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Ground Water Arsenic Contamination: A Local Survey in India

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ABSTRACT

Background: In the present times, arsenic poisoning contamination in the ground water has caused lots of health-related problems in the village population residing in middle Gangetic plain. In Bihar, about 16 districts have been reported to be affected with arsenic poisoning. For the ground water and health assessment, Simri village of Buxar district was undertaken which is a flood plain region of river Ganga.

Methods: In this study, 322 water samples were collected for arsenic estimation, and their results were analyzed. Furthermore, the correlation between arsenic contamination in ground water with depth and its distance from river Ganga were analyzed. Results are presented as mean ± standard deviation and total variation present in a set of data was analyzed through one-way analysis of variance. The difference among mean values has been analyzed by applying Dunnett's test. The criterion for statistical significance was set at $P < 0.05$.

Results: This study shows novel findings ever done in this area. Halwa Patti and Doodhi Patti strips were the most affected strips with high-arsenic concentration in hand pumps. Furthermore, a correlation between the arsenic concentration with the depth of the hand pumps and the distance from the river Ganga was also a significant study.

Conclusions: The present study concludes that in Simri village there is high contamination of arsenic in ground water in all the strips. Such a huge population is at very high risk leading the village on the verge of causing health hazards among them. Therefore, an immediate strategy is required to combat the present problem.

Keywords: Arsenic contamination, ground water, river, village

INTRODUCTION

In the present scenario, water pollution has caused lots of health hazards to humans. Developing countries bear the maximum burden of pollution in comparison to the other developed countries. Heavy metals as chemical pollutants in water cause severe toxicity, carcinogenicity, and severe health-related diseases in the population.[1] Natural as well as anthropogenic sources are quite responsible for the distribution of pollutants like heavy metals throughout the environment. Arsenic abundant presence in the earth's crust, especially in soil, minerals, surface, and groundwater has led to its vulnerability to cause contamination.[2]

The Gangetic belt constitutes of states Uttarakhand, Uttar Pradesh, Bihar, and West Bengal and the entire belt

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is the most populated area of India. The agricultural land area of this belt is highly fertile; therefore, agricultural practices are the main occupation of the population. In India, the arsenic-related health problems in the population were observed for the first time in the West Bengal in the 1980s with correlation to groundwater arsenic poisoning.[3-5] In the present scenario, more than 5 million people of the state are drinking arsenic contaminated water with concentration >50 μg/L. Most recently, these problems have also been observed in the districts of Bihar and Uttar Pradesh. At present, in Bihar, 16 districts are reported with arsenic poisoning in groundwater.[6-9] Semria Ojha Patti village of Bhojpur district was the first arsenic affected area of the state which showed high-arsenic concentrations in ground water with serious health-related problems in the population.[10] Recent findings have also reported high-arsenic concentrations in ground water in the three districts of Uttar Pradesh - Ballia, Varanasi, and Gazipur.[11] High-arsenic concentration in groundwater and its consumption by the village people has caused lots of health-related problems in the population in these areas such as hyperkeratosis, keratosis, melanosis, loss of appetite, anemia, gangrene, skin lesions insole and palm, and skin cancer.[12-15]

In India, arsenic contamination in ground water is very severe in West Bengal, and now it has reached the Gangetic plain regions of Bihar and Uttar Pradesh. The most unfortunate part is that the village people of these arsenic hit area are unaware of arsenic contamination in their drinking water and are unknowingly consuming this water without aware of its facts as well as its consequences. In Bihar, the demographic assessment of arsenic in ground water is a meager reporting. This prompted us to evaluate the arsenic concentrations in the ground water of Simri village of Buxar district of Bihar, which is one of the arsenic hit areas of the state.

METHODS

Location

The study was conducted in India in Simri village of Buxar district of Bihar. The village is a flood plain region (25°38'17.6"N 84°06'49.4"E) of Simri Block of Buxar district. The population of the Simri village is 17,670 in 2011.[16] There are 2621 households in 2011.[16] The village is so large in area that it is divided into seven strips - Bakulaha Patti, Bhan Bharauli, Khaira Patti, Ramo Patti, Halwa Patti, Doodhi Patti, and Gope Bharauli. Among these seven strips, Doodhi Patti strip acquires the largest part of the Simri village.

Arsenic analysis and survey

For the collection of water samples, 500 ml polypropylene bottles were utilized and were cleaned and pretreated with hydrochloric acid. Altogether, 322 water samples in duplicates were collected from hand pumps of the households every 50 m of distance in each strip of the Simri village. After the collection, water samples were on spot analyzed utilizing Merckoquant Arsenic Field test kit (Merck, Germany). Final confirmation was done using Thermo Fisher ultraviolet-visible spectrophotometer through the silver diethyldithiocarbamate method against a blank at 520 nm.

For the estimation of the per capita consumption of drinking water through hand pumps by the village people, a survey in all the seven strips of the village was conducted utilizing a questionnaire method. The questionnaire was filled after proper interrogation with elderly, adults, and youths of the village (2680 people) related to the amount of daily consumption of drinking from their hand pumps, their household hand pump depth, and their health-related problems. Handheld global positioning system receivers with an estimated accuracy of ≈10 m were utilized for the determining the exact location of the area. The correlation between arsenic contamination in ground water with depth and its distance from river Ganga were also analyzed.

Statistical analysis

Statistical analysis was done utilizing statistical software (GraphPad Prism 5), and the values were expressed as mean ± standard error of mean. The difference between the groups were analyzed statistically by one-way analysis of variance using Dunnett's test.

RESULTS

Ground water arsenic contamination in Simri village

The Simri village is situated near the vicinity of the river Ganga. The nearest point from Simri village that is Khaira Patti strip to the river Ganga is hardly 1.65 km. The study also emphasizes that longer the distance from the river, the higher is the arsenic concentration in the ground waters of hand pumps [Table 1].

High prevalence of arsenic contamination in ground water was found after analysis of 322 water samples [Figure 1]. The different strips showed different patterns of arsenic contamination in ground water. All the seven strips showed a unique pattern of arsenic contamination in the groundwater as the middle region of the strips were arsenic free, but their periphery showed severe arsenic contamination in the hand pumps [Figure 2]. Among the most severely affected strips were Halwa Patti and Doodhi Patti where the arsenic contamination was much higher in most of the analyzed water samples [Figures 3-10]. The Halwa Patti strip showed hand pumps with arsenic contamination between 60 ppb and 300 ppb while Doodhi Patti strip showed hand pumps with arsenic contamination between 60 ppb and 400 ppb. The

Table 1: Comparative analysis between distance from river Ganga to different strips of Simri village, average arsenic concentration in groundwater in strips and average depth of hand pumps (analysis of variance test)

Strips	Distance from river Ganga (km)	Average arsenic concentration in groundwater in strips (ppb)	Average depth of hand pumps (feets)
Khaira Patti	1.65	24.10	87.54
Bakulaha Patti	2.48	38.16	80.78
Ramo Patti	2.64	40.56	79.27
Halwa Patti	2.90	90.0	85.81
Bhan Bharauli	2.95	67.5	78.33
Doodhi Patti	3.40	95.03	85.70
Gope Bharauli	3.90	62.5	92.50
Mean±SEM	2.846±0.269	84.28±1.923	59.69±10.16
ANOVA (*P*)*	<0.0001	<0.0001	<0.0001

ANOVA=Analysis of variance, SEM=Standard error of mean

average depth of the hand pumps in all the strips were 80 feet (24.38 m) [Figure 11]. The correlation between arsenic contamination in ground water with depth and its distance from river Ganga were analyzed which was found to be highly significant [Table 1].

DISCUSSION

The groundwater arsenic contamination has been well studied in the villages of Ganga Delta of West Bengal and Bangladesh.[17-20] In Bihar, the similar trend in the ground water was firstly reported in 2002 in Bhojpur district[21] and then after, the number has increased to 16 districts.[6] The most of the arsenic affected districts are from the Gangetic plain area denotes again the onset of similar pattern in Bihar also.

The utilization of digging hand pumps in every household eventually started in Bihar in the late 1980s. But, due to the immense utilization of ground water for agricultural practices in the 1990s caused lot of damage at the geological level in the Gangetic plains. This in turn led to the lowering down of the water table in summer season causing oxygen to reach into the aquifers. The oxygen caused oxidation of arsenic-rich iron sulfide in sediments leading to contamination of the entire aquifer with arsenic after water recharge.[10,22,23] In Bihar, the arsenic poisoning in Buxar district has been well documented.[6,7]

In this study, the groundwater assessment in Simri village is the novel work ever done in this field. The most fascinating finding deciphers that the arsenic poisoning in hand pumps of the village strips are in the periphery of it. The reason behind is that the village is located near river Ganga in oxbow lake area, formed due to meandering of river. Such area has alternating point bars and clay plugs. Usually, the

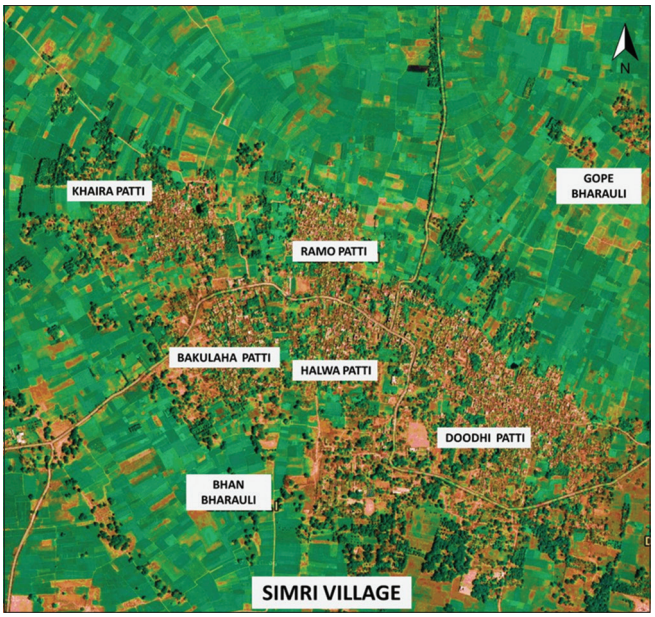

Figure 1: Aerial map of Simri village of Buxar district

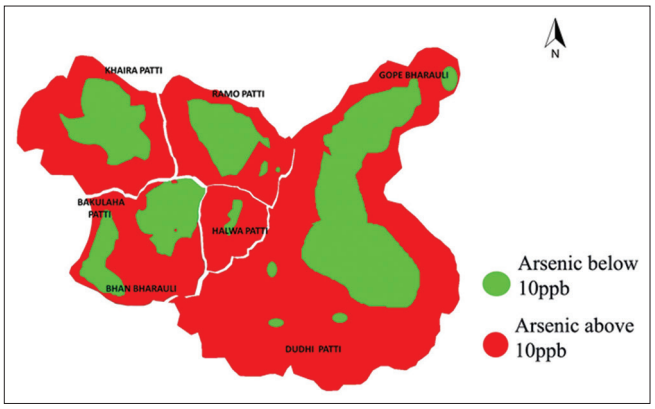

Figure 2: Arsenic map of Simri village

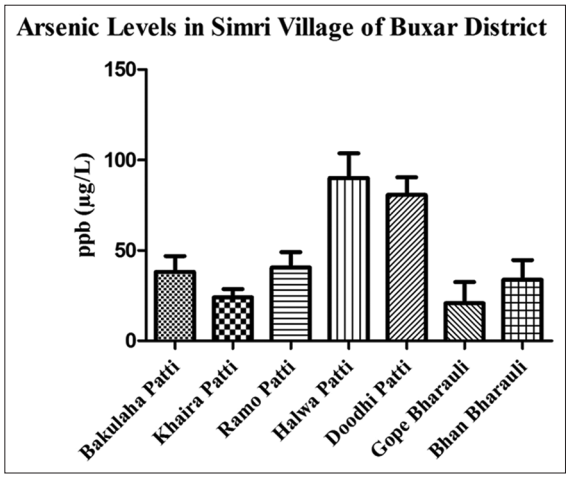

Figure 3: Graph figure of arsenic contamination in ground water in seven strips of Simri village

population is high in uplands where new alluvium containing arsenopyrite is less and these point bars

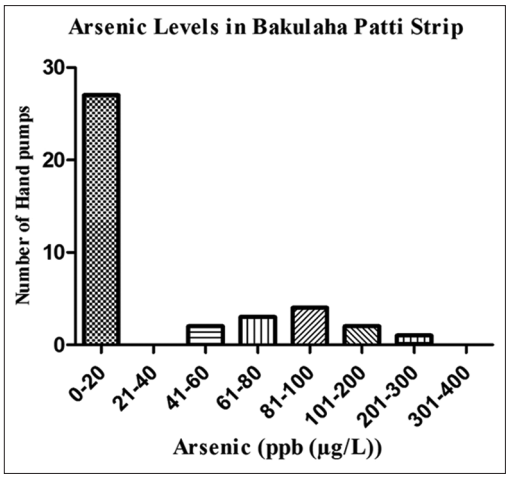

Figure 4: Graph figure of arsenic contamination in hand pump water in Bakulaha Patti strip of Simri village

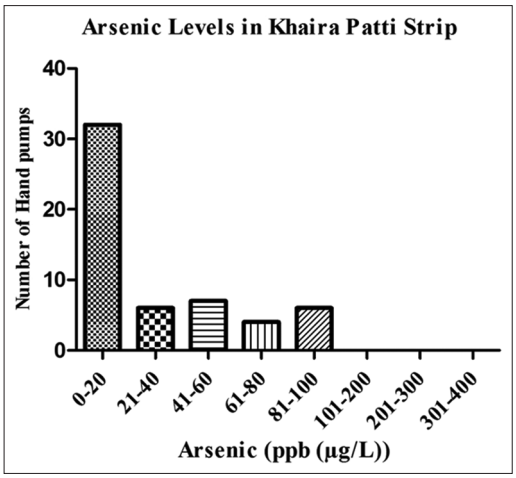

Figure 5: Graph figure of arsenic contamination in hand pump water in Khaira Patti strip of Simri village

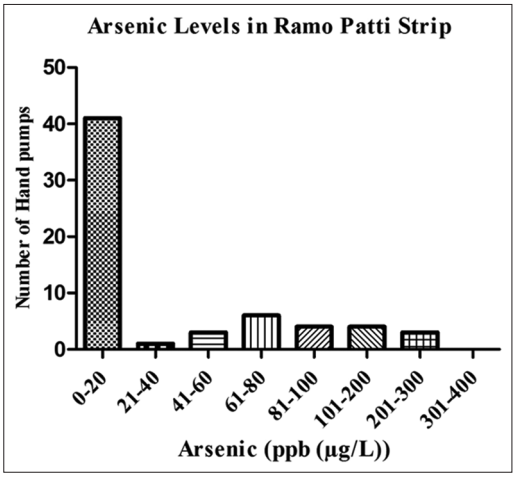

Figure 6: Graph figure of arsenic contamination in hand pump water in Ramo Patti strip of Simri village

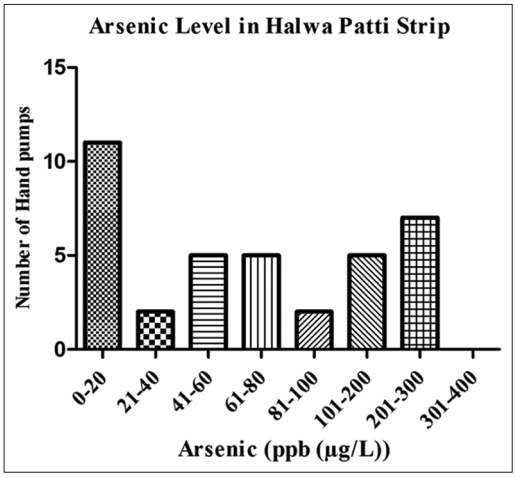

Figure 7: Graph figure of arsenic contamination in hand pump water in Halwa Patti strip of Simri village

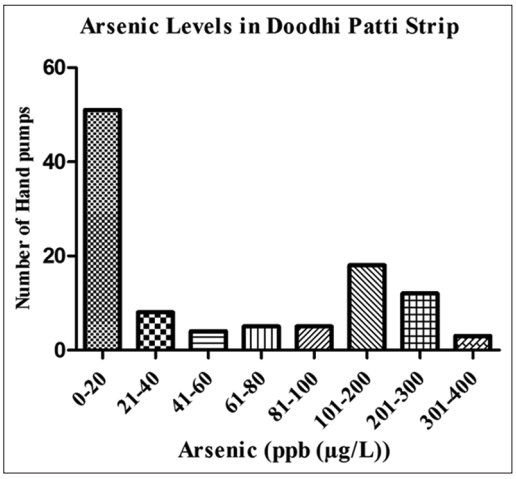

Figure 8: Graph figure of arsenic contamination in hand pump water in Doodhi Patti strip of Simri village

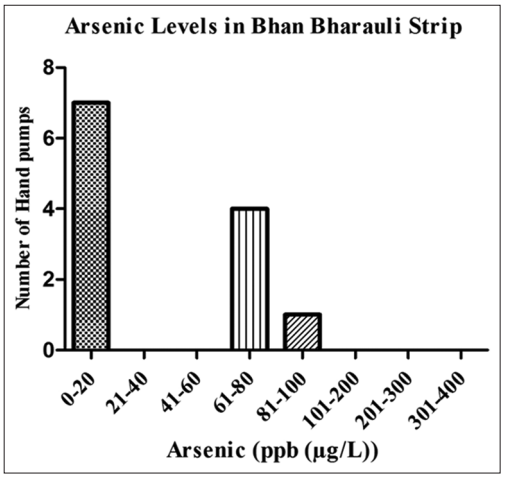

Figure 9: Graph figure of arsenic contamination in hand pump water in Bhan Bharauli strip of Simri village

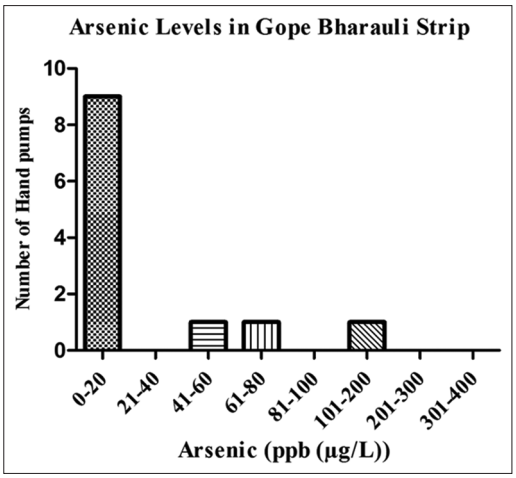

Figure 10: Graph figure of arsenic contamination in hand pump water in Gope Bharauli strip of Simri village

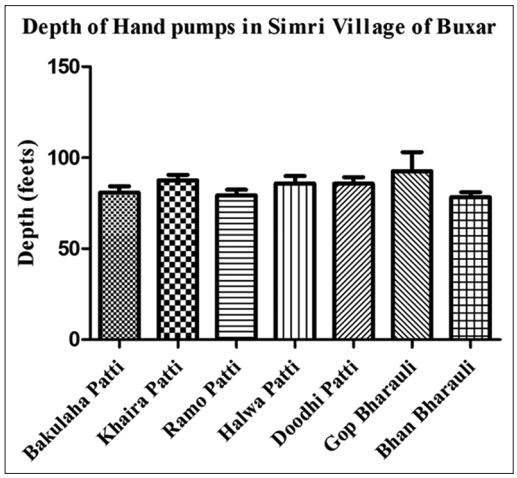

Figure 11: Graph figure of depth of hand pumps in seven strips of Simri village

are insulated by alternating clay plugs which blocks arsenic mobilization from other point bars where arsenopyrite arsenic is higher. It is also interpreted that a free-moving groundwater flux is present in the highly permeable gravel and gravelly sand below the sequence boundary. The flux effectively flushes the permeable sediment, hence, the low-arsenic concentration. Arsenic-enriched water that percolates downward from the point-bar sand to the sequence boundary accumulates at the top of the free-moving groundwater flux; hence, the peak in arsenic concentration.[24] The second most important finding also deciphers that the strips which are closer to the river Ganga especially Khaira Patti and Ramo Patti are having low concentrations of arsenic in the groundwater but the strips which are far away from the river Ganga such as Halwa Patti, Doodhi Patti, Bakullaha Patti, Bhan Bharauli, and Gope Bharauli strips are having higher concentrations of arsenic in the groundwater. The reason behind is that the village is located near river Ganga in oxbow lake area, formed due to meandering of river. Such area has an alternating point bars and clay plugs. Usually, the population is high in uplands where new alluvium containing arsenopyrite is less, and these point bars are insulated by alternating clay plugs which blocks arsenic mobilization from other point bars where arsenopyrite arsenic is higher. It is also interpreted that a free-moving groundwater flux is present in the highly permeable gravel and gravelly sand below the sequence boundary. The flux effectively flushes the permeable sediment, hence the low-arsenic concentration. Arsenic-enriched water that percolates downward from the point-bar sand to the sequence boundary accumulates at the top of the free-moving groundwater flux; hence, the peak in arsenic concentration.[24]

The depth of the hand pumps of the village showed no arsenic concentration up to 60 feet but below that depth between 70 feet and 300 feet high-arsenic concentration was observed. The most affected strips were Halwa Patti and Doodhi Patti strips with high-arsenic concentration in hand pumps. The present research work on arsenic concentration pattern in hand pumps in the Simri village is the exclusive novel study ever reported.

CONCLUSIONS

Thus, present study concludes that the village people of Simri village are at very high risk as they are consuming drinking water having high-arsenic concentration in their hand pumps. This has led to severe health-related problems in the population of the village people.

Therefore, an immediate proper strategy is required to cater the health-related problems in the population of the Simri village caused by arsenic poisoning.

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Conflicts of interest

There are no conflicts of interest.

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REFERENCES

1. Park K. Park's Textbook of Preventive and Social Medicine. 16th ed. Jabalpur, India: B D Bhanot Publishers; 2001. p. 483-97.
2. Antman KH. Introduction: The history of arsenic trioxide in cancer therapy. Oncologist 2001;6 Suppl 2:1-2.
3. Haque R, Mazumder DN, Samanta S, Ghosh N, Kalman D, Smith MM, *et al.* Arsenic in drinking water and skin lesions: Dose-response data from West Bengal, India. Epidemiology 2003;14:174-82.
4. Acharyya SK, Chakraborty P, Lahiri S, Raymahashay BC, Guha S, Bhowmik A. Arsenic poisoning in the Ganges delta. Nature 1999;401:545.
5. UNICEF Plan of Action to Combat Situation Arising Out of Arsenic Contamination in Drinking Water: Plan to Assist Government of West Bengal Report. United Nations Children's Fund; December, 1998.
6. Singh SK, Ghosh AK, Kumar A, Kislay K, Kumar C, Tiwari RR, *et al.* Groundwater arsenic contamination and associated health risks in Bihar, India. Int J Environ Res 2014;8:49-60.
7. Ghosh AK, Shatrunjay KS, Bose N, Sushant KS, Singh A, Mishra RC, *et al.* Study of Arsenic Contamination in Ground Water of Bihar (India) along the River Ganges: International Workshop on Arsenic Sourcing and Mobilization in Holocene Deltas. Department of Science and Technology, Government of India, on; 12-13 December, 2007. p. 83-7.
8. Ghosh AK, Singh SK, Bose N, Singh K. Arsenic hot spots detected in the state of Bihar (India) a serious health hazards for estimated human population of 5.5 Lakh. In: Ramanathan AL, Bhattacharya P, Keshari AK, Bundschuh J, Chandrashekharam D, editors. Assessment of Ground Water Resources and Management. New Delhi: I. K. International Publishing House Pvt. Ltd.; 2009. p. 62-70.
9. Saha D. Arsenic groundwater contamination in parts of middle Ganga plain, Bihar. Curr Sci 2009;97:753-5.
10. Chakraborti D, Basu GK, Biswas BK, Chowdhury UK, Rahman MM, Paul K, *et al.* Characterization of arsenic bearing sediments in Gangetic delta of West Bengal-India. In: Chappell WR, Abernathy CO, Calderon RL, editors. Arsenic Exposure and Health Effects. New York: Elsevier Science; 2001. p. 27-52.
11. Ahamed S, Kumar Sengupta M, Mukherjee A, Amir Hossain M, Das B, Nayak B, *et al.* Arsenic groundwater contamination and its health effects in the state of Uttar Pradesh (UP) in upper and middle Ganga plain, India: A severe danger. Sci Total Environ 2006;370:310-22.
12. ATSDR US Agency for Toxic Substances and Diseases Registry. Toxicological Profile for Arsenic; 2005.
13. ATSDR/DTEM Agency for Toxic Substances and Disease Registry, Division of Toxicology and Environmental Medicine. ToxFAQs: CABSTM/Chemical Agent Briefing Sheet Arsenic; 2006.
14. Karim M. Arsenic in groundwater and health problems in Bangladesh. Water Resour 2000;34:304-10.
15. Bagla P, Kaiser J. India's spreading health crisis draws global arsenic experts. Science 1996;274:174-5.
16. Census: Interim Report of Population Census of India; 2011. Available from: http://www.censusindia.gov.in.
17. Nickson R, Sengupta C, Mitra P, Dave SN, Banerjee AK, Bhattacharya A, *et al.* Current knowledge on the distribution of arsenic in groundwater in five states of India. J Environ Sci Health A Tox Hazard Subst Environ Eng 2007;42:1707-18.
18. Chakraborti D, Rahman MM, Paul K, Chowdhury UK, Sengupta MK, Lodh D, *et al.* Arsenic calamity in the Indian subcontinent what lessons have been learned? Talanta 2002;58:3-22.
19. Chakraborty AK, Saha KC. Arsenical dermatosis from tubewell water in West Bengal. Indian J Med Res 1987;85:326-34.
20. Garai R, Chakraborty AK, Dey SB, Saha KC. Chronic arsenic poisoning from tube-well water. J Indian Med Assoc 1984;82:34-5.
21. Chakraborti D, Mukherjee SC, Pati S, Sengupta MK, Rahman MM, Chowdhury UK, *et al.* Arsenic groundwater contamination in middle Ganga plain, Bihar, India: A future danger? Environ Health Perspect 2003;111:1194-201.
22. Chowdhury TR, Basu GK, Mandal BK, Biswas BK, Samanta G, Chowdhury UK, *et al.* Arsenic poisoning in the Ganges delta. Nature 1999;401:545-6.
23. Das D, Samanta G, Mandal BK, Roy Chowdhury T, Chanda CR, Chowdhury PP, *et al.* Arsenic in groundwater in six districts of West Bengal, India. Environ Geochem Health 1996;18:5-15.
24. Donselaar ME, Bhatt AG, Bose N, Bruining J, Ghosh AK. Entrapment of Arsenic-Contaminated Groundwater in Point Bars: Case Study of Holocene Ganges River deposits, Bihar, India, Proceedings of 10th International Conference on Fluvial Sedimentology, University of Leeds, UK; 14-19 July, 2013.