

Research article

Geogenic source of arsenic and their effect on vegetable seed germination

Shyni Paul^{1#}, Sudhir K. Upadhyay^{2*} and Nripendra Singh³

¹Department of Biological Sciences, S.H.I.A.T.S., Allahabad-211007, Uttar Pradesh, India

[#]Present address: St. Annes's convent school, Sector 32-C, Chandigarh-160031 India

²Department of Environmental Science, V.B.S. Purvanchal University, Jaunpur-222003, Uttar Pradesh, India

³Department of Pharmacy, V.B.S. Purvanchal University, Jaunpur-222003, Uttar Pradesh, India

*Corresponding Author: sku.env.lko@gmail.com

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Abstract: The serious health and environmental problem arises due to arsenic, across the globe. Several researcher have drawn their attention to these problems, arsenic mainly found in soil, aquifer water/drinking water through naturally. In the present study, physicochemical and arsenic content were observed in two types of soil from different agricultural sites of district Ballia, one type of agricultural sites were irrigated by BWDI and other agriculture sites were not BWNDI. Agricultural soil sites ($\sum N=209$) of BWDI revealed that all soil samples have arsenic content and maximum arsenic concentration (55 ppb) were observed at sites of Basdih, district Ballia, while arsenic content was not detected on the soils of other agricultural field sites ($N=\sum 30$) which were based on BWNDI. Interesting and significant observation observed on the surveys based on farmers of the chosen sites, there are no industries or activities found who are able to correlate the high concentration of arsenic in soil except bore well water. Arsenic contents were observed in the 250 bore well water samples and their concentrations were varied with bore well depth. Beyond the 100 feet depth of bore well water showed the maximum concentration of arsenic as compared with 40 feet depth. The high concentration of arsenic, as well as its more retention time, reduces seed viability of radish and carrot plants.

Keywords: Arsenic - Aquifer water - Agricultural soil - Seed viability - Radish & carrot plant.

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INTRODUCTION

Arsenic metal has a metalloid property exist in inorganic as well as organic form, highly mobilized in environment through soluble in water or in air through their volatile behavior in the form of arsine AsH_3 , monomethylarsine (CH_3AsH_2), dimethylarsin ($\text{CH}_3)_2\text{AsH}$, and trimethylarsine ($\text{CH}_3)_3\text{As}$ (Cullen & Reimer 1989, Smedley & Kinniburgh 2002). Arsenic is widely present in soil, rock, sediment, and metal ore in the form of sulfide or compounds of various metals (Aronson 1994). Arsenic introduced into soil/groundwater by weathering of rocks and minerals by leaching and surface runoff naturally. Man-made activities also enhance the arsenic availability in soil or water body through organic chemicals, pesticides, insecticides, mining etc. (Benbrahim & Waalkes 2008, Meharg *et al.* 2009). In spite of that many factors are responsible to regulate the concentration of arsenic and its transport in environment including ground water, like redox potential, adsorption/absorption, dissolution. pH and biological transformation etc. Four oxidation states (+5, +3, 0, -3) of arsenic exist under normal Eh condition in aquatic system, while predominant form of arsenic is inorganic form having As^{+3} stage and As^{+5} stage (Smedley & Kinniburgh 2002). Jain & Ali (2000) reported that As^{+3} stage is about 60 times more toxic as compared to As^{+5} stage and inorganic arsenic is about 100 times toxic than organic toxic; in general toxicity of arsenic species are arsenite > arsenate > monomethyl arsonate > dimethyl arsinic. Adriano (2001) reported that uses of arsenicals as pesticides has significantly contributed to increase the concentration of arsenic in soil; use of arsenic in 1992 was about 23,900 metric tons of which 67% was used for the production of wood preservative (Adriano 2001). High concentration of arsenic in drinking water

becomes a big human health problem across the globe, several people from India have been endangered by the protest of consuming water contaminated with arsenic at higher recommended level (10 ppb or $10 \mu\text{g l}^{-1}$) by WHO and US-EPA (Flanagan *et al.* 2012). Several disease and disorders are caused by higher dose of arsenic like keratosis, cancer, arsenicosis etc (Smith *et al.* 1992, Hughes *et al.* 2011). High level of recommended arsenic concentration is reported at few places of Gangetic plains in India, researchers have drawn their more attention to observe adverse effects of arsenic (Maharjan *et al.* 2005). Several reports revealed that the arsenic contamination is mostly restricted to the alluvial aquifers of the Ganges delta; due to sulphide rich mineralized area of Bihar etc. (Bhattacharya *et al.* 1997). The main source of the economy of district Ballia is based on agriculture and maximum people are engaged in agricultural practices. Arsenic inhibits plant growth; accumulation in plant biomass reduced yield, fertility of plant and fruit production (Garg & Singla 2011). Vegetables are early grown crops and frequently produce economy for farmers in the Ballia district as compared with cereals. Keeping this after view the present work is based on (i) Physico-chemical and arsenic concentration at different agricultural soil (Bore well water depend irrigation and Bore well water not depend irrigation) and bore well water of district Ballia. (ii) Influence of high concentration & retention time of arsenic on seed viability.

MATERIAL AND METHODS

Survey of sites and sample collection

Exhaustive survey was conducted at different sites of district Ballia [28.20° N & 79.37° E ; (Fig. 1)] Uttar Pradesh during the year 2014, to observed irrigation and agricultural farming practices among the farmers. Bore well depth and mode of agricultural farming were observed on the basis of self-administrative questionnaires. Agricultural soils were sampled by two ways (i) Bore well water depend irrigation [BWDI] (ii) Bore well water not depend irrigation [BWNDI]. Soil samples 250 g and 500 ml of bore well water respectively, were collected in sterilized bottles and kept it at 4°C for further observation. Seeds of radish and carrot plants were taken from Indian Institute of vegetable research Varanasi.

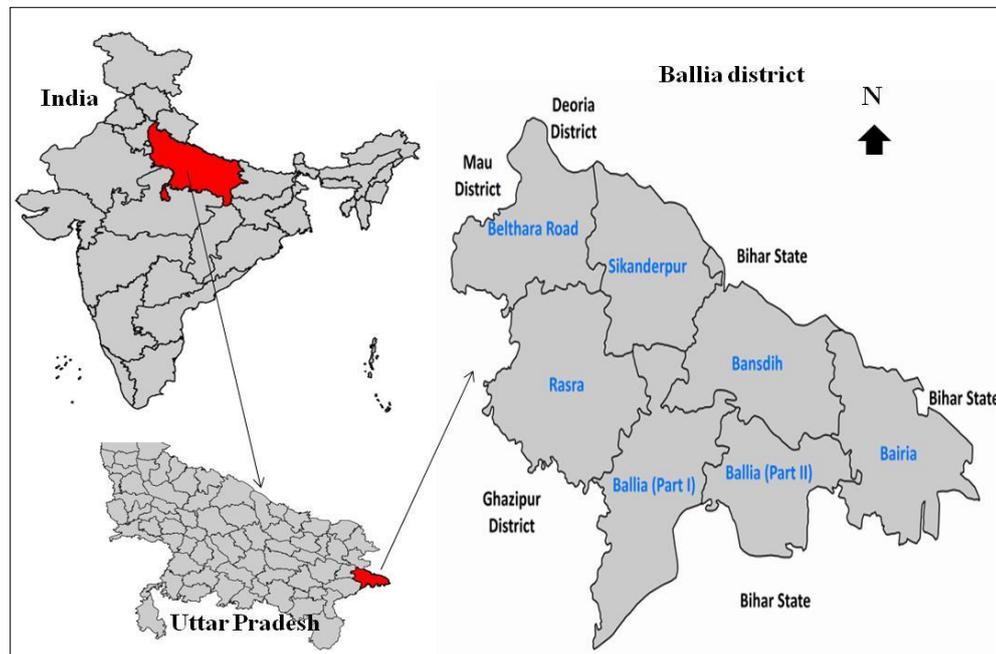


Figure 1. Study sites and samples (agricultural soil and bore well water sample) collection; District Ballia Uttar Pradesh India.

Physico-chemical and Arsenic content analysis

Soil and water pH, Ece were observed as earlier described method of APAH (2012). Organic carbon was examined in 1 gm of soil sample which was inoculated in 100 ml conical flask followed by 10 ml of 1N $\text{K}_2\text{Cr}_2\text{O}_7$ and 20 ml of concentrated H_2SO_4 for 30 minutes, and then it was centrifuge for 5 minutes at 8000 rpm, supernatant was collected and measured the intensity of green color at 660 nm Datta *et al.* (1962). The available nitrogen of soil samples were estimated by the method described by Subbaih & Asija (1956). Available phosphorus in agricultural soil was estimated with earlier described method (Olsen 1954). 2 g soil sample was transferred to a 100 ml wide mouth glass bottle and a pinch of Darco G- 60 and 25 ml of 0.5 M NaHCO_3

solution was added. The suspension was shaken for 30 minute on mechanical shaker and filtered through Whatman No.1 filter paper to obtain the filtrate. 5 ml of the filtrate was transferred to a 25 ml volumetric flask, with 5 ml of ammonium molybdate solution. The solution was shaken slowly to drive out the CO₂ evolved, SnCl₂ solution was added, the volume was made up with distilled water to 20 ml and mixed, blue color intensity was observed at 660 nm by spectrophotometer. Potassium content was measured by flame photometer. The samples of soil and water were digested with a solution of 3:1 HNO₃:HClO₄ (v/v). The concentrations of arsenic were determined using the atomic absorption spectrophotometer by the method (Wei & Chen 2002).

Seed viability assay

Vegetable seeds were surface sterilized in 1% (w/v) sodium hypochloride for 2 to 3 min, washed several times with sterilized distilled water (SDW), and soaked in SDW supplemented with different concentration of arsenic [Na₂HAsO₄·7H₂O (w/v) of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 ppb] for 6h, 12h, 18h and over night (Sun & Zhou 2008). Similarly, control was prepared without arsenic concentration. Twenty soaked seeds were sowed directly into the 0.8% agar plate and incubated for three days in dark room (Upadhyay *et al.* 2011, 2012).

RESULTS AND DISCUSSION

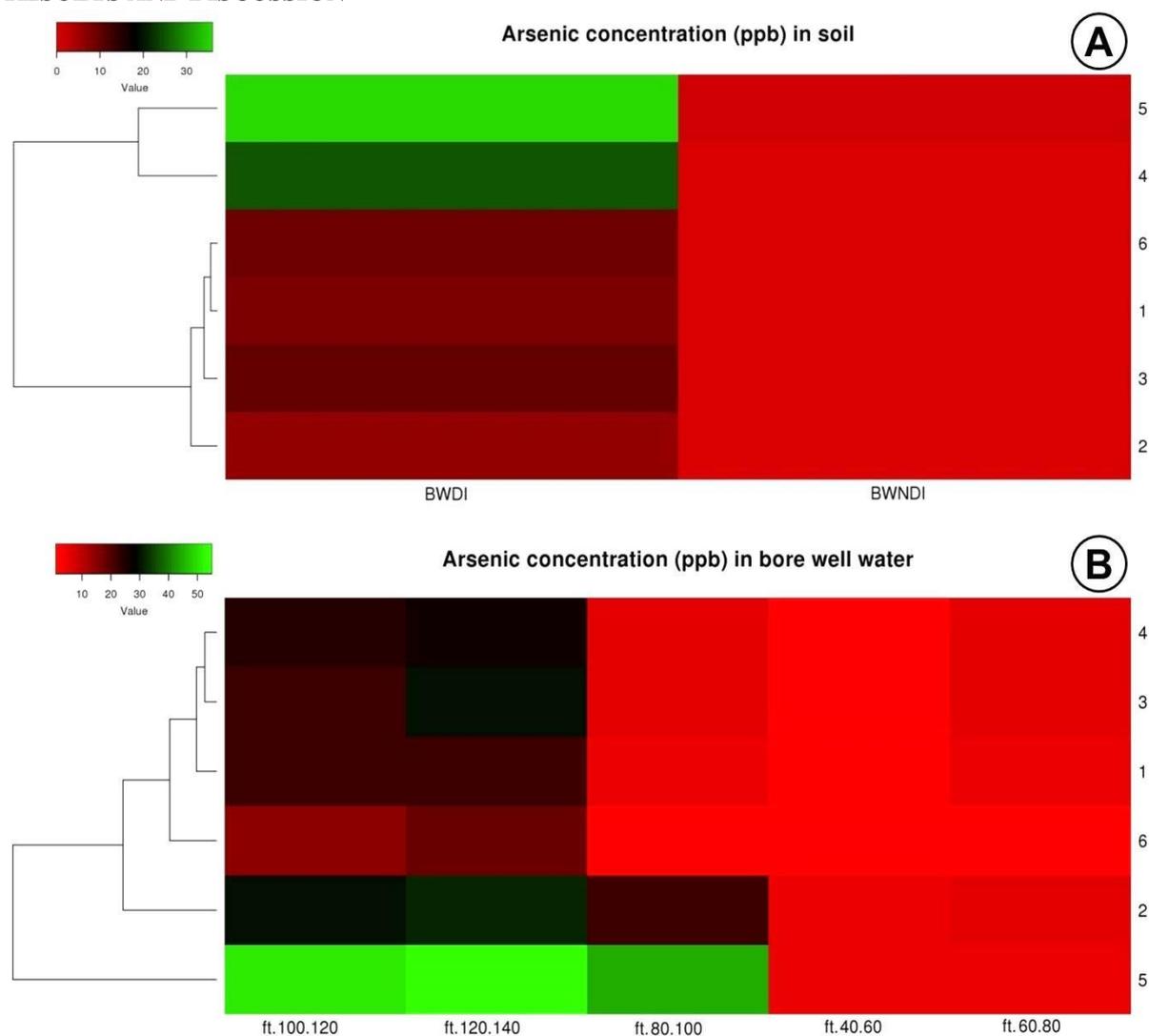


Figure 2. Arsenic concentration (ppb) in two different sites: **A**, Agriculture soil (i) BWDI (bore well depend irrigation) and (ii) BWNDI (bore well not depend irrigation); **B**, Arsenic concentration (ppb) in bore well water with different depth on X axis. (140–120 feet), [(120–100 feet), (100–80 feet), (80–60 feet) and (60–40 feet) at different sites of district Ballia. [N= Number of agricultural field sites, bore well; ppb= Part per billion; ft.= Depth of bore well in feet. Y axis represent site of study; 1= Rasara (N=32); 2= Bilthara (N=34); 3= Nagra (N=42); 4= Sahatwar (N=30); 5= Bansdih (N=30); 6= Sohaon (N=41)].

Six major places of district Ballia (Fig. 1) were selected in the present study, which are Rasara (N=32), Bilthara (N=34), Nagra (N=42), Sahatwar (N=30), Bansdih (N=30) and Sohaon (N=41); N represent the number of agricultural field and each N was apart from about 5 km. In the present study, all the selected agricultural soil

sites ($\sum N=209$) of BWDI (Table 1) revealed that soil pH, ECe and OC of the agricultural soil were with the

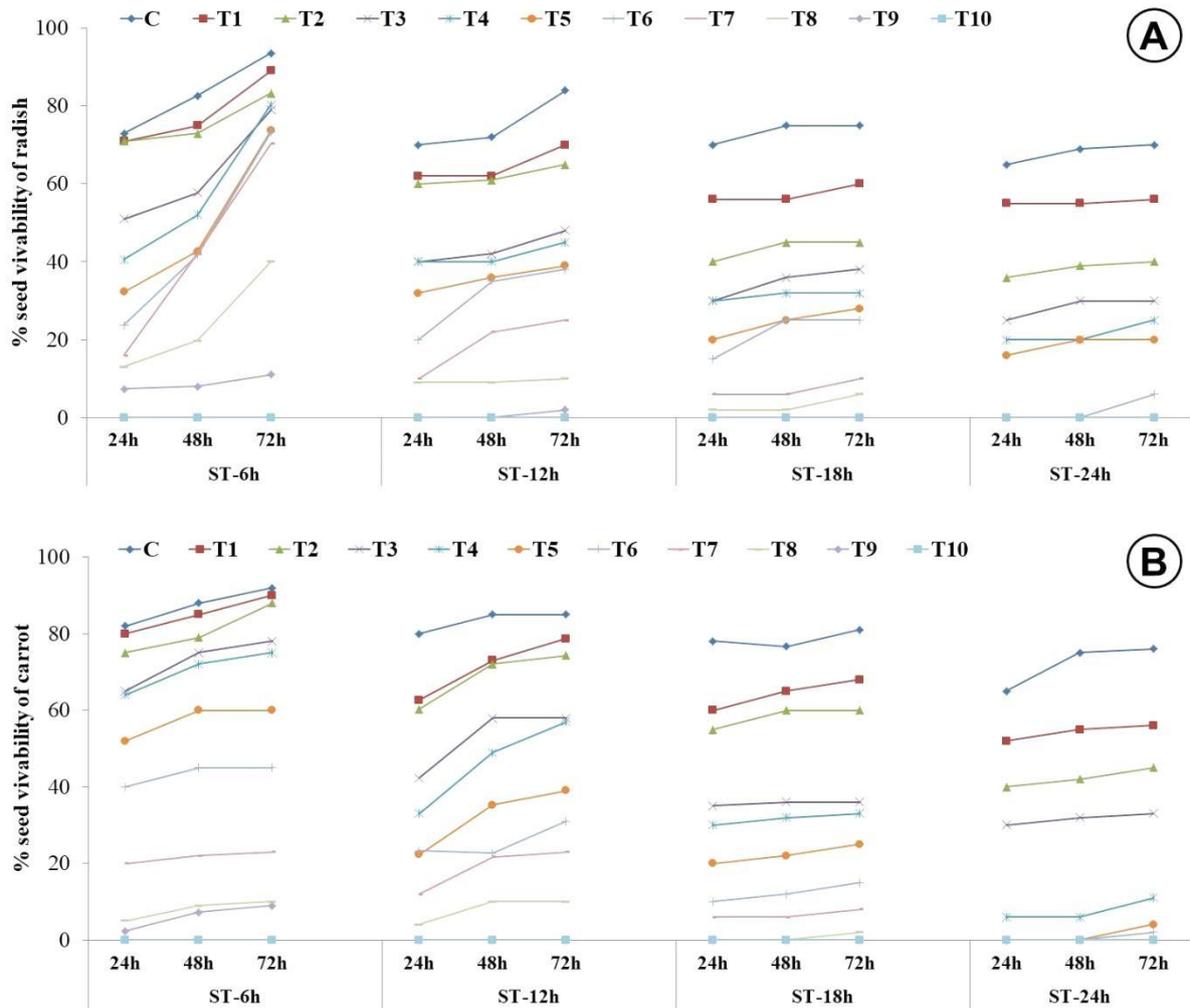


Figure 3. Percent seed viability of radish (a) and carrot seed (b) after 24 h, 48 h and 72 h respectively, at 0.8% agar plate, seed were shocked for 6 h, 12 h, 18 h and 24 h respectively in SDW supplemented with different concentrations of arsenic w/v [T1 to T10] C=control (seed shocked in SDW without arsenic), ST=shocked time.

range of 7.4 to 7.7, 2.5 to 9.2 and 2.52 to 4.2 respectively, total nitrogen, phosphorous and potassium content were with range of 10.62 to 20.5, 6.32 to 11.5 and 1.62 to 2.1 percent, respectively. An interesting results were observed in the case of arsenic concentration in soil; all of the soil samples were arsenic content while maximum arsenic concentration (55 ppb) were observed at sites of Basdih, district Ballia (Table 1). In the year of 2011, central Team on Arsenic mitigation in rural drinking water sources reported most of the water aquifers have greater than 50 ppb of arsenic in district Ballia (Report 2011). Arsenic concentration of few agricultural soil sites exceeded the standard permissible level of arsenic *i.e.* 10 ppb (WHO), questionnaire based survey revealed that no any industries or activities are present in district Ballia which could be responsible for arsenic content in agricultural soil. Vast track of Indo Gangetic alluvium have elevated concentrations of arsenic in wells placed in the late quaternary and Holocene aquifers, weathering of sulphide mineral could be responsible for arsenic concentration in holocene sediment, redox reaction in the sediment arsenic interact with biochemical reaction (Datta & Subramanian 1998, Smedley & Kinniburgh 2002). Physico chemical and arsenic content also observed in different agricultural soil ($N=\sum 30$) from BWNDI and arsenic content was not detected in these soil samples while OC, N, P and K were quite less than the soil form BWDI (Table 2). Questionnaire based observation among $\sum 425$ agricultural formers of selected places were revealed that they were using bore well water for irrigation practices. Keeping this information, in the present study, arsenic content was examined in 250 bore well water samples and interesting results were found, almost all the bore well water having arsenic content and the concentration of arsenic content were varied with bore well depth (Fig. 2). Beyond the 100 feet depth of bore well water showed maximum concentration of arsenic as compared with 40 feet depth, maximum concentration of arsenic content (36 ppb) was observed in the different bore well water of Basdih, district Ballia.

Influence of arsenic content was significantly observed in seed germination of radish and carrot plant (Fig. 3A & B). Percent germination of both the plant's seeds were reduced under high concentration of arsenic and more retention time of arsenic, radish seeds were more tolerate as compared with carrot (Fig. 3A & B). More soaked time (retention time) of seeds with water and water supplemented arsenic both were reduced the percent seed viability, maximum seed viability observed in 6h soaked time followed by 12 h, 18 h and 24 h (Fig. 3A & B). Seed viability was delayed due to higher concentration and observed at after t3 treatment in radish at 24 h (ST-6 h) than carrot seed (Fig. 3B). Paul *et al.* (2014a, b) earlier reported that the length, fresh weight and growth of radish and carrot plant significantly reduced at 30 to 40 ppm of arsenic in pot experiment; both the plants were capable to uptake arsenic from soil; thus way arsenic content enter in trophic level and reaches to human beings. Few species were earlier reported that they behave hyper accumulator for arsenic species like; in the form of AsO_3^{3-} arsenic transported xylum of Chinese brake fern (Su *et al.* 2008). Ma *et al.* (2001) first reported the As-hyperaccumulator *Pteris vittata* L. that accumulated As in shoots up to 22,000 mg kg⁻¹ (Huang *et al.* 2004). Translocation of arsenic in shoot and root of the plant were varied, fifteen times and about 50 times higher arsenic concentration was repowered in root followed by shoot in *Spartina pectinata* Bosc ex Link and rice plant respectively (Rahman *et al.* 2007, Rofkar & Dwyer 2011).

Table 1. Physico-chemical and arsenic concentration in agricultural soil (BWDI) of different sites at district Ballia.

Place and number of sampling sites (N)	Latitude	Longitude	pH	ECe (dS m ⁻¹)	OC (%)	N Content (%)	PO ₄ Content (%)	K ₂ O content (%)
Rasara (N=32)	25.8564239	83.8636319	7.71±.56	5.69±.2	4.2±.1	12.19±2.1	11.5±4.2	1.59±.6
Bilthara (N=34)	25.86225	83.89515	7.5±.25	2.5±.9	3.8±.6	16.5±2.5	8.2±4.4	2.1±.3
Nagra (N=42)	25.8733857	83.8599585	7.6±.38	9.2±.6	3.5±.4	22.5±4.3	9.2±2.5	1.11±.4
Sahatwar(N=30)	25.8344328	84.3127425	7.4±.29	4.6±.4	3.6±.3	16.2±3.5	10.5±2.6	1.6±.5
Bansdih (N=30)	25.87743	84.3912	7.5±1.2	6.4±.8	2.9±.9	15.1±4.1	7.2±2.5	2.1±.3
Sohaon (N=41)	25.857195	83.849825	7.6±.58	5.1±.6	4.0±.4	10.6±2.1	6.3±1.6	1.6±.2

Note: BWDI= Bore well water depend irrigation; N= Number of agricultural field sites; ECe= Electrical conductivity; OC= Organic carbon; N= Total nitrogen content; PO₄= Available phosphate; K₂O= Potassium content.

Table 2. Physico-chemical and arsenic concentration in agricultural soil (BWNDI) of different sites at district Ballia.

Place and number of sampling sites (N)	Latitude	Longitude	pH	ECe (dS m ⁻¹)	OC (%)	N Content (%)	PO ₄ Content (%)	K ₂ O content (%)
Rasara (N=2)	25.8564239	83.8636319	7.3±1.3	8.6±1.5	3.5±0.5	11.2±2.5	12.2±5.2	1.2±0.5
Bilthara (N=5)	25.86225	83.89515	7.4±1.6	6.9±1.2	3.4±0.6	14.6±3.2	6.8±2.1	1.8±0.9
Nagra (N=3)	25.8733857	83.8599585	7.2±0.6	10.2±1.1	4.1±1.2	15.9±2.3	7.5±1.6	1.1±0.2
Sahatwar(N=7)	25.8344328	84.3127425	7.3±0.5	11.5±2.6	3.2±0.6	10.5±2.3	9.2±1.3	1.2±0.2
Bansdih (N=4)	25.87743	84.3912	7.2±1.4	5.2±1.1	2.9±0.8	14.2±2.5	5.2±1.5	1.3±0.1
Sohaon (N=9)	25.857195	83.849825	7.8±1.3	16.5±3.8	3.8±1.1	9.5±2.8	9.3±1.8	1.5±0.6

Note: BWNDI= Bore well not depend irrigation; N= Number of agricultural field sites; ECe= Electrical conductivity; OC= Organic carbon; N= Total nitrogen content; PO₄= Available phosphate; K₂O= Potassium content.

CONCLUSION

Problems arose due to arsenic were great concern by the researchers across the globe since few decades back. Most of the workers reported on the sources of arsenic in soil and aquifer/water bodies are due to geogenic activities like organic chemicals and pesticides, very little information available to highlight the sources of arsenic based on geogenic activities. The present study revealed that more depth of Bore well water have high arsenic concentration as compared to low depth of bore well water and bore water have been wildly applying for irrigation practices at district Ballia. This way the bore well water could be a source of arsenic in the soil at higher concentration. Higher arsenic concentration and its retention time both were significantly induced adverse effects on seed viability.

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