 year's intervention study indicating beneficial effect of safe water on skin lesions. The systemic disease symptom score was also found to improve, but less significantly, at the end of three years in both the cohorts. Most important observation during the follow up study was persistence of severe symptoms of chronic lung disease in spite of taking arsenic safe water. Further, death could not be prevented to occur because of lung cancer and severe lung disease.

Limited information is available in the literature regarding the long-term effect of chronic arsenic toxicity after stoppage of consumption of arsenic-containing water. To determine the effect of providing safe water to affected people, a cohort of 24 patients with chronic arsenicosis were re-examined after drinking arsenic-free water (<10 µg/l) for a period varying from 2 to 10 years (13 patients 10 years, 11 patients 2–5 years) by Guha Mazumder et al in 1999. [11] These people had been drinking arsenic-contaminated water (130–2000 µg/l) for 4–15 years. Weakness and anaemia were present in 91.6% and 58.3% of cases initially and were persistent in 60.8% and 33% of cases, respectively, on repeat examination. Partial improvement of pigmentation and keratosis were observed in 45% and 46% of patients, respectively. However, liver enlargement was persistent in 86% of cases. The most distressing observation was the new appearance of signs of chronic lung disease (cough, shortness of breath and chest signs) in 41.6% of cases. There was a slight reduction of clinical symptoms of neuropathy. It was present in 11 cases (45.8%) at the time of initial examination and in 8 cases (33.8%) during the subsequent period ($P < 0.5$). No new cases of neuropathy were detected in any of the follow-up patients. However, diminished hearing was observed in 5 cases during follow-up examination, although it was present in 2 cases initially. Similarly, 3 patients complained of dimness of vision during follow-up examination, although none had such symptoms earlier. None of these three patients had cataracts or any other abnormality on fundoscopy.[11]

Changes of severity of skin lesions over a period of 10 years were investigated amongst an affected cohort in an area having arsenic contaminated shallow wells due to tin mining activities in Southern Thailand where interventions to reduce arsenic contaminated water had been implemented. Over 10 year period, both regression and progression of lesions occurred, though the majority of the subjects followed up remained the same. Drinking predominantly arsenic free water increased the probability of regression in subjects with mild stage lesions but not in those with more advanced stage lesions. By contrast, a high arsenic content in the household well water, even though it was not used for drinking decreased the probability of lesion regression among the subjects in more advanced stage but not among milder stage cases. Irrespective of initial stage, a period of absence from the affected area increased the likelihood of lesion regression.[7]

Another cohort follow-up study was carried out by Guha Mazumder et al 2003[12]on 1074 people (arsenic exposed people 623 control population 451) in South 24 Parganas, West Bengal five year after an original baseline clinical examination. Out of 199 people with skin lesion among the arsenic exposed population who were consuming safe water during the last 5 years, the skin lesions cleared or decreased in 49.7% of people. However new skin lesions appeared in 32(10.5%) out of 306 people who were not diagnosed with such lesions previously.

In a study carried out in Inner Mongolia, China, Sun et al (2006) [13] reported that skin lesions improved to some extent after drinking low arsenic containing water for one year. However, a five-year follow- up study showed no more significant improvement of skin lesions, while the potential risk of arsenic induced cancers after cutting off high arsenic exposure was still uncertain and indefinite.

The current study, for the first time documented with sequential photographic records that arsenical skin lesions improve with intake of arsenic safe water. However, it needs to be mentioned that improvement in skin score noticed were due to clearance of mild skin lesions (skin score1-2) which was present in 67% of participants in the present study. But in an endemic situation of ground water arsenic contamination of a country like West Bengal, the prevalence of arsenical skin lesions are mild (skin score1-2) in majority (87.56%) of the cases[5].Hence , the main strategy for arsenic mitigation program need to be addressed to ensure availability of arsenic safe water in an arsenic endemic region.

However, the prognosis of arsenicosis cases with severe skin lesion and major systemic disease like chronic lung disease are unsatisfactory, and fatality occurs due to severe lung disease and cancers, like lung cancer.

Conclusion

Intervention with arsenic safe water was found to cause improvement of skin score in significant number of cases of arsenicosis with skin lesion .However systemic score showed milder improvement in both arsenic exposed people with and without skin lesion. Symptoms of severe skin lesion and Bowens persisted. Both cancer and non-cancer causes of death due to involvement of lung were found to be the major causes of mortality in arsenic exposed study people in Nadia

References

1. IARC, Some drinking-water Disinfectants and contaminants, including Arsenic. *Monographs on the Evaluation of Carcinogenic risks to Humans* Lyon, France, WHO 2004; 84 : 61-96.
2. Guha Mazumder DN, Haque R, Ghosh N, De BK, Santra A, Chakraborty D, Smith AH. Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India. *Int J Epidemiol* 1998a; 27 : 871-7.
3. Haque R, Guha Mazumder DN, Samanta S, Ghosh N, Kalman D, Smith MM, Mitra S, Santra A, Lahiri S, Das S, De BK, Smith AH. Arsenic in drinking water and skin lesions : Dose-response data from West Bengal, India. *Epidemiology* 2003a; 14 : 174-182.
4. Tondel M, Rahman M, Magnuson A, Chowdhury OA, Faruquee MH, Ahmad SA. The relationship of arsenic levels in drinking water and the prevalence rate of skin lesions in Bangladesh. *Environ. Health Perspect.* 1999; 107 : 727-729.
5. Majumder KK, Guha Mazumder DN, Ghose N, Lahiri S. Systemic manifestations in chronic arsenic toxicity in absence of skin lesions in West Bengal. *Indian J Med Res* 2009; 129 : 75-82.
6. Guha Mazumder DN, Das Gupta J, Santra A, Pal A, Ghose A, Sarkar S. Chronic arsenic toxicity in West Bengal – The worst calamity in the world. *J Indian Med Assoc* 1998b; 96 : 4-7.
7. IARC, Some drinking-water Disinfectants and contaminants, including Arsenic. *Monographs on the Evaluation of Carcinogenic risks to Humans* Lyon, France, WHO 2004; 84 : 61-96.
8. Guha Mazumder DN, Haque R, Ghosh N, De BK, Santra A, Chakraborty D, Smith AH. Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India. *Int J Epidemiol* 1998a; 27 : 871-7.
9. De BK, Majumdar D, Sen S, Guru S and Kundu S. Pulmonary Involvement in Chronic Arsenic Poisoning from Drinking Contaminated Ground-water. *J Assoc of Physcn* India 2004; 52 : 395-400.
10. Guha Mazumder DN, Steinmaus C, Bhattacharya P, von Ehrenstein OS, Ghosh N, Gotway M, Sil A, Balmes JR, Haque R, Hira-Smith MM, Smith AH. Bronchiectasis in persons with skin lesions resulting from Arsenic in Drinking Water. *Epidemiology* 2005; 16 : 760-765
11. Guha Mazumder DN. Arsenic and non-malignant lung disease. *Journal of Enviromental Science and Health*, Part A 2007; 42 : 1859-1868.
12. Guha Mazumder DN, Ghosh N, De BK, Santra A, Das S, Lahiri S, Haque R, Smith AH, Chakraborti D. Epidemiological study on various non carcinomatous manifestations of chronic arsenic toxicity in a district of West Bengal. In: C.O. Abernathy, R.L. Calderon and W.R. Chappell, eds. *Arsenic Exposure and health effects IV*, Oxford, UK: Elsevier Science. 2001; 153-164.
13. Guha Mazumder DN, Chakraborty AK, Ghosh A, Das Gupta J, Chakraborty DP, Dey SB, Chattopadhaya N. Chronic arsenic toxicity from drinking tube-well water in rural West Bengal. Bull World Health Organ 1988; 66 : 499-506.

Arsenic
Knowledge and Action Network

Case Study Two

Sustainable Arsenic Mitigation and Management through Community Participation in Buxar District of Bihar

By *Ashok Kumar Ghosh*[1]
and
Arun Kumar[2]

Description of the background

In recent times water pollution has become a gigantic health issue globally. Inorganic arsenic is one of water contaminant naturally present in very high concentration in the groundwater of many countries, creating an important public health issue affecting a population of 200 millions globally. The Gangetic flood plain region of Bihar is the most severely arsenic affected area with more than 5 million population. In Buxar district of Bihar, the Tilak Rai Ka Hatta (TRKH) village is the severely arsenic exposed area. The major chunk of population exhibits typical symptoms of arsenicosis. Arsenic exposure appears linked to increase in cancer, heart disease and developmental problems.

Location: The Buxar district is situated between $25^{\circ}18'$ to $25^{\circ}45'$ latitude North & $84^{\circ}20'$ to $84^{\circ}40'$ longitude East. Its geographical area is 1624 Km^2. The total population of district is 10,87,676 (Rural 9,96,855 Urban 90,821). The population density is 621 person/Km^2 and sex ratio 899 females/1000 males. The study was done at Tilak Rai Ka Hatta village (Figure.1) ($25^{0}41'36''$N, $84^{0}07'51''$E) of Buxar district of Bihar. The population of the Tilak Rai Ka Hatta village is 5,348 with 340 households (Census, 2011).

Figure. 1. Showing aerial view of the study area.

[1]Mahavir Cancer Sansthan & Research Centre, Patna, Bihar, India

[2]Mahavir Cancer Sansthan & Research Centre, Patna, Bihar, India

Ground water arsenic assessment in Tilak Rai Ka Hatta (TRKH) village

The analysis of 80 water samples from the entire village represented high levels of arsenic contamination in the ground water. The maximum arsenic concentration in ground water sample reported was 1908 µg L^{-1}. The ground water samples showed high arsenic concentration in 86% of samples analysed. Only 14% samples had normal levels (below 10 µg L^{-1}), 25% had levels between 11-50 µg L^{-1} while rest 61% samples were highly arsenic contaminated water samples (Figure. 2).

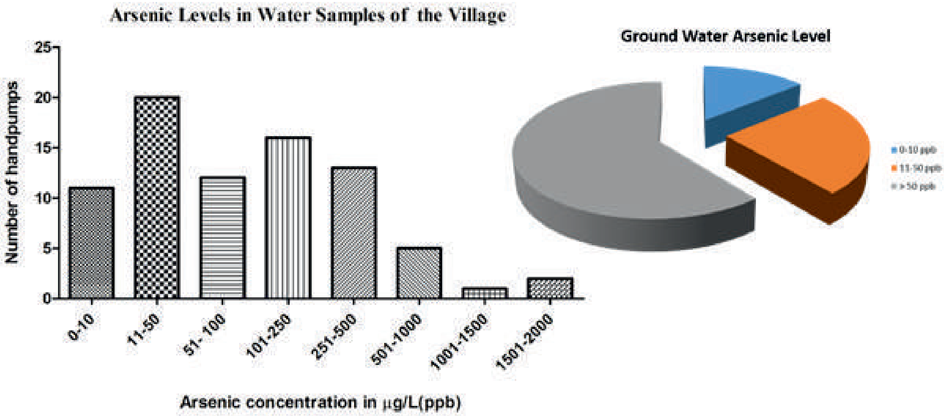


Figure. 2. Showing Arsenic levels in the Water Samples of the village TRKH

Clinical Observations and Health Assessment

The village people exhibited typical symptoms of arsenicosis like hyperkeratosis in sole and palm, hyperpigmentation in palm (Figure.3) as they were consuming very high concentration of arsenic contaminated drinking water. Many village people exhibited hyperpigmentation (spotted pigmentation) on their whole body, leuco-melanosis in trunk, melanosis, blackening of tongue and cancer incidences.

Figure 3 A. Hyperkeratosis of sole in 50 yrs old male (As in drinking water 1908 µg L^{-1})

B. Hyperkeratosis of sole in 12 yrs old girl (As in drinking water 1908 µg L^{-1})

C. Hyperpigmentation in palm 55 yr old female (As in drinking water 534.2 µg L^{-1})

D. Hyperkeratosis in sole in same female (As in drinking water 534.2 µg L^{-1})

The village population (n= 5,348, total subjects studied n=530) had the skin related problems – hyperkeratosis in palm & sole (68%), melanosis (22%) as the common problems while in gastrointestinal problems – gastritis (90%), liver related problems (58%), loss of appetite (60%) were also observed. The hyperkeratosis in sole and palm in (18%) of the children (below 12 years) were observed. Few cases of cancer 2% were also observed in the population especially with skin cancer, gall bladder cancer, intestinal cancer, liver cancer and breast cancer (Table.1).

Table. 1. Showing the disease symptoms in the population

Disease	% in the studied population
Hyperkeratosis in palm & sole	68%
Melanosis	22%
Gastritis	90%
Liver related problems	58%
Loss of appetite	60%
Hyperkeratosis in sole and palm in of the children	18%
Cancer	2%

Cancer cases: The most unfortunate part of the study were the cases of cancer like ovarian, breast, melanoma, gall bladder and liver, leukaemia and colorectal cancer. There were 12 cancer cases reported in 2016-2017. All the cancer patients have died except the melanoma and colorectal cancer case patient. All the patients exhibited the typical arsenicosis symptoms. The patient's drinking water source was found to be 534.2µg L^{-1} while his blood sample had arsenic concentration 54.9µg L^{-1} (Figure 4).

Figure 4 A. Hyperkeratosis, melanosis, rain drop pigmentation with ovarian cancer in a 58yrs old female (As in drinking water 534.2 µg L^{-1})

B. Hyperkeratosis, melanosis with liver cancer in 55 yrs old female (As in drinking water 624.5µg L^{-1})

C. Skin melanosis in a 52 yr old female (As in drinking water 663.1 µg $L^{-1)}$

Intervention

A community based arsenic filter was installed in the study area with the help of community participation through collaborative effort of Mahavir Cancer Institute and Research Centre, Patna and Lehigh University, Pennsylvania, USA, which is based on adsorbent Hybrid Anion Exchange Nano Resin (Figure 5). This filter is providing arsenic safe water giving good health outcomes.

Figure 5. Installation of Arsenic Filter

Impacts

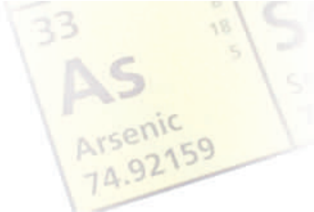
The survey of the village TRKH of Buxar district, demonstrated very high arsenic concentration in drinking water. Many arsenic induced health related problems were observed in the population like keratosis, melanosis, leuco-melanosis, hormonal imbalance and 14 cases of cancer in year 2016-2017. But, after the arsenic filter installation in June 2017 through community participation, the situation is improving slowly. Presently, this filter is providing safe drinking water to more than 100 households. People from distant villages are also coming to fetch water. Installation of arsenic filter has made drastic change in the health status of the arsenic exposed village population. Following are the changes observed in the village population after usage of arsenic filter water –

- Decrease in the hyperkeratosis, melanosis and other skin manifestations.
- Decrease in the problems related to their gastrointestinal issues.
- Decreased in the hormonal related problems in the females.
- Increased appetite.
- Increased immunity level.
- Positive changes in the neurological behavior.
- Positive changes in the mood – feel good effect of getting safe drinking water.
- Increased awareness in the population related to use of safe drinking water.
- Village people have become more conscious about their health.
- Demand for similar units are coming from adjoining arsenic exposed villages.

Conclusion

The successful running of the Arsenic filter in the village Tilak Rai Ka Hatta in the coming years will show the benefit of the arsenic free drinking water utilized by the village people. Although, drastic changes has been observed in them. The most important is that the village population has become more conscious about usage of safe drinking water and their health. This will not only eliminate their present problems but will prevent their future generation to become diseased. Such filters should be promoted for larger population benefit so as to prevent them from the hazards of arsenic poisoning.

Acknowledgement: The authors acknowledge Tagore-Sengupta Foundation for providing fund for installation of Arsenic filter.



Case Study Three

A Case Study on Capacity Building and Empowerment of Rural Community in Entrepreneurship and Application of Technology for Safe Water Supply to the Rural Community

By *Dr. Bindeshwar Pathak[1], Prof. K J Nath[2] and Mr. A K Sengupta[3]*

Background

Health authorities have acknowledged that safe drinking water has a decisive impact on diarrhoeal diseases prevention (WHO 2004). The most admitted guideline is the complete absence of pathogens in water at the point-of-use. Furthermore, WHO has acknowledged that intervention to maintain water quality at the point of use are the most promising and convincing in terms of cost effectiveness.

Diarrhoea can be caused by a wide range of micro-organisms through various ways of transmission: ingestion of contaminated food or beverage, contacts between individuals, direct or indirect contact with faeces.

Sulabh International Social Service Organization (SISSO) has contributed immensely in the promotion of sanitation in the country. It was felt that safe water, along with sanitation, should also be provided to the community so that gain to the public health becomes comprehensive. International Academy for Environmental Sanitation and Public Health (IAES&PH), an associate of SISSO, in Collaboration with 1001 Fontaines, France, undertook the present project on Water Supply to the Rural Community in Six Blocks of West Bengal in the Districts of 24 Parganas (South & North), Nadia, Murshidabad, West Midnapur (four in the first phase and two later on).

Project Approach, Objective & Methodology:

Approach consists in providing each village with a safe drinking water production capacity for the benefit of the village community while relying on an entrepreneurship model as a way to ensure the project's sustainability. Although

[1]Founder, Sulabh International Social Service Organization (SISSO), Chancellor, International Academy of Environmental Sanitation & Public Health (IAES&PH)

[2]MChairman, S&T, SISSO, President, IPHE, India, Former Director, AIIH&PH

[3]Advisor, SISSO, Former NPO, WHO, India

the creation of such water production capacities is essential to allow beneficiaries to assess drinking water, this must be supplemented with various other actions aiming at- on one hand maximizing the number of beneficiaries and on the other hand maximizing the project impact on each of the beneficiary's health.

Behavioural change can be accelerated through various actions provided that these actions are implemented according to the following logical order:

- Create a water production capacity and ensuring its sustainability,
- Secondly, extend the number of "consumers",
- Then take the poorest and the most vulnerable segments of the population into account.

Key Objectives

1. Major aims of the programme is to provide a steady, sustainable and impeccable safe drinking water supply services as well as regular education and information activities towards target population. The area which is having heavily chemical and bacteriological contamination water sources will be targeted in the first phase.
2. The programme purpose will be to provide drinking water supply in local schools, anganwadi centers, health care centers and local community.
3. Provide safe water to 8,000 to 12,000 people by establishing six new water treatment plants and distribution facilities.

Objective(s)	Strategies	Implementation process
To provide affordable safe drinking water to the rural community.	1. Cost effective treatment of water from surface water sources (pond, river, cannels, lakes, wells etc.). 2. Training & capacity building of the local workers. 3. Creation of local management, infrastructure for operation.	1. Selection of site and obtaining of land. 2. Sensitization & awareness generation. 3. Water quality analysis. 4. Design of treatment process. 5. Construction & operation. 6. Safe water distribution among the community.

Methodology:

Creating a drinking water production activity

The annual rainfall is quite satisfactory and there are many perennial and sustainable water sources like ponds and rivers in the rural areas. Unfortunately, these are often abused by human behaviour and as a result get heavily contaminated, resulting in epidemics of diarrheal diseases and endemicity of the same in the community. In the projects supported by IAES&PH/SISSO, it is proposed that a number of such water bodies could be used to create a drinking water production unit. A low cost & community friendly treatment process was introduced so that it becomes totally safe for drinking and other domestic use.

Guaranteeing water quality at the point of use

A comprehensive water treatment system is installed in each village which, because the quantity of water treated every day is small, is able to adapt to the best raw water source available – through appealing to a well-trained team to install each treatment unit, analyzing different raw water sources before installation, and changing raw water source if need be. This also ensures that arsenic free water is made available to the consumers at their door steps.

- Water treatment and bottle filling-up processes are monitored through a quality control procedure including frequent bacteriologic analysis during all site's lifetime duration.
- Water is transported to clients' homes in sealed 20-litres bottles.
- Water storage is well taken care of in bottles that have been disinfected beforehand by a well-trained operator, instead of random storage in whatever container is available.
- Persistent water purification is obtained by using a minimal quantity of silver ions.
- Attention is paid to producing water with a taste that people like as well as to making bottle handling easier so as to maximize consumers' satisfaction.

In each of the six sites, where water supply production has been initiated, one local NGO has been engaged. Locations of the water production units and the districts are namely, Madhusudankati in North 24 Parganas, Murshidabad in Murshidabad district, Mayapur in Nadia, Suvasgram in South 24 Parganas, ISKON Haridaspur in North 24 Parganas and Chaksultan in West Midnapur. Six local NGOs in each of these sites are supporting the programme by providing land and ensuring source of water as well as maintenance support. Since ground water sources in most of these locations have high level of arsenic, surface water sources and well water with no arsenic contamination are being tapped to provide bottled drinking water to the community

Ensuring sustainability

Ensuring the sustainability of safe drinking water production capacities consists in the two following imperatives:

- On one hand, transforming a few villagers or any Community Based Organization (CBO) into a real entrepreneur able to purify every day the quantity of water that is necessary to meet consumers' needs while respecting a treatment process guaranteeing perfect water quality under WHO's standards, but also able to diffuse key hygiene messages in the village, where water supply is maintained.
- On the other hand, reaching as soon as possible a production level that makes sales high enough even with a very low selling price – to cover for all operating costs including the entrepreneur's income.
    - Discussions with the community about key prerequisites such as the operator(s) selection, the selling price for bottled water, the decision (or not) to set "discount" prices for the poorest families, the decision (or not) to use resellers, etc.

- Supply of all necessary technical components and installation on site,
- Operators training, checkouts and qualitative analyses until complete control of water quality,
- Sales starting up in parallel with information and education campaigns in villages.
- IAES&PH provides a one – year support and follow – up phase, with technicians visiting the site regularly and formal assessment are being carried out. Along with this phase, additional information and education campaigns are carried out.

As families are using contaminated drinking water for a long time and in spite of very high children mortality rates as well as high prevalence of water – borne diseases, these populations are not adequately aware of the health risks that are related to unsafe water consumption.

The launching of drinking water production capacities comes thus with many information and education campaigns that are carried out in villages with a special focus on school going children.

Sites Selection

IAES&PH has selected the six sites and all are situated in the West Bengal, India, where arsenic is an important sanitary issue. A first evaluation of potential villages among their areas of action for sanitation programs had been made. The criteria used for selection were: the motivation and reliability of the local NGOS; willingness to get implied in the project and to provide a land; size of population to insure feasibility of the project (minimum of 1,500 families) and accessibility of the site (even during rainy season).

Project Site at a glance:

Name of NGO	Village	Targeted Population	Source of Water
Sri Mayapur Vikash Sangha	Bamonpukur, Baganepara	1500-2000 Nos	Ganga river
West Bengal Voluntary Health Association	Phoolbagan, Muragoar, Pathanpara, Kumarpara, ayeshbagh		Ganga river
Madhusudankati Krishi Unnayan Samity	Bishnupur, Jamdani, Tegharia, Faridkati, Madhusudankati.		Private pond
Akshaynagar Pallisri Sangha, Suvasgram	Akhna, South Garia		Pond
ISKON	Haridashpur Bangaon		Well
Mehanati Kishan Samabay Krishi Unnayan Samity Ltd.	Chaksultan, Mirzapur, West Midnapur		Well

Design & Construction of the Water Treatment Plant

Hydraulic and structural designs have been completed as per the instruction guidelines provided by IAES&PH to insure the quality of the water produced. The design of the treatment plant was finalized by the project team and the engineered drawing has been done by an external service company. The capacity of water treatment plant defined is 4000 liters per day with 8 hours operation time.

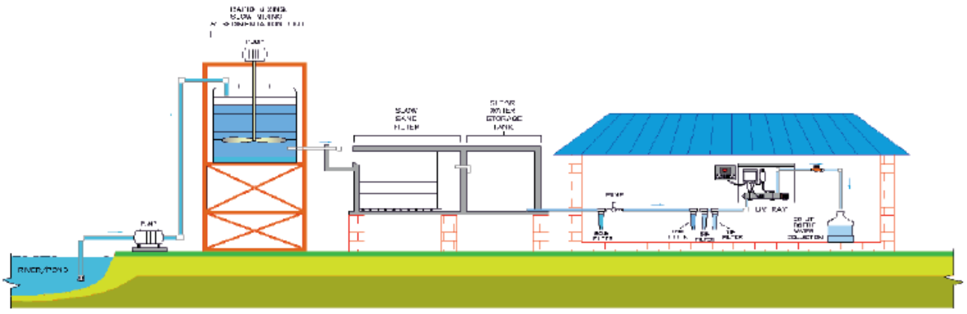


Figure 1. Diagram of river water treatment plant

The water from the ponds/well or the river is pumped into an over-head reservoir from where it is delivered into a flocculating tank where chemicals (alum and bleaching powder) are mixed with the water at a desired rate. The settle water is then passed through a slow sand filter. The filtered water is then collected in a clear water reservoir, from where the water is passed through activated carbon bed and fine membranes of varying sizes (60μ, 40μ, 10μ, 1μ). This will remove the finest contaminants from the water which will then be treated with UV ray to make it totally bacteria free. The resultant treated water which is free from all pathogenic microorganisms, is then poured into 20 litre bottles and sealed. The consumers either collect the bottle from the kiosk or the same is delivered to their houses. This process is followed in principle in all the three sites.

Cost

The cost of this project is around Rs14,00,000 – 15,00,000 for pond/ river sources and 11,00,000 – 12,00,000 for well with a production capacity of 8000 liters per day. Initially, capital cost is shared between Funding Agency, SISSO and the balance contribution came from the local NGO in the form of land material, labour etc. The water is available at the rate of fifty paise per litre/Rs 10 per 20 litres bottle at home. The water supplied to community is bacteriologically and chemically safe for drinking.

The water is also supplied free of cost to primary/ higher secondary schools and anganwadi centres. Apart from that free water supply is provided to people suffering from Arsenicosis regularly and even to people suffering from diarrhoeal diseases in case of emergency. The villagers/consumers are showing great interest and the acceptance for this drinking water which is rather cheap and readily available.

Reaching out to: The Arsenic affected people of Madhusudankati, West Bengal

Sulabh has set up in Madhusudankati, a remote hamlet in West Bengal near the India-Bangladesh border, a pilot project Sulabh Purified Water Plant, which treats water collected in a deep, man-made pond at the village. It has been developed jointly by Sulabh and French NGO 1001 Fontaines. The plant started operating several months ago with the capacity to produce everyday 8,000 litres of potable water called Sulabh Jal. The water costs 50 paise (less than one cent) per litre, which makes it the cheapest purified bottled water. For residents of Madusudankati, the plant has proved to be a great help after years of suffering from skin and other diseases caused by arsenic in ground water pumped from wells. After commencement of the Sulabh Water Treatment Plant, the residents are getting clean Sulabh Jal. There has been considerable improvement in the health of the people affected by the arsenic poison. Apart from supplying safe drinking water, Sulabh is also treating people suffering from arsenic poisoning at a health centre adjacent to the water plant.

Roles and responsibilities of various partner institutions:
SISSO:

- Selection of project team members for planning, implementation, training of operators, awareness and monitoring of the systems.
- Selection of treatment sites in consultation with the Local NGO.
- Training and Demonstrate Local NGO personnel on 'Operation & Maintenance' of the treatment unit.
- Procurement & installation of the treatment units constructed at the site.
- Provide initial (one time) financial support to the Local NGO for installation of the treatment unit, purchase of containers to carry treated water to the consumers, container sealing device(s), transport vans and initial three months honorarium for three/four persons engaged in the project work.
- Provide financial and technical support in setting-up of water testing (turbidity & bacteriological) facility.
- Overall supervise the project work.
- Provide Resource person(s) in the awareness camps.

1001 Fontaines / Any Funding Agency

- Selection of sites.
- Support to supervise the Project work
- Monitoring the progress of work.
- Funding the project partially or fully.

The Local NGO/ CBO

- Selection of site and ensure water availability of adequate quality all year round.
- Land availability for construction of treatment units.

- Provision of staff to operate and maintain the systems, distribution of bottled water and collect the revenue.
- After three months the NGOs are expected to be economically self-supported by selling the bottled-treated water to the villagers at an affordable price and thus, the programme may prove to be a sustainable one.
- The Local NGO will provide suitable space, preferably near to the surface water source, for installation of the water treatment units.
- Conduct awareness camps/gatherings to motivate people to consume safe water.
- Generate demand and create bottled-treated water market through such awareness camps.
- 'Operation & Maintenance' of the water treatment unit and quality control of the treated water.
- Ensure timely supply of bottled-treated water to the consumers as per their need.
- Maintain transparent accounts of the drinking water business.
- Provide manpower to be trained on water quality testing.
- Test the water quality of bottled drinking water on regular basis and maintain the record.
- Provide space for establishment of water quality test laboratory.
- Ensure payback the supervision cost from the date of the commencement of the project
- Involve local panchayat machinery for the support of the project.
- Ensure bottled water supply to the schools in the area of influence of the project.
- Provide timely technical and financial reports to SISSO as per the schedule.
- Participate and contribute in all the workshops/training programmes organized under the project.
- Ensure running of the project and maintaining water supply chain after the project initial period of 18 months to make the project sustainable.

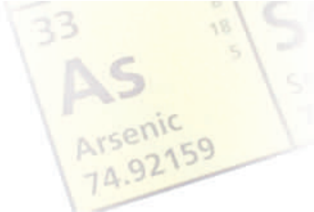
Figure 2. Purified Water ATM Plant at West Bengal

Sulabh Purified Drinking Water: An innovative initiative for community service

Purified Water ATM Plant at West Bengal: The Sulabh Purified Drinking Water is the latest technological initiative from Sulabh. Impure water from rivers, ponds, wells, water bodies and taps is purified by this Sulab technology, and the treated water becomes safe for human consumption. Sulabh has installed water treatment plants at six sites of West Bengal in Madhusudankati in North 24 Parganas, Murshidabad in Murshidabad district, Mayapur in Nadia, Suvasgram in South 24 Parganas, ISKON Haridaspur in North 24 Parganas and Chaksultan in West Medinipur. Raw water is drawn from the river Ganga in Mayapur and Murshidabad, while in Madhusudankati it is taken from a local pond. In Haridaspur, Chaksultan and Mirzapur, (West Medinipur), it is taken from well. After its treatment at the Sulabh Water Treatment Plant, the water from the river/pond/well becomes purified and absolutely safe for drinking. Sulabh is bottling this water which is known as Sulabh Safe Drinking Water. It is available for 50 paise per litre in West Bengal.

For residents of Madusudankati, the plant has proved to be a great help after years of suffering from skin and other diseases caused by arsenic in groundwater pumped from wells. After commencement of the Sulabh Water Treatment Plant, the residents are getting clean Sulabh Jal. There has been a considerable improvement in the health of the people affected by the arsenic poison.

Apart from supplying safe drinking water, Sulabh is also treating people suffering from arsenic poisoning at a health centre adjacent to the water plant.



Case Study Four

Promoting Community Health and Preventing Waterborne Diseases with the Jalkalp Water Filter

By *Lalit Sharma*[1]

Myriad efforts aimed at achieving the millennium development goal of providing safe drinking water to half of the world's population have not proved to be adequate, as a large bracket of the world's population continues to lack sufficient availability of good-quality water. Microbes, iron, arsenic, and turbidity are present individually or coexist in drinking water across numerous states in India.

The World Health Organization noted (WHO 2007) that "Lack of safe water perpetuates a cycle whereby poor populations become further disadvantaged, and poverty becomes entrenched." The lack of safe drinking water contributes to poor household economy due to loss of livelihood income during illness and increased financial stress from treatment costs.

Physical, chemical, and biological forms of contamination make the water unfit for drinking. Diarrhoeal and other waterborne diseases are caused by pathogens present in water. The geographical spread of such biological contamination is observed throughout India, with no estimates available on the number of districts affected (Shankar et al. 2011).

Consumption of contaminated water has particularly adverse health impacts on children and women. In India, the single largest cause of ill health and death among children is diarrhoea, which kills nearly half-million children (Pacific Institute 2010). Exposure to waterborne diseases is the foremost causal link behind inequalities in child mortality and poor nutritional status (Khurana & Sen 2006). The duration of illness due to diarrhoeal diseases and its severity are found to be higher among malnourished children where repeated exposure to diarrhoea results in weight loss, stunted growth, and vitamin deficiency. Morbidity due to waterborne diseases

[1]*Director, Adaptive Technologies, Sehgal Foundation*

increases the chances of children performing poorly or dropping out of school, and the prevalence of bacterial contamination in water increases the health risks for women especially during pregnancy.

Evidence suggests that prolonged consumption of water contaminated with arsenic is associated with development of cancer, particularly skin, lung, and bladder cancer (WHO 2004). Arsenic contamination above permissible limits is found across alluvial plains of Ganges, and is more recently been detected in the north-eastern regions of India (Saurav et al. 2015).

Excess iron in the body leads to health hazards like haemochromatosis. Drinking water with high iron content gives rise to iron bacteria—tiny creatures that feed off iron and leave behind iron waste deposits. They cause unpleasant stains, tastes, and odours; leave behind slime that sticks to pipes and fixtures, and can introduce other harmful bacteria.

Arsenic contamination, so far considered endemic to north-eastern parts of India, has now spread to a large part of Bihar state. With nearly twenty districts in Bihar in the grip of arsenic contamination, the situation has worsened for masses exposed to this slow and consistent toxin. The presence of arsenic in the region was first noticed in Bangladesh in 1991, and in Nepal, adjoining Bihar, in 2001. Arsenic was first found in Bihar in 2002, and extensive testing has since been carried out. The map below shows that eighteen districts of Bihar had arsenic pollution in the groundwater in 2014. In most of these areas, the groundwater also contains high levels of iron and biological contamination. In these mostly flood prone areas, drinking water remains the biggest challenge during flood periods. But contamination in the drinking water and associated risks remain a big challenge even beyond flood periods.

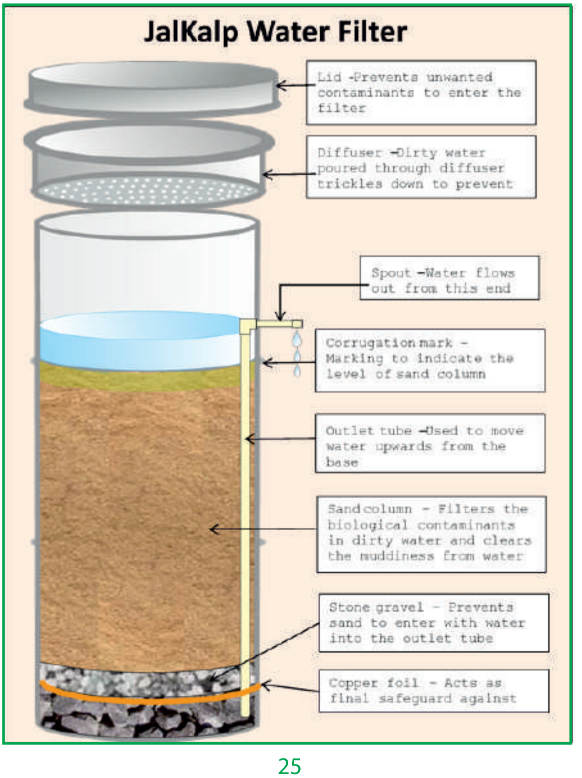
Source: DR A K Ghosh, professor-in-charge, Department of environment and water management, A N College, Patna

Most of the rural population does not currently use any method for purifying water, or have any other adequate solution. Widespread occurrence of these contaminants and the lack of awareness have created a public health crisis that calls for immediate attention. A solution that can facilitate the elimination of these frequently occurring contaminants simultaneously is an urgent requirement.

Though there have been efforts to put water treatment plants to address arsenic and iron in some villages, most were not sustained for various reasons such as:

- Technological limitations of the plants
- Plants not serviced and maintained timely and/or properly
- Communities not trained, mobilized, and motivated to undertake the maintenance
- Lack of community participation
- Lack of education and awareness among communities
- Poor community dynamics and socioeconomic conditions

Household water treatment technologies have the potential to avoid 122.2 million DALYs (disability adjusted life years) throughout the world (Pacific Institute 2010). JalKalp water filter is one such technology that removes biological contaminants, iron, arsenic, and turbidity from water, making it suitable for drinking. JalKalp works under the force of gravity without using any form of energy or on-line pressure.



SM Sehgal Foundation Promotes Safe Drinking Water

Through a project supported by Water Technology Initiative of Department of Science and Technology, Government of India, S M Sehgal Foundation is promoting the adoption of the low-cost sustainable JalKalp water filter in selected villages of Bihar. Sensitizing communities about the presence of contaminants, their impact on health, and need of safe drinking water is the key component of the project. The project goal is to benefit poor rural communities who are unaware of the importance of safe drinking water and those who cannot access the prevalent high-tech water treatment systems due to lack of affordability or erratic power and/or water supplies.

Working & maintenance of JalKalp water filter

(A) JalKalp water filters remove pathogens with four processes—

- Predation: A bio-layer that forms on top of the sand contains bacteria that consume harmful bacteria and parasites as new water enters the filter.
- Adsorption: Viruses adhere to the surface of specially prepared sand, which has a slight electrostatic charge, and die there.
- Anaerobic Die-off: As there is no oxygen, light, or air further down in the filter, any remaining microbes die off.
- Mechanical Filtration: Fine-grain sand prevents the passage of bacteria, parasites, and worms, which are relatively large.

(B) The technology of arsenic removal in the filter is based on generating Fe^{2+} by contacting water with zero valent iron (ZVI) and efficiently using the iron (Fe^{2+} present in the groundwater and Fe^{2+} produced by corrosion of ZVI) for removal of arsenic. Fe^{2+} forms hydrous ferric oxide (HFO-adsorbent for arsenic) on oxidation of Fe^{2+} during subsequent filtration; HFO is an effective adsorbent for arsenic. The process is so designed that efficient oxidation of As(III) to As(V) is achieved; and As(V), thus formed, is adsorbed on HFO.

© The iron-contaminated water passes through the diffuser, drips down in the form of droplets, and the surface area of the water increases. With the increased surface area, the oxygen absorption of the water also increases and thereby iron in the water is oxidized. The compound formed by oxidation is insoluble in water, so it is trapped on the top surface of the sand column and the iron is removed from the water.

As there are no moving parts, JalKalp filter does not require any replacements. With time, the flow rate of filtered water may reduce due to an accumulation of silt (came with water) over the sand top layer. When the flow rate slows down, the maintenance to be conducted is simple: lift off the lid, pour water into the filter, take out the diffuser box, and do a "swirl and dump," gently swirling the water above the top layer of sand. The deposition is suspended in the water over the sand, and that cloudy water can be removed. This may be repeated once or twice more if the flow rate is not recovered.

Innovations at three levels promote adoption of a low-cost, zero-maintenance JalKalp water filter to address arsenic, iron, biological water contaminations, and turbidity:

a. Approach innovation

Household water treatment technologies hold an edge over community-level technology as they minimize the chances of secondary infections.

b. Product innovation

JalKalp is a low-tech, low-cost, and easy-to-maintain water filter with a more innovative design than conventional biosand filters. It works under gravity without any external energy/on-line pressure, and has no parts that require replacement. Features include:

- Integration of germicidal properties of copper increases coliform-removal efficiency to 100%.
- Integration of Zero Valent Iron Technology removes arsenic.
- Filtration rate of 0.6 litres per minute is increased over the 0.4 in conventional design.
- Stainless steel cell design weighs only 4.5 Kg vs. the original concrete design weighing 70 Kg.
- Portability and quality control is better than conventional biosand filters.
- Operation and maintenance do not require any special skills.

c. Process innovation

The key to sustainability is ownership and active participation by beneficiaries. Therefore, major emphasis is placed on sensitizing communities about issues of water quality and waterborne diseases. This process triggers the demand for a solution. When communities are sensitized and demand a solution, JalKalp is offered as a safe and affordable solution.

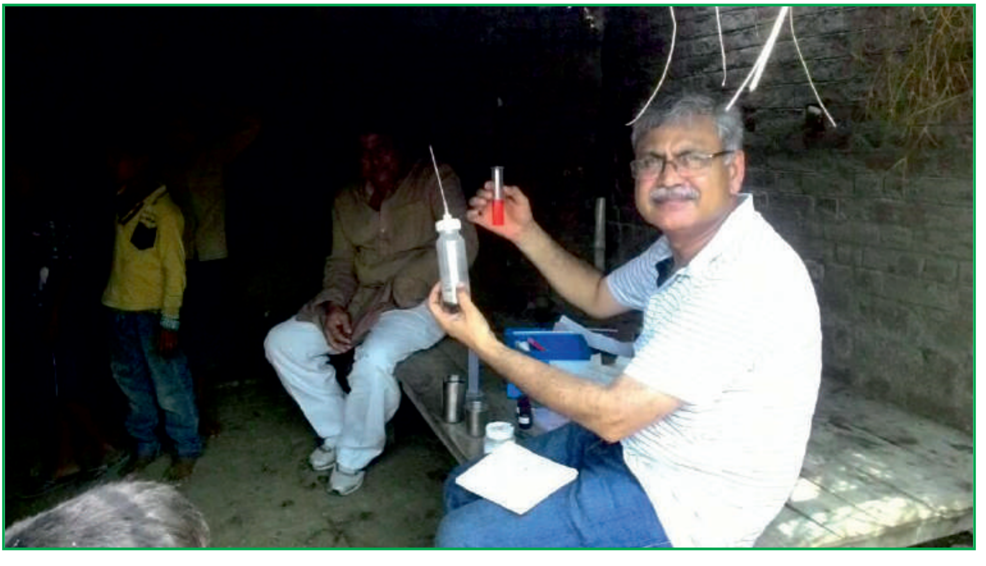
Mr. Prince of district Vaishali, a fan of JalKalp

Mr. Prince Singh, age 22 lives with his family (2 male and 4 female) in village Kharika of block Bidupur, Vaishali district (Bihar). Most hand pumps in his village are marked RED by related departments, forbidding people to use the water from these pumps. Many cases of skin cancer are found in the village, causing many deaths. Mr. Prince's grandmother died of skin cancer after a long medical treatment.

People in the village know how dangerous the water is, so most of them buy water to drink, but for cooking they use the hand pump water, which allows consumption of arsenic through food. So buying water for drinking was not a complete solution. Mr. Prince used to buy water for drinking—before he met Mr. Dharmendra Singh from Sehgal Foundation. Mr. Singh told him about the JalKalp water filter and proposed that he try it. Mr. Prince immediately agreed. Mr. Singh first tested the water from the hand pump using a field kit, which showed arsenic contamination over 250 PPB (parts per billion), iron over 3 PPM (parts per million), and the presence of coliform indicating biological contamination. (Permissible limits are arsenic: 10 PPB, iron: 0.3 PPM, and no presence of coliform.)

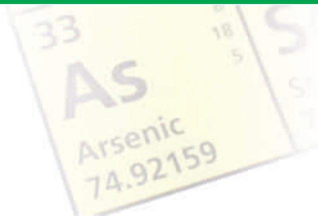
A JalKalp water filter was installed at Mr. Prince's house and the contamination in water was monitored after a week. The JalKalp water filter had brought down arsenic, iron, and coliform to not-detectable levels.

Mr. Prince was amazed with the results. He said he saw changes in his water. Earlier when we used to prepare tea using hand pump water, its color was almost black; but now the JalKalp filter's water shows the true colour of tea. The family no longer purchases water to drink. They use JalKalp for drinking water and for cooking. They not only notice better water colour, but also better taste of their food. He said he is also very happy that, since the day he started using the JalKalp, his digestion problems (acidity, constipation, etc.) have disappeared.



References

1. Khurana, I. & Sen, R., 2006. Drinking water quality in rural India: Issues and approaches. *WaterAid*. Available at http://www.ctara.iitb.ac.in/en/system/files/drinking-water-quality-rural-india.pdf
2. Pacific Institute, 2010. World water quality facts and statistics. Available at http://www.pacinst.org/wp-content/uploads/sites/21/2013/02/water_quality_facts_and_stats3.pdf
3. Saurav, D. et al., 2015. Groundwater Arsenic Contamination In North Eastern States Of India. *Journal of Environmental Research and Development*, 9(3), 621.
4. Shankar, P.S.V., Kulkarni, H. & Krishnan, S., 2011. India's Groundwater Challenge and the Way Forward. *Economic and Political Weekly*, xlvi(2), 37–45.
5. WHO, 2004. Arsenic in drinking-water. IARC *Monographs on the Evaluation of Carcinogenic Risks to Humans*, 84, 41–267.
6. WHO, 2007. *Combating waterborne disease at the household level: International Network to Promote Household Water Treatment and Safe Storage,* Available at http://www.who.int/household_water/advocacy/combating_disease.pdf



Case Study Five

Women Against Arsenic: A Success Story

By *Prof. Abhijit Das & Mr. Sayantan Chakrabarti*

'In arsenic infested Haringhata, West Bengal, few housewives are in the business of saving lives by supplying safe drinking water.'

The Challenge: Provision of safe drinking water in arsenic infested areas of West Bengal

India today, has arguably entered, or at least is on the verge of entering, a phase of 'Hydro Schizophrenia'. In other words, we are opting for myopic solutions towards fulfilling the crisis of safe water scarcity, i.e. Millennium Development Goal-7. Our efforts, in general, are failing to recognise the unity and integrity of the hydrologic cycle. Therefore localities are 'slipping' back after being covered under rural drinking water schemes. The situation is further complicated by the presence of several impurities in groundwater. A primary one amongst those is arsenic, a proven carcinogen.

In arsenic affected regions of West Bengal, lack of access to safe drinking water sources is compelling individuals to consume a dose of poison every time they quench their thirst. Millions of people from the state are affected by the arsenic crisis, and more than one-third of them have no access to safe drinking water sources according to the last report. Majority of those consuming arsenic laced water also belong to the lowest economic strata thereby increasing their vulnerability manifold. Arsenic reduces the working capacity of the affected significantly. In the case of these poverty-stricken and ill-educated individuals affected by arsenic, their capacity to perform labour jobs is their only resource to generate income. What makes the situation worse is the fact that there is no medication for arsenic induced illnesses. The affected die a gradual death and become a burden on the meagre resources at their families' disposal much before their eventual demise.

Experience sharing from the field visit: A success story

A large number of arsenic mitigation measures were installed in Nadia district. But all were rendered defunct due to the lack

[1]Associate Professor, Head of Department of Economics, Vijaygarh Jyotish Ray College, Kolkata, India

[2]Kolkata, India

of community participation. In December 2010, a community based arsenic mitigation system under Swajaldhara scheme was installed in the village Haringhata of Haringhata block under Haringhata- I Gram Panchayat in Nadia district. The exact location of the Swajaldhara water project is in the premises of Haringhata Rural Hospital, beside Bara Jaguli Chowmatha of National Highway-34 (Figure 1).

Figure: Location of the Swajaldhara Project

Source: Field Survey

The Solution: Make women, the traditional custodian of water in India, in charge of community based safe water filtration and supply programmes

In one such arsenic devastated region, i.e. Haringhata, Nadia district, West Bengal, a silent revolution is on its way. Women of the community, who have been bearing the brunt of the contamination, have taken up matters in their own hands. They have been traditionally providing water for all household requirements. However with the advent of arsenic contamination of groundwater the water they served became slow poison. The psychological scar of this inability to provide for the safety and prosperity of the family was intolerable for them. This triggered a self-inspired movement to take charge of the community based Arsenic Removal Plant (ARP) set up in their locality in the year 2010 with 6000 litre plant capacity. The total installation cost of the water project is Rs.7.33 lakh financed by Central government. Initially, there was no need of community contribution as it was installed in a government plot. The villagers have constituted a water committee so that they can themselves manage the treatment unit. What is important is that the committee has a number of women members at every stage. The water committee has decided that it is maintained and operated by women led SHGs (total 17 members by shifting duties, two hours per day) and the beneficiaries have to contribute a small water tariff (20 paisa/litre) towards maintenance of the project. The women got together. They formed a Self Help Group (SHG) named 'Sreema' and ensured nobody from their village ever needed to consume unsafe water. In the initial days they had to provide the facilities for free for near about 15 days, but later on the panchayat followed by the Zilla Parishad acknowledged their work and granted them permission for a salaried and paid service. Recently from 2016 this facility is under the jurisdiction of Haringhata Municipal Corporation.

The idea of forming Village Water Suraksha Committees (VWSC) for operation and maintenance (O&M) of water related assets have been mooted by Rajiv Gandhi National Drinking Water Mission (RGNDWM). But sadly, the idea has largely remained on paper. In this context, the Haringhata experience stands out as a welcome exception. This arsenic removal water-treatment unit which is women led, owned, and operated is serving safe water and, in turn, ensuring India's progress on several counts of the MDG. To achieve the goals of universal safe water supply this SHG has put a very affordable price on safe water. The revenue thus generated not only ensures fulfilment of expenses incurred on the account of operation of the plant, but has also generated livelihood for women who operate the unit. It exemplifies the statement by Organisation for Economic Co-operation and Development's secretary-general, Angel Gurria: "Women are the most underutilized economic asset in the world's economy."

The women led VWSC in Haringhata has invested their profits from the ARP venture into establishing a Community Sanitary Complex (CSC). Resultantly basic water-borne ailments such as diarrhoea, dysentery, jaundice, intestinal worms, urinary tract infections (UTI), dengue, malaria, and typhoid amongst others have also reduced significantly. The peace of mind because of not needing to defecate in the open is yet another gift to the villagers from this group.

The result: A holistically sustainable system which is an epitome of women empowerment

The salary of the members of the SHG who run this unit has increased Rs.500 / month to Rs.1000/month (for working 2 and ½ hours, a day). They have been recently provided with shift break tea and refreshment cost by committee. The work is carried out in five shifts (work comprising recurring periods in which different groups of workers do the same jobs in relay). Duration of each shift is 2 hours at a stretch (7-9 am, 9-11 am, 11am-1 pm, 3-5 pm, 5-7 pm). Daily water supply is provided at a very low cost at 40 paisa per litre (following a coupon system). During our first visit the cost of supplying water was 20 paisa per litre. The unit increases the accounts for savings in the tune of Rs. 12000 - 13000/- per month (as reported in our first visit September, 2012) to Rs. 17000-18000/- per month (as reported in our second visit May, 2017). They have truly convinced the community to pay for the natural resources they consume and in return, ensured a steady supply of essential resources.

The client base, at the time of the field visit in September 2012 was approximately 250 – 300 families on a daily basis. The tremendous popularity of the project can be deciphered from the fact that people travelled for almost 15-20 km to source water from it and now 400-500 families collect water from this plant (as on May, 2017). The SHG was earning in the range of Rs. 800 – 1400 / day as reported in September, 2012. Now it is Rs 1300-1800/day in May, 2017. The SHG in September 2012 had a savings of more than Rs. 1 lakh and a fixed deposit of Rs. 75000 at a nationalised bank. The interest from these investments took case of all operational expenses including salaries of operator, accountant and SHG members. It also footed electricity bills and other material expenses. What was even more encouraging was the fact that this income was well managed and also subsequently invested. In 2016 near about 2.5 lakh has been invested for changing the media vis-a-vis for operation and maintenance purpose.

The water treatment plant is cleaned and maintained on a regular basis, the back-wash operation is performed by dedicated workmen at Rs.1500/month salary and the unclean water is passed out through a pipe set up on the backside of the facility. Water testing (quarterly fashion) is also carried out by the Nadia Zilla Parishad. The facility is cleaned up every day and has been a standing example as well as been able to supply clean contaminant free water to many households. Though this area has water supply facilitated by GAP (Ganga Action Plan), the locals complain about presence of chemical smell in the treated water; thus preferring the water supplied by the facility.

At a personal level, all the members have become economically independent for most of their requirements. From buying a mobile phone to accounting for their children's tuition fees, these super women have become truly self-sufficient. Their success has removed the blanket of anxiety and grief which shrouded Haringhata and turned it into a reincarnation of 'Buen Vivir', literally a place that exudes joy and celebrates the good life. In their achievement one finds the realisation of Mahatma Gandhi's famous saying, “Educate one man, you educate one person, but educate a woman and you educate a whole civilisation.”

The SHG has also actively engaged in community welfare activities. For example, Anjaman Biwi, a 75 year old destitute belonging to the below poverty line category lost her house during 'Aila', the cyclone. When the state machinery failed to support this woman it was the SHG which built her a new house. They also supply new clothes to the poor during the Durga Puja festivities. They also make sure that all patients, their kin and the staff of the nearby hospital get free access to safe water, regularly.

There is only a small group of people who may have been complaining about the spectacular success of the SHG. The owners of local medicine shops used to earn a substantial part of their revenue by selling common gastro-intestinal drugs. After all, gastro-intestinal problems are one of the most common ailments caused by ingestion of arsenic contaminated groundwater. However, they too seem rather happy with the developments. When asked, they replied that they too were suffering from the arsenic induced ailments, and with regular availability of safe water, their stomach has been also been giving them no troubles!

The women led SHG has been a landmark achievement in the war against arsenic. The success of these women has inspired hopes in nearby villages that they may also get access to safe drinking water. In fact, the SHG have been invited by several adjacent localities to start similar safe water delivery networks, and they are willing to expand their operation to newer horizons, soon.

Case Study Five

Helping Communities Get Pure Water: The Story of Ballia

By *Puneet Srivastava*[1]

WaterAid India (WAI) through its programme intervention spread across ten states across the country focuses on the provision of safe water and sanitation services coupled with awareness on hygienic behaviour and practices. It believes that safe water and sanitation is essential for human development and poverty reduction.

This story is about the communities in twelve blocks of Ballia district in Uttar Pradesh who now have access to arsenic free water at their doorstep. Arsenic in groundwater sources has been a major problem in Ballia and the government's response had been from an initial denial to acceptance mode and thereafter to solutions mode, but the solutions looked upon were only short term or interim. This case study is about the problem of arsenic and WAI's intervention to provide communities arsenic free water through arsenic removal filters.

These filters were inaugurated in the presence of Honourable Rural Development Minister, Government of Uttar Pradesh, Mr. Daddu Prasad and District Magistrate, Ballia Mr. Pandian on September 14, 2009

The case of Ballia

Ballia district located on the easternmost part of the state of Uttar Pradesh lies between the parallels of 25° 33' and 26°11' North latitudes and 83°38' and 84° 39' East longitudes and covers an area of 3168 sq. km.[1] It is surrounded by two major rivers namely the Ganges and Ghaghra (Saryu). This district comprising of 17 development blocks has a population of 2.7 million[1]. Being located in the Indo-Gangetic plain and having a rainfall of over 1000 mm the availability of water is not a concern. However the groundwater sources in the district is contaminated with Arsenic

Arsenic problem in Uttar Pradesh was first reported in 2003 by School of Environmental Studies, Jadavpur University (SOES-

[1]*WaterAid India*

JU). In its findings which were published in 2005 the SOES reported that the problem of arsenic contamination in this region is as grave as in the highly endemic areas of West Bengal, Bihar and Bangladesh. Several villages of Ballia, Ghazipur and Varanasi reported a level of arsenic in the water samples to be as high as 50 µg/l.

The sources of Arsenic contamination in water are generally industrial wastes. Though rare, natural arsenic pollution can occur in groundwater in specific geo-morphological conditions. The symptoms of chronic arsenic poisoning include various types of dermatological lesions, muscular weakness, paralysis of lower limbs, etc. Arsenic is a potential carcinogen and skin and lung cancer occur after exposure.

From denial to acceptance: the state's response

The state government's initial response to the findings was that of disbelief and it out rightly rejected the presence of arsenic in the state. This proved to be a major constraint in addressing the arsenic problem in Ballia. However, of late there has been an acceptance of arsenic problem and certain steps have been taken by the state which includes water quality monitoring for hand pumps; colour coding hand pumps in red when arsenic is detected and installation of deep bore well hand pumps in few villages.

The Uttar Pradesh Jal Nigam (UPJN) which is the key agency responsible for conducting survey and executing arsenic mitigation measures has tested 10,151 hand pumps for arsenic in all the seventeen blocks of the district and has reported 1,122 hand pumps in twelve blocks to be contaminated with arsenic exceeding 50 µg/l. Of the twelve blocks, five are most severely affected. As far as mitigation measures are concerned, till 2006, 250 deep hand pumps (up to 90 m) have been set up in the affected villages. 15 Rain Water Harvesting (RWH) systems, 15 Dug Wells (DW) and 170 Domestic Filters (DF) have also been set up in the affected villages[2].

WaterAid India's response

When WaterAid India (WAI) first visited the villages of the district it observed that despite knowing the that fact the water sources (hand pumps) are contaminated with arsenic people were forced to drink arsenic contaminated water. People opined that "this is the only nearby source of water for us, and that they know that the water is not good for our health but what other option do they have?" WAI partner Diocese of Varanasi (DOV) had been working in this area on a UNICEF supported project on raising the awareness of people on arsenic which was considerably low and its ill impacts on health. The level of awareness can be gauged from the fact that people were treating incidences of stomach pain with antacid like Digene, quite ignorant of the fact of the long term impact of arsenic which they consumed through their drinking water.

WAI through its partner Diocese of Varanasi (DOV)initiated a project with the aim "to reduce mortality and morbidity in Ballia caused by arsenic contamination of the groundwater" with the following objectives:

- To assess the level of arsenic in ground water in the district and its impact in the lives of the people;

- To significantly reduce the quantity of arsenic ingested;
- To create a good database through MIS and GIS on arsenic contamination and mitigation;
- To increase access to a sustainable safe water supply; and
- To create a community management structure for operation and maintenance (O&M) of schemes implemented and regular water quality check

Assessing the course of action

To begin with DOV, the WAI partner initiated an assessment of levels of arsenic in groundwater and found out that there was adequate secondary data available on arsenic contamination in the region and hence decided not to go ahead with detailed assessment of water sources for arsenic. The need was thus not in generation of data but for providing solutions for making arsenic free water available to the communities. On the basis of secondary data available seventeen villages were selected on the basis of the extent of problem. One of the selection criteria for the villages was also the fact that these have somewhat excluded in the provisioning of services by the government agencies. A baseline survey was also conducted to understand the problem and gauge the people's willingness to pay for safe water. The result was that many communities wanted free water and were not willing to pay for water. An exposure visit to Water for People, Kolkata was carried out for the project staff in December 2008. This organisation has been providing arsenic free water to communities through community filters which are operated and maintained by communities themselves.

One would believe that the state government was also contemplating the idea of installing arsenic removal filters in Ballia but was resistant to undertake the same. This provided an impetus to WaterAid India and its partner to install three community filters to provide arsenic free water to the people of the region.

Making the communities aware

But the journey was not as smooth as it was thought. As mentioned before, one of the measures initiated by the government to overcome the arsenic problem was the installation of deep bore well hand pumps in all the villages. Deep bore well hand pumps have been presumed to have no arsenic but recently the Government of India has banned the same as arsenic can leach into deep aquifers in long term. But this fact was not known to the communities. They believed that the testing of water quality which had been done before has marked the hand pumps in green colour which meant that they are safe for use. Some people also viewed that they have been drinking this water for years and had no problem, so what would be the problem now.

To raise awareness of the communities on the impact of arsenic self-help groups (SHGs) were formed in all the villages and awareness campaign through nukkad natak (street plays), school hygiene education programmes and rallies were carried out. Once the people were made aware and they realised the gravity of the situation they demanded a solution for the problem. For this purpose a team from Bengal Engineering and Science University (BESU) did an initial survey and shared Bengal's experience with regard to arsenic mitigation. The team through a simple demonstration exercise made people realise the contamination of water. The exercise was to dip in cut leaves of

Guava into a glass of water plant which after some time the water turned into brown colour because of presence of iron. The communities were shocked to see the water they drink had developed a deep brown colour.

Thereafter a brainstorming was carried out on the two important questions, these were:

- What have been the health impacts?
- How much do people spend on their treatment?

In course of the discussions the communities were also shown pictures of arsenicosis symptoms which resulted in people coming out and sharing similar symptoms. The villagers also shared the high expenditure incurred by them on treatment of arsenicosis symptoms. The people demanded that arsenic removal filters was the only long term solution to the health problems. Three villages namely Charaspura, Sawan chapra and Sripalpur were identified for installation of arsenic removal filters called as AMAL filters (See Box 1).

Box 1: Arsenic filter technology

The technology of AMAL filter has since been refined the active ingredients were made more effective; the filtration chamber evolved from a single compartment to a dual compartment, multiple output design for schools, and so on. The components of the basic filter are as follows:

- The wellhead unit consist of a cylindrical stainless-steel tank with 14–inch diameter and seven foot, two-inch height along with two distinct compartments;
- The upper chamber or head space of the column contains a splash distributor and atmospheric vent connections. This chamber ensures oxidation of dissolved iron into insoluble hydrated Fe (III) oxides or HFO particles;
- Underneath the head space is the fixed-bed activated alumina followed by graded gravels and the treated water collection chamber;
- The design flow rate of the column operating under gravity is 8–10 L/min;
- The column is routinely backwashed for 10–15 min everyday and the backwash water is passed through a coarse sand filter to retain the HFO particulates.

Advantages of AMAL filter:

- System involves a single chamber unit fitted to a hand pump / tubewell;
- One unit fulfils drinking and cooking needs of 300 families or 1500 school students;
- No requirement of addition of chemicals, pH adjustment and use of electricity;
- Materials to be used (including the sorbent) can be procured from indigenous source only;
- Manual maintenance and simple operation;
- Hardy and robust - suitable for communities and schools;
- Arsenic removed from contaminated groundwater retained within the same premises, without any indiscriminate disposal;

- Easy (pumped) and better backwash – therefore better water quality;
- 'Look – good' appearance of filter; and
- Generates psychological satisfaction and assurance of 'safe water'.

Setting up the plant

To make the communities in these villages own the project and to increase their participation, villagers were asked to form a water management committee. In all the three villages, water management committee was formed with 50 per cent women as members. The committee was made responsible for mobilisation of the community to pay for the treated water after installation of filter, contribution in form voluntary labour during construction and to ensure quality control. It took some time to convince the people for contributing voluntary labour and be responsible for the operation and maintenance of the water purification system. The biggest challenge was however the selection of the site for installing the treatment plant. The land belonged to the state government where the hand pumps were currently installed but due to the feudalistic social structure nature few households have made it a personal property by constructing a fence around the hand pumps. To overcome this problem, the constituted water management committee and the village pradhan jointly identified the site where the filter can be installed and then proceeded to convince the households to donate some land for benefit of community at large.

Thereafter laboratory analysis for arsenic was done in the selected sites and its surrounding sources. All of the eight sites tested positive for arsenic with four sources showing the level of arsenic to be above the permissible limit of 0.5ppb. On the basis of the findings, the two sites of Charaspura and Sawan chapra were finally selected for installing the filter and the third site of Sripalpur was selected as the household nearby was willing to donate land near the for installation of filter. The level of arsenic though not as high as the remaining two but had substantial amount of the contaminant. The filters were installed in the month of July, 2009 in these villages.

Norms for usage

- The water management committee formed in the villages had drafted certain norms for the running and usage of the plant. These include:
- A charge of Rs. 30/- per month per family will be levied for 30 litres of water every day;
- The water from the purification unit will only be used for drinking purposes;
- The charge will be more during occasions like marriage and festive seasons;
- An operator will be selected to operate and maintain the filter who will be paid a monthly honorarium for Rs.500 to 600 /-;
- The water management committee will be responsible for O & M of the filter, collection of user charges in Charaspura and Sawan chapra while in Sripalpur the user charges will be collected by a SHG and in turn they will get an incentive for the same.

Each of the users will be given a 'water user card' which is a record of their daily consumption. This is being done by the committee alongside maintaining the accounts of the community contribution. Initially the filter has been put on trial run where the communities can take drinking water on a daily basis. Simultaneously testing of water for arsenic is also being done and the level of arsenic in the filtrate has been found to be zero.

In Sawan Chapra forty five households have registered to take water from the filter and a self help group has been formed. This group named 'water chain' will motivate other households in the village to register as users for the filter and use this water for drinking. It is expected that by the end of this month 50 per cent of the households in the village will start using water from the filter for drinking and cooking purposes. The committee has also decided to procure and keep in stock hand pump spare parts like washer, nut, bolt so that repairs and faults can be immediately rectified.

This initiative has triggered in a wave of happiness in the villages. Initial response of the villagers has been filled with enthusiasm. Says Sudhir Kumar Singh a resident of Charaspura, "The water from the filter is good for health. Earlier we used to suffer from frequent stomach problems which have been reduced". A cheerful housewife Lalitha points, "the dal that we make from the treated water tastes better than before, water also tastes good." The intake of Digene tablets in the villages have also gone down because of the reduction in incidences of stomach pain claim the villagers.

What we have learnt!

- In water quality affected areas quick solutions to provide safe water is a priority more than assessment;
- Pay for water should be the principle than the concept of free water;
- Cost recovery should be guiding principles once the filter is a success and be promoted as a business model rather than a service model;
- Multiple players – government, donors, CSOs, community and private players need to collaborate for the success of any initiative; and
- Community empowerment is the key for success and sustainability of the programme.

The way ahead

This is just a small step in our mission to provide safe water to the people of the region. We have a long road to traverse as the project will be successful only when all the households use the water from the filter for drinking. This is just a demo model but the learning's of this will provide insights into the government initiative for replicating such a system for arsenic mitigation. This model also sheds the myth that people are not willing to pay, they certainly are willing provided we are able to provide a sustainable solution and make them realise the intended benefits.

References

1. *http://ballia.nic.in/*
2. *http://www.ecofriends.org/reports/065.htm*

SUPPORT US

We at Arsenic Knowledge and Action Network are working towards creating a more comprehensive case study compendium with solutions for arsenic mitigation in water. We request individuals and organisations to send in their case studies for this compendium and look forward to the same. You can mail your case study in PDF or Doc to manish@saciwaters.org or anshika@saciwaters.org or to our office's postal address.

SECRETARIAT

SaciWATERs
B- 87, 3rd Avenue,
Sainikpuri, Secunderabad - 500 094
Telangana, India
www.saciwaters.org

For any queries you may get in touch with us:

arsenicnetwork@saciwaters.org

www.arsenicnetwork.in

Arghyam
Safe, sustainable water for all