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ASSESSMENT OF ARSENIC CONTAMINATION IN SOILS OF AMBAGARH CHOWKI BLOCK, RAJNANDGAON DISTRICT, CHHATTISGARH INDIA

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ABSTRACT

This study aims to evaluate the arsenic content in soils of the Ambagarh Chowki block in Rajnandgaon district, Chhattisgarh. Soil samples from two different depths (0-20 cm and 20-40 cm) were collected from thirteen arsenic-contaminated villages: Metepar-Gaulitola, Kaudikasa, Joratarai, Atergaon, Pangri-Keshitola, Biharikala, Arajkund, Jadutola, Magatola, Sangli, Telitola, and Sonsaitola. Sampling was conducted during both pre-monsoon and post-monsoon seasons`. In the pre-monsoon season, total soil arsenic content ranged from 0.94 to 5.69 mg kg^{-1} at 0-20 cm depth and 0.65 to 3.91 mg kg^{-1} at 20-40 cm depth. In the post-monsoon season, arsenic content varied from 0.78 to 5.26 mg kg^{-1} at 0-20 cm depth and 0.58 to 3.46 mg kg^{-1} at 20-40 cm depth. Among the soil orders studied, *Vertisols* contained relatively higher arsenic levels compared to *Alfisols* and *Inceptisols*. The highest concentration of arsenic was recorded in Kaudikasa-1, with a mean value of 7.52 mg kg^{-1} at 0-20 cm and 4.94 mg kg^{-1} at 20-40 cm depth during the pre-monsoon season, and 6.92 mg kg^{-1} at 0-20 cm and 4.01 mg kg^{-1} at 20-40 cm depth during the post-monsoon season. All villages were found to be within the permissible limit for arsenic in agricultural soils set by the FAO (50 mg kg^{-1}). The concentration of arsenic in soil was higher during the pre-monsoon season compared to the post-monsoon season, and surface soils (0-20 cm) exhibited higher arsenic levels than sub-surface soils (20-40 cm).
Keywords: Arsenic contamination, Soil analysis, Ambagarh Chowki, Pre-monsoon and Post-monsoon.

Introduction

Arsenic contamination of surface and groundwater is a widespread and persistent issue, presenting significant socio-political challenges in many regions around the world. Numerous water bodies globally report arsenic levels exceeding the safe threshold of 50 µg L^{-1}, posing severe environmental and health risks. In India, the situation is particularly concerning, with severe health impacts documented among populations in several states, including West Bengal, Bihar, Assam, and Chhattisgarh (Chowdhury *et al.,* 2000; Acharyya, 2002; Jain, 2002; Chakraborti *et al*., 2003). The prevalence of arsenic contamination in these regions has led to increased morbidity and mortality, necessitating urgent attention and mitigation efforts.

Ambagarh Chowki in Rajnandgaon, India, has been identified as a region with high levels of arsenic contamination (Patel *et al.,* 2005; Shukla *et a*l., 2010; Singhal *et al*., 2018). Groundwater arsenic contamination in the Ambagarh Chowki block of Rajnandgaon district was first documented by Chakraborti *et al*. (1999). This initial study involved the analysis of groundwater samples from 146 sites, including Public Health Engineering Department (PHED) tube wells and dug wells across 22 villages. The results revealed that arsenic concentrations in these water sources significantly exceeded the World Health Organization (WHO) guidelines. Specifically, tube well water exhibited arsenic levels up to 520 µg L^{-1}, which is more than ten times the recommended limit of 50 µg L^{-1}. In comparison, dug wells, with depths generally less than 50 meters, showed even higher arsenic concentrations, reaching up to 880 µg L^{-1}.

The prolonged use of arsenic-contaminated irrigation water can lead to arsenic accumulation in agricultural soils, potentially reaching toxic levels that are detrimental to crop health. This accumulation can adversely affect crop yields and significantly increase dietary arsenic intake among the local population, thereby posing additional human health risks (Flanagan *et al*., 2012). Both humans and livestock are exposed to arsenic through contaminated drinking water and the consumption of food grown in arsenic-laden soil or irrigated with arsenic-contaminated water (Benejad and Olyaie, 2011).

Given the confirmed groundwater arsenic contamination in the villages of Ambagarh Chowki block, Rajnandgaon district, there is a substantial potential for arsenic accumulation in the soil. Such accumulation could have long-term ecological and health implications for the local population. Therefore, this study aims to provide a comprehensive estimate of the arsenic content in soils of Ambagarh Chowki block, Rajnandgaon. By assessing the extent of soil contamination, this research seeks to inform appropriate remediation strategies and contribute to the broader efforts of managing arsenic pollution in the region.

Table 1: Safe limit of arsenic

Organization/Country	Concentration of As	References
1. Agricultural soil		
FAO	50.00 mg kg^{-1}	Bhattacharya *et al.* (2009)
European community	20.00 mg kg^{-1}	Bhattacharya *et al.* (2009)
World limit	10.00 mg kg^{-1}	Ahsan and Del valls (2011)
2. Residential soil		
Australian health	100.00 mg kg^{-1}	Huq *et al.* (2006)
Environmental guidelines	20.00 mg kg^{-1}	Huq *et al.* (2006)

Materials and Methods

52 Soil samples were systematically collected from arsenic-affected villages within the Ambagarh Chowki block, specifically Metepar, Gaulitola, Arajkund, Kaudikasa, Biharikala, Pangari, Keshitola, Atargaon, Sangali, Telitola, Joratarai, Jadutola, Dhatutola, Mangatola, and Sonsoitola. Sampling was conducted during both the pre-monsoon and post-monsoon seasons to capture seasonal variations in arsenic content. Out of the total soil samples, 23 belonged to *Vertisols*, 21 to *Alfisols*, and 8 to *Inceptisols*.

Utilizing GPS technology, soil samples were collected from different depths (0-20 cm and 20-40 cm) within each selected village, ensuring precise location tracking for all samples (Fig. 1). The collected soil samples were then air-dried, crushed, and passed through a 2 mm sieve to obtain a uniform particle size for analysis. To ensure accuracy and consistency in sample preparation, an electronic weighing machine with 0.001 g precision was employed for weighing all soil samples.

The total arsenic content in the soil samples was determined using atomic absorption spectroscopy (AAS) with a vapor generation assembly (VGA). This method is highly sensitive and specific for detecting trace levels of arsenic, following the protocol described by Behari and Prakash (2006).

This rigorous methodological approach, including GPS-based sampling, precise weighing, and advanced analytical techniques, ensures the robustness and reproducibility of the study. By analyzing samples from both pre-monsoon and post-monsoon seasons, the study captures the potential temporal fluctuations in arsenic levels, offering a comprehensive understanding of arsenic contamination in the soils of Ambagarh Chowki block.

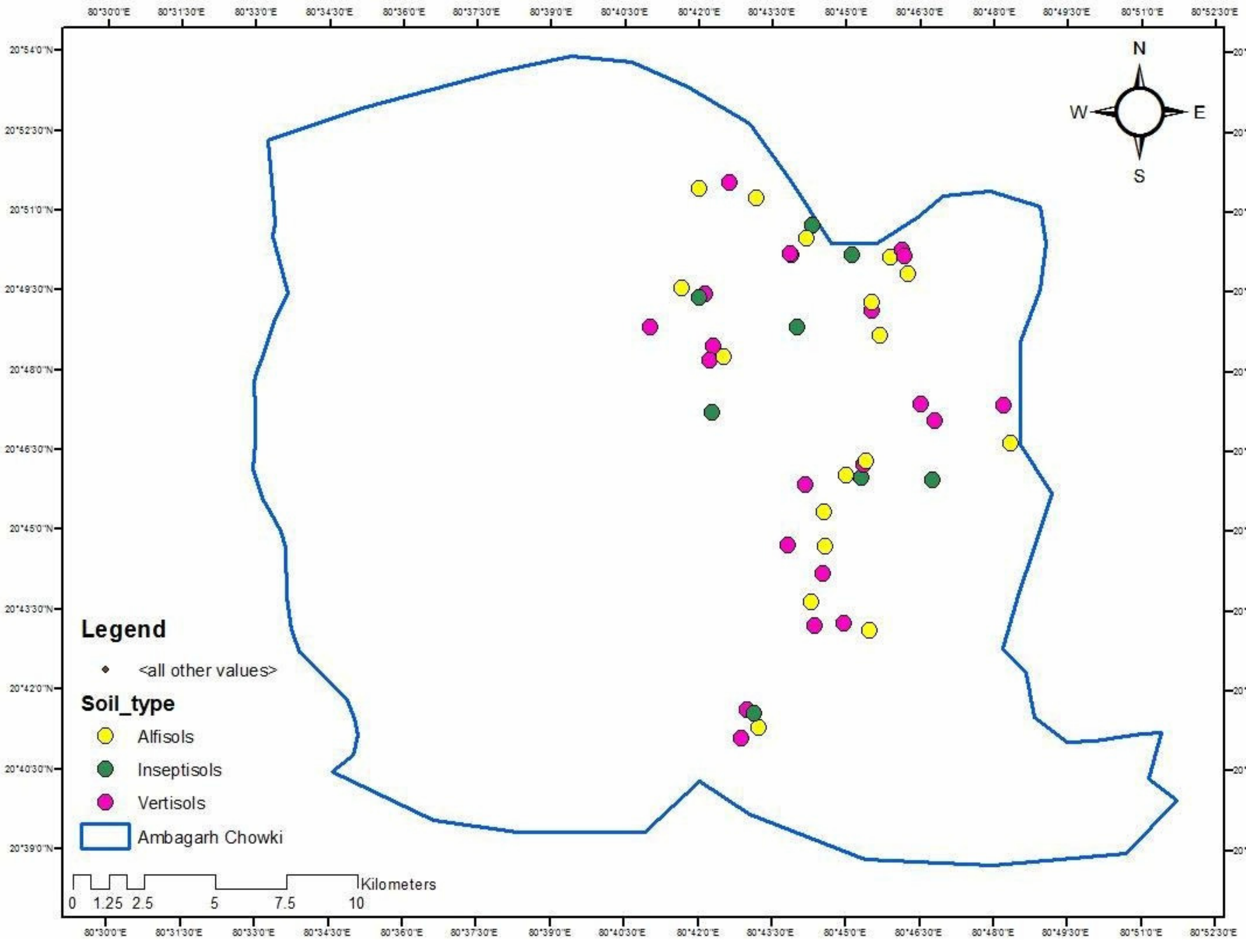

Fig. 1: Location of soil samples collected from Ambagarh Chowki, Rajnandgaon

Results and Discussions

Total Arsenic Content in Soil

The village-wise data of arsenic content in surface (0-20 cm) and subsurface soil (20-40 cm) for the study area are summarized in Table 2 (pre-monsoon season) and Table 3 (post-monsoon season).

Total Arsenic Content in Soil during Pre-Monsoon Season

In the pre-monsoon season, the range of soil arsenic content was found to be 0.94-5.69 mg As kg^{-1} with a mean of 3.36 mg kg^{-1} in the 0-20 cm depth and 0.65-3.91 mg As kg^{-1} with a mean of 2.54 mg kg^{-1} in the 20-40 cm depth. It was observed that the arsenic content in the examined samples varied slightly within different soil orders. Among the soil orders, *Vertisols* recorded the highest mean arsenic content in both surface soil (3.86 mg kg^{-1}) and subsurface soil (2.88 mg kg^{-1}), followed by *Alfisols*. In contrast, *Inceptisols* showed the lowest arsenic content. The arsenic content in *Vertisols, Alfisols, and Inceptisols* ranged from 0.95-7.52 mg kg^{-1}, 0.80-5.21 mg kg^{-1}, and 1.88-3.40 mg kg^{-1} in surface soil (0-20 cm), respectively, and 0.71-4.94 mg kg^{-1}, 0.58-3.58 mg kg^{-1}, and 1.08-2.50 mg kg^{-1} in subsurface soil (20-40 cm), respectively.

Village-wise analysis indicated that the arsenic content varied from 0.94-5.69 mg kg^{-1} in surface soil (0-20 cm depth) and 0.65-3.91 mg kg^{-1} in subsurface soil (20-40 cm depth). The highest arsenic content (7.52 mg kg^{-1} in 0-20 cm and 4.94 mg kg^{-1} in 20-40 cm depth) was found in Kaudikasa-1, followed by Sonsoitola-1 (6.23 mg kg^{-1} in 0-20 cm and 4.25 mg kg^{-1} in 20-40 cm depth). The lowest arsenic content (0.80 mg kg^{-1} in 0-20 cm and 0.58 mg kg^{-1} in 20-40 cm depth) was recorded in Metepar-Gaulitola-1.

Total Arsenic Content in Soil during Post-Monsoon Season

The data on arsenic distribution in surface and subsurface soil samples collected during the post-monsoon season are presented in Table 3. During this season, the arsenic content in soils of the study area ranged from 0.78-5.26 mg kg^{-1} in 0-20 cm depth and 0.58-3.46 mg kg^{-1} in 20-40 cm depth. The highest arsenic content in surface soil (3.35 mg kg^{-1} and subsurface soil (2.55 mg kg^{-1}) was recorded in

Vertisols. Mean arsenic content in *Alfisols* and *Inceptisols* was found to be 2.89 and 2.21 mg kg^{-1} in 0-20 cm depth, and 2.19 and 1.59 mg kg^{-1} in 20-40 cm depth, respectively. The arsenic content in *Vertisols*, *Alfisols*, and *Inceptisols* varied between 0.81-6.92 mg kg^{-1}, 0.67-4.87 mg kg^{-1}, and 1.70-2.90 mg kg^{-1} in surface soil (0-20 cm), respectively, and 0.60-4.01 mg kg^{-1}, 0.51-3.18 mg kg^{-1}, and 1.00-2.09 mg kg^{-1} in subsurface soil (20-40 cm), respectively. The variation of arsenic content in different soil orders might be associated with local differences in parent materials (*e.g.*, As-bearing minerals), farm management practices (*e.g.*, use of arsenical pesticides), continental inputs (*e.g.*, dry and wet deposition), and other biogeochemical activities. Fine-textured soils have much more surface area than coarse-textured soils. Additionally, Fe oxides, mainly present in the clay size fraction, provide clays with a higher arsenic scavenging potential compared to sandy soils (Fitz and Wenzel, 2002; Heikins *et al*., 2007).

In post-monsoon analysis, village-wise mean arsenic content ranged from 0.78-5.26 mg kg^{-1} in 0-20 cm and 0.58-3.46 mg kg^{-1} in 20-40 cm depth. The highest arsenic content in surface soil (6.92 mg kg^{-1}) and subsurface soil (4.01 mg kg^{-1}) was found in Kaudikasa-1, followed by Sonsoitola-1. Metepar-Gaulitola-1 reported the minimum arsenic in both surface soil (0.67 mg kg^{-1}) and subsurface soil (0.51 mg kg^{-1}). These findings are generally consistent with the experimental results reported by Patel *et al*. (2016), Srivastava and Sharma (2013), and Patley *et al*. (2017).

Seasonal Variation in Arsenic Content

It was observed that the arsenic content in surface soil was higher compared to subsurface soil. A laboratory-based column study by Huq *et al*. (2006) showed that 60-70 percent of arsenic applied in influent water with arsenic concentrations similar to irrigation water leached out of the column. This study demonstrated that arsenic concentration in soil decreased with depth. Khan *et al*. (2010) also reported relatively low mobility of applied arsenic, indicating likely continued detrimental accumulation within the rooting zone.

The accumulation of arsenic in Vertisols of village Kaudikasa showed slightly higher arsenic content compared to other villages. This may be attributed to various climatic and geomorphic conditions of the area, such as rainfall, runoff, rate of infiltration, and groundwater levels (Bhattacharya *et al*., 2002). The buildup of arsenic in soil associated with the use of arsenic-contaminated irrigation water has been shown to lead to elevated levels of arsenic in soil solution (Meharg and Rahman, 2003; Dittmar *et al*., 2007).

This study also reported seasonal variations in arsenic content. The concentration of arsenic in soil during the pre-monsoon season was found to be higher than in the post-monsoon season. Similar findings were reported by Biswas *et al*. (2014) and Patley *et al.* (2017). The significant decrease in arsenic content during the post-monsoon season is attributed to the influence of rainwater and the resultant dilution of dissolved arsenic (Biswas *et al.,* 2014).

Compliance with FAO Guidelines

All the villages were found to be within the permissible limits set by FAO (50 mg kg^{-1} for agricultural soil) in both pre- and post-monsoon seasons. Generally, most soils contained less than 10 mg kg^{-1} of arsenic, meeting the guidelines for agricultural soils of 20 mg kg^{-1} as required by the European Community and 10 mg kg^{-1} as required by the World Health Organization.

Conclusion

In the pre-monsoon season, the range of soil arsenic content was found to be 0.94-5.69 mg As kg^{-1} at a depth of 0-20 cm and 0.65-3.91 mg As kg^{-1} at a depth of 20-40 cm, while in the post-monsoon season, it ranged from 0.78-5.26 mg As kg^{-1} at 0-20 cm depth and 0.58-3.46 mg As kg^{-1} at 20-40 cm depth. Order-wise, *Vertisols* contained relatively higher amounts of arsenic than *Alfisols* and *Inceptisols*, with pre-monsoon values of 3.86 mg As kg^{-1} at 0-20 cm depth and 2.88 mg As kg^{-1} at 20-40 cm depth, and post-monsoon values of 3.35 mg As kg^{-1} at 0-20 cm depth and 2.55 mg As kg^{-1} at 20-40 cm depth. Lower values of arsenic accumulation were observed in *Inceptisols*. Village-wise, higher arsenic concentrations were reported in Kaudikasa-1, with values of 7.52 mg kg^{-1} at 0-20 cm and 4.94 mg kg^{-1} at 20-40 cm depth in the pre-monsoon season, and 6.92 mg kg^{-1} at 0-20 cm and 4.01 mg kg^{-1} at 20-40 cm depth in the post-monsoon season. All villages were within the permissible limits given by FAO (50 mg kg^{-1} or agricultural soil) in both pre- and post-monsoon seasons. The study also reported seasonal variation in arsenic content, with higher concentrations during the pre-monsoon season compared to the post-monsoon season, and higher concentrations in surface soil compared to sub-surface soil.

Table 2: Total arsenic content in soils of Ambagarh Chowki, Rajnandgaon during pre monsoon season.

Name of the village	Arsenic content (mg kg^{-1}) in pre monsoon season							
	Vertisols		*Alfisols*		*Inceptisols*		Mean As content in the village	
	0-20 cm	0-40 cm	0-20 cm	0-40 cm	0-20 cm	0-40 cm	0-20 cm	0-40 cm
Metepar, Gaulitola 1	0.95	0.71	0.80	0.58	--	--	0.94	0.65
Metepar, Gaulitola 2	1.08	0.80	0.91	0.51	--	--		
Arajkund 1	4.54	3.71	3.21	2.61	2.31	2.61	3.42	3.03
Arajkund 2	3.61	3.18	--	--	--	--		
Kaudikasa 1	7.52	4.94	5.21	3.58	--	--	5.69	3.91
Kaudikasa 2	5.71	3.92	4.32	3.21	--	--		
Biharikala 1	4.89	3.25	4.08	3.01	2.90	2.10	3.99	2.95
Biharikala 2	4.10	3.45	--	--	--	--		
Pangari, Keshitola 1	2.89	2.67	2.09	1.72	1.88	1.08	2.41	1.97
Pangari, Keshitola 2	2.76	2.40	--	--	--	--		
Atargaon 1	4.54	2.98	3.21	2.73	--	--	4.19	2.93
Atargaon 2	4.98	3.12	4.01	2.90	--	--		
Sangali 1	3.01	2.35	2.98	2.01	2.08	1.70	2.72	2.08
Sangali 2	--	--	2.80	2.24	--	--		
Telitola 1	3.76	2.40	3.10	2.21	--	--	3.46	2.43
Telitola 2	4.01	2.91	2.98	2.18	--	--		
Joratarai 1	4.34	3.31	3.21	2.37	2.76	2.20	3.34	2.54
Joratarai 2	--	--	3.06	2.29	--	--		
Jadutola 1	3.54	2.40	3.10	2.30	--	--	3.19	2.41
Jadutola 2	3.12	2.51	2.98	2.42	--	--		
Dhatutola 1	3.21	2.69	2.97	2.14	2.50	2.10	3.01	2.36
Dhatutola 2	3.34	2.51	--	--	--	--		
Mangatola 1	3.12	2.82	2.80	2.20	2.10	1.87	2.86	2.45
Mangatola 2	3.43	2.90	--	--	--	--		
Sonsoitola 1	6.23	4.25	4.23	3.28	3.40	2.50	4.48	3.38
Sonsoitola 2	--	--	4.07	3.90	--	--		
No. of samples	**23**		**21**		**08**		**52**	
Range	**0.95-7.52**	**0.71-4.94**	**0.80-5.21**	**0.58-3.58**	**1.88-3.40**	**1.08-2.50**	**0.94-5.69**	**0.65-3.91**
Mean	**3.86**	**2.88**	**3.15**	**2.40**	**2.49**	**1.95**	**3.36**	**2.54**

Table 3: Total arseniccontent in soils of Ambagarh Chowki, Rajnandgaon during post monsoon season

Name of the village	Arsenic content (mg kg^{-1}) in post monsoon season							
	Vertisols		*Alfisols*		*Inceptisols*		Mean As content in the village	
	0-20 cm	0-40 cm	0-20 cm	0-40 cm	0-20 cm	0-40 cm	0-20 cm	0-40 cm
Metepar, Gaulitola 1	0.81	0.60	0.67	0.51	--	--	0.78	0.58
Metepar, Gaulitola 2	0.88	0.61	0.75	0.58	--	--		
Arajkund 1	4.04	3.67	3.01	2.01	2.07	1.21	3.03	2.47
Arajkund 2	3.00	2.98	--	--	--	--		
Kaudikasa 1	6.92	4.01	4.87	3.18	--	--	5.26	3.46
Kaudikasa 2	5.21	3.65	4.05	3.00	--	--		
Biharikala 1	3.65	3.12	3.52	2.98	2.72	2.00	3.37	2.78
Biharikala 2	3.60	3.01	--	--	--	--		
Pangari, Keshitola 1	2.09	1.60	1.91	1.50	1.70	1.00	1.94	1.32
Pangari, Keshitola 2	2.06	1.19	--	--	--	--		
Atargaon 1	3.34	2.79	2.91	2.59	--	--	3.47	2.84
Atargaon 2	3.88	2.98	3.75	3.00	--	--		
Sangali 1	3.00	2.40	2.80	2.10	1.98	1.21	2.57	1.94
Sangali 2	--	--	2.48	2.03	--	--		
Telitola 1	3.03	2.20	2.79	2.23	--	--	2.98	2.36
Telitola 2	3.31	2.88	2.80	2.13	--	--		
Joratarai 1	4.04	3.00	3.01	2.18	1.96	1.51	3.00	2.19
Joratarai 2	--	--	3.00	2.08	--	--		
Jadutola 1	3.03	2.00	2.80	2.11	--	--	2.87	2.06
Jadutola 2	2.95	2.11	2.68	2.02	--	--		
Dhatutola 1	3.20	2.29	2.57	1.98	2.32	1.98	2.81	2.12
Dhatutola 2	3.14	2.21	--	--	--	--		
Mangatola 1	3.02	2.50	2.17	1.98	2.00	1.70	2.59	2.24
Mangatola 2	3.18	2.78	--	--	--	--		
Sonsoitola 1	5.68	4.00	4.05	2.98	2.90	2.09	4.10	3.00
Sonsoitola 2	--	--	3.76	2.92	--	--		
No. of samples	**23**		**21**		**08**		**52**	
Range	**0.81-6.92**	**0.60-4.01**	**0.67-4.87**	**0.51-3.18**	**1.70-2.90**	**1.00-2.09**	**0.78-5.26**	**0.58-3.46**
Mean	**3.35**	**2.55**	**2.89**	**2.19**	**2.21**	**1.59**	**2.98**	**2.25**

References

Acharyya, S.K. (2002). Arsenic contamination in groundwater affecting major parts of Southern West Bengal and parts of Western Chhattisgarh, Source and mobilization process. *Environment Geology*, 82(8), 740-744.

Ahsan, D.A. and Del Valls, T.A. (2011). Impact of arsenic contaminated irrigation water in food chain, An overview from Bangladesh. *Int. J. Environ. Res.,* 5(3), 627,638.

Banejad, H. and Olyaie, E. (2011). Arsenic toxicity in the irrigation water-plant environment, A significant. *Journal of American Science*, 7(1), 125-131.

Behari, J.R. and Prakash, R. (2006). Determination of total arsenic content in water by atomic absorption spectroscopy (AAS) using vapour generation assembly (VGA).*Chemosphere*, 63, 17–21.

Bhattacharya, P., Chatterjee, D. and Jacks, G., (1997). Occurrence of As- contaminated groundwater in alluvial aquifers from Delta Plains, Eastern India, options for safe drinking water. *Water Resource Development*, 13, 79–92.

Bhattacharya, P., Samal. A.C., Majumdar, J. and Santra, S.C. (2009). Transfer of arsenic from groundwater and paddy soil to paddy plant (*Oryza sativa* L.), A micro level study in West Bengal, India. *World Journal of Agricultural Sciences*, 5(4), 425-431.

Biswas, A., Biswas, S. and Santra, S.C. (2014). Arsenic in irrigated water, soil and rice, perspective of the cropping season. *Paddy Water Environ.*, 12, 407- 412.

Chakraborti, D., Biswas, B.K., Roy, C.T, Basu, G.K., Mandal, B.K., Chowdhury, U.K., Mukherjee, S.C., Gupta, J.P., Chowdhury, S.R. and Rathore, K.C. (1999). Arsenic ground water contamination and sufferings of people in Rajnandgaon district, Madhya Pradesh, India. *Curr, Sci.*, 77, 502–504

Chakraborti, D., Mukherjee, S.C., Pati, S., Sengupta, M.K., Rahman, M.M., Chowdhary, U.K., Chanda, C.R., Chakraborti, A.K. and Basu, G.K. (2003). Arsenic groundwater contamination in Middle Ganga plain, Bihar, India, A future danger? *Environmental Health Perspectives*, 111(9), 1194-1201.

Chowdhury, U.K., Biswas, B.K., Chowdhury, T.R., Samanta, G., Mandal, B.K., Basu, G.K., Chanda, C.R., Lodh, D., Saha, K.C., Mukherjee, S.K., Roy, S., Kabir, S., Quamruzzaman, Q. and Chakraborti, D. (2000). Ground water arsenic contamination in Bangladesh and West Bengal-India. *Environmental Health Perspectives*, 108, 393–397.

Dittmar, J., Voegelin, A., Roberts, L.C., Hug, S.J., Saha, G.C., Ali, M.A. and Kretzschmar, R. (2007). Spatial distribution and temporal variability of arsenic in Irrigated rice fields in Bangladesh. Paddy *Soil.Environ. Sci. Technol.*, 41, 5967–5972.

Fitz, W.J. and Wenzel, W.W. (2002). Arsenic transformation in the soil-rhizoshere- plant system, fundamental and potential application to phyto remediation. *Journal of Biotechnology*, 99, 259-278.

Flanagan, S.V., Johnston, R.B. and Zheng, Y. (2012). Arsenic in tube well water in Bangladesh, health and economic impacts and implications for arsenic mitigation. Bull, *World Health Organ.*, 90,839–846.

Heinkins, A., Panaullah, G.M. and Meharg A.A. (2007). Arsenic behavior from ground water and soil to crops, impact on agriculture and food safety. *Reviews of Environmental Contamination and Toxicology*, 189, 43-87.

Huq, S.M.I., Joardar, J.C. Parvin, S., Corell, R. and Naidu, R. (2006). Arsenic contamination in food-chain, Transfer of arsenic into food material through groundwater irrigation. *J. Health Popul Nutr.,* 24(3), 305-316.

Jain, C.K., (2002). Arsenic contamination in ground water, Indian Scenario. *Industries Journal Environmental Health*, 44, 238–243.

Khan, M.A., Islam M.R., Panaullah, G.M., Duxbury, J.M., Jahiruddin, M. and Loeppert, R.H. (2010). Accumulation of arsenic in soil and rice under wetland condition in Bangladesh. *Plant Soil*, 333, 263–274.

Meharg, A.A. and Rahman, M. (2003). Arsenic contamination of Bangladesh paddy field soils, Implications for rice contribution to arsenic consumption. Environ. *Science Technology*, 37, 229-234.

Patel, K.S., Sahu, B.L., Ramteke, S. and Bontempi, E. (2016). Contamination of paddy soil and rice with arsenic. *Journal of Environmental Protection*, 7, 689-698.

Patel, K.S., Shrivas, K., Brandt, R., Jakubowski, N., Corns, W. and Hoffmann, P. (2005). Arsenic contamination in water, soil, sediment and rice of central India. *Environ. Geochem. Health*, 27(2), 131-45.

Patley, S., Sengar, S.S., Baghel, N. and Keshri, P. (2017). Depth wise distribution of Arsenic in soils of Ambagarh Chowki block of Rajnandgaon district, Chhattisgarh. International Journal of Chemical Studies, 5(3), 569-572.

Shukla, D.P., Dubey, C.S., Singh, N.P. and Chaudhry, T.M. (2010). Sources and controls of Arsenic contamination in groundwater of Rajnandgaon and Kanker District, *Chhattisgarh Central India. Journal of Hydrology*, 395, 49–66.

Singhal, V.K., Anurag, Rathiya, G.R. and Kumar, T. (2018). Arsenic concentration in drinking and irrigation water of Ambagarh Chowki Block, Rajnandgaon (Chhattisgarh). *I. J. C. S.* 6(2), 733-739.

Srivastava, S. and Sharma, Y.K. (2013). Arsenic occurrence and accumulation in soil and water of eastern districts of Uttar Pradesh, India. *Environ Monit Assess*., 185(6), 4995-5002