

Physico-Chemical and Heavy Metals in the Groundwater Samples Collected from Arsenic Endemic Areas of Shuklaganj (Unnao)

Anju Agrawal*, Nishi Kumar Shukla

Department of Zoology, S N Sen B V P G College, CSJM University, Kanpur, India

Abstract Human health is greatly affected by exposure to arsenic through drinking water. Arsenic is a carcinogen and its consumption can negatively affect the gastrointestinal tract, cardio-vascular and central nervous systems. World Health Organisation (WHO) and US Environmental Protection Agency have set the maximum acceptable level of arsenic in drinking water as 10 µg/L. Attempts have been made to determine and establish a database on the drinking water quality of Shuklaganj area with particular emphasis on the physico-chemical characteristics and levels of heavy metals in the water samples. The physico-chemical parameters determined were pH, hardness, alkalinity, conductivity, TDS, salinity and chloride content. The samples were collected in premonsoon and postmonsoon of Shuklaganj area. The pH of all the samples varied from 7.0 to 8.5 in both premonsoon and postmonsoon period. Hardness during in premonsoon varied from 180-212 mg/L and in postmonsoon varied from 140-210 mg/l. Alkalinity varied from 84-112 mg/L in premonsoon and 60-128 mg/L in postmonsoon. However conductivity was quite high and it ranged from 320-2140 µs/cm in premonsoon and 358-1944 µs/cm during postmonsoon. The TDS ranged from 181-1019 mg/l in premonsoon samples and 163-1102 mg/l in postmonsoon. Salinity varied from 0.0-1.0 ppt in premonsoon and 0.0-1.3 ppt in postmonsoon. Chloride content varied from 12.1-36.4 in premonsoon and 8.08-44.5 mg/L in postmonsoon. The picture of heavy metals and arsenic present in the water collected during premonsoon and postmonsoon periods were also determined. However, in premonsoon samples Cr, Cd and Ni were absent in most of the samples. It was noticed that Cd and Ni content was almost absent in the samples collected during postmonsoon season. Copper varied from 0.0 to 0.0178 mg/L during premonsoon and 0.0002 to 0.0098 mg/L during postmonsoon. Zinc content varied from 0.0 to 3.26 in premonsoon period and from 0.0-3.6 mg/L in postmonsoon period. Iron varied from 0.0 to 17.99 mg/L in pre monsoon and varied from 0.0692 to 12.53 in postmonsoon samples. Manganese varied from 0.0 to 0.4454 mg/L in premonsoon samples and 0.0018- 4.74 mg/L in premonsoon samples. Arsenic in premonsoon season varied from 0-250 ppb and from 0-250 ppb in postmonsoon. It is seen that with increase in pH above 8.5, Arsenic desorbs from the oxide surfaces, thereby increasing concentration of Arsenic in solution. It is suggested that the most desirable and significant mechanism for the groundwater Arsenic problems is due to oxidising conditions and desorption of Arsenic from Arsenic contaminated sediments at high pH.

Keywords Arsenic, Heavy Metals, Handpumps

1. Introduction

Human health is greatly affected by exposure to arsenic through drinking water. Arsenic is a carcinogen and its consumption can negatively affect the gastrointestinal tract, cardio-vascular and central nervous systems. World Health Organisation (WHO) and US Environmental Protection Agency have set the maximum acceptable level of arsenic in drinking water as 10 µg/L [1,2]. Arsenic occurs in groundwater primarily as a result of natural weathering of

arsenic containing rocks, although in certain areas high arsenic concentration are caused due to industrial waste discharges and application of arsenical herbicides/pesticides [3]. Arsenic is present in water mainly in the forms of arsenate As (V) and arsenite (As III). In the environmentally relevant pH range 4-10, the dominant As (V) species are negatively charged ($\text{H}_2\text{AsO}_4^{2-}$), while the dominant As (III) species is neutrally charged (H_3AsO_3).

Arsenic is introduced in the soil and groundwater during weathering of rocks and minerals followed by leaching and runoff. Also it can be introduced in soil and groundwater from anthropogenic sources. Many factors control Arsenic concentration and transport in groundwater which include Redox potential, absorption/desorption/precipitation/dissolution. Arsenic groundwater has far reaching consequences

* Corresponding author:

anjuagrawal2@gmail.com (Anju Agrawal)

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including its ingestion through food chain, which are in the form of social disorders, health hazards and socioeconomic dissolution besides its sprawling with movement and exploitation of groundwater. The food crops which are grown using arsenic contaminated water are sold off to other places, including contaminated regions where the inhabitants may consume arsenic from contaminated food. This may give rise to new danger.

It is well known that trace elements of Arsenic is both advantageous to plant and animal nutrition[4,5,6], but there are no reports of this type in humans[7]. However, higher levels of Arsenic are found to be harmful to humans. The contamination of Arsenic of surface and groundwater occurs worldwide and has become a sociopolitical issue in several parts of the globe. For example, there are lots of people who are at risk of drinking As-contaminated water in West Bengal (India)[8,9] and Bangladesh[10]. Scores of people from China[11], Vietnam[12], Taiwan[13], Chile[14], Argentina[15], and Mexico[16] are likely at risk as well. Skin manifestations of many types and other arsenic toxicity were observed from melanosis, keratosis, hyperkeratosis, dorsal keratosis, and non pitting edema to gangrene and

cancer. Overall, prevalence of clinical neuropathy was noticed in various studies in populations of 24- Pargana-North, 24- Pargana-South, Murshidabad, Nadia, and Bardhaman districts of West Bengal and in the states of Bihar, Uttar Pradesh, Jharkhand and Chhattisgarh. Adults are less affected due to arsenic than children. Most of the population suffering from arsenic skin lesions is from a poor socio-economic background and adults are less affected to arsenic than children. Albertus Magnus in 1250 AD for the first time documented the hazardous effects of Arsenic. The hazardous effects of Arsenic on both flora and fauna are well known[17]. The consumption of arsenic contaminated water is the main path for its transportation into the environment and biological systems[3,18,19,20,21] is also well known. Attempts have been made to determine and establish a database on the drinking water quality of Shuklaganj area with particular emphasis on the physico-chemical characteristics and levels of heavy metals in the water samples.

2. Materials and Methods

Table 1. Shows GPS location and physico – chemical properties of water collected from handpumps around Shuklaganj area in premonsoon

S.N.	GPS Location	Location	pH	Temp °C	Hardness mg/l	Alkalinity mg/l	Conductivity µs/cm	TDS mg/l	Salinity ppt	Cl -
1	N260 '29.925' E0800 '27.594'	Gajiyakheda (Shuklaganj)	8.5	25	200	100	872	438	0.3	20.2
2	N260 '29.925' E0800 '27.594'		8.5	25	180	88	828	412	0.2	16.2
3	N260 '28.616' E0800 '23.046'		7.5	25	180	112	570	285	0.0	12.1
4	N260 '28.066' E0800 '22.246'		7.5	25	212	100	538	275	0.2	18.2
5	N260 '28.069' E0800 '22.248'	Majhara pipalkheda (Shuklaganj)	7.5	25	180	84	466	229	0.2	16.2
6	N260 '28.668' E0800 '22.363'		7.5	25	200	92	587	293	0.1	32.3
7	N260 '28.659' E0800 '22.363'		8.5	25	200	84	320	164	0.0	18.2
8	N260 '28.537' E0800 '22.468'		8.5	25	212	100	322	163.6	0.0	14.1
9	N260 '28.486' E0800 '22.869'		8.5	25	208	96	676	337	0.2	14.1
10	N260 '29.137' E0800 '23.542'	Jabbupurwa (Shuklaganj)	8.5	25	180	88	934	466	0.3	32.3
11	N260 '29.389' E0800 '23.633'	Poni Bajar (Shuklaganj)	7.5	25	200	108	1028	514	0.4	12.1
12	N260 '29.331' E0800 '23.655'	Poni(Primary school, Shuklaganj)	7.5	25	208	108	1284	643	0.6	18.2
13	N260 '29.352' E0800 '23.698'	Nihalkheda (Shuklaganj)	7.5	25	200	100	2140	1102	0.3	16.2
14	N260 '29.430' E0800 '23.844'		7.5	25	180	112	1094	547	0.4	12.1
15	N260 '29.391' E0800 '20.824'		8.0	25	200	100	1242	619	0.6	32.3
16	N260 '27.984' E0800 '25.891'		7.5	25	212	96	902	452	0.3	18.2
17	N260 '27.953' E0800 '25.831'		7.5	25	200	92	1892	960	1.0	36.4

The data is the mean of three samples collected from each source (N=3)

Table 2. Shows GPS location and physico – chemical properties of water collected from handpumps around Shuklaganj area in the postmonsoon

S.N	GPS Location	Location	pH	Temp °C	Hardness mg/l	Alkalinity mg/l	Conductivity µs/cm	TDS mg/l	Salinity ppt	Cl ⁻
1	N26° 29.025' E080° 24.899'	Maheshkheda (Shuklaganj)	7.3	26.8	210	72	1944	1019	1.3	38.4
2	N26° 29.605' E080° 24.240'	Nayakheda (Shuklaganj)	7.5	27.0	190	76	633	317	0.3	16.2
3	N26° 29.357' E080° 24.170'		7.3	28.2	170	96	861	430	0.3	40.4
4	N26° 29.039' E080° 23.750'	Panchwati Mandir (Shuklaganj)	7.3	28.1	150	76	432	230	0.0	10.1
5	N26° 28.580' E080° 22.994'	Swaraswati palace (Shuklaganj)	7.4	28.4	180	116	1281	639	0.8	38.4
6	N26° 29.191' E080° 23.601'	Shuklaganj	7.4	28.1	170	76	488	244	0.2	10.1
7	N26° 29.159' E080° 23.560'		7.3	28.2	190	116	467	233	0.2	16.2
8	N26° 29.657' E080° 24.058'		7.4	28.4	210	116	898	427	0.5	40.4
9	N26° 28.485' E080° 22.836'		7.8	27.5	130	112	1672	839	1.1	36.4
10	N26° 28.699' E080° 22.382'	Mishra colony (Swarg dham)	7.3	27.0	170	84	847	422	0.5	38.4
11	N26° 28.632' E080° 22.518'	Mishra colony (Ganga ghat)	7.0	27.4	190	88	1558	786	1.0	32.3
12	N26° 29.096' E080° 23.081'	Champurwa	7.4	28.3	180	76	559	279	0.2	20.2
13	N26° 28.946' E080° 22.915'	Champurwa (manshukheda)	7.1	27.3	140	108	1055	526	0.6	34.5

The data is the mean of three samples collected from each source (N=3)

Drinking water samples were collected from India mark II handpumps in and around Shuklaganj area. Samples for physico-chemical analysis were collected in plastic sterilized bottles and transported to the laboratory. Before filling the samples these bottles have been rinsed two or three times with water. The record of every sample is maintained by an appropriate labelling including the name of the sample collector, the date, timing and exact location. Identification of the sites was made by recording the co-ordinates using the GPS. The samples were collected in premonsoon and

postmonsoon of Shuklaganj area. For analysis of metals the water samples have been collected in glass or plastic (polyethylene) bottles and 2.0 ml of nitric acid is added in each bottle. All the samples have to be stored at 4°C for storage and analysis. For quantitative metal analysis a multi-elemental standard solution of Cu, Cr, Cd, Zn, Fe, Mn, Ni, As was collected in 2% nitric acid commercial 1g/L. Individual standard solution was stored in polyethylene bottles. Measurement was made on Inductivity Couple Plasma (ICP) Instrument (Thermo Electric Corporation

Intrepid II x DL) with axial viewing configuration. The complete process of sample preparation and analysis of physico-chemical and metals was made as per the standard methods[22].

3.Results and Discussion

The physico-chemical parameters and the GPS location of the water samples collected in and around Shuklaganj area are shown in Table1,2,3. The parameters determined were pH, hardness, alkalinity, conductivity, TDS, salinity and chloride content. The samples were collected in premonsoon and postmonsoon of Shuklaganj area. The pH of all the

samples varied from 7.0 to 8.5 in both premonsoon and postmonsoon period. Hardness during premonsoon varied from 180-212mg/L and in postmonsoon varied from 140-210 mg/l. Alkalinity varied from 84-112mg/L in premonsoon and 60-128 mg/L in postmonsoon. However conductivity was quite high and it ranged from 320-2140 μ s/cm in premonsoon and 358-1944 μ s/cm during postmonsoon. The TDS ranged from 181-1019 mg/l in premonsoon samples and 163-1102mg/l in postmonsoon. Salinity varied from 0.0-1.0 ppt in premonsoon and 0.0-1.3 ppt in postmonsoon. Chloride content varied from 12.1-36.4 in premonsoon and 8.08-44.5 mg/L in postmonsoon.

Table 3. Shows GPS location and physico – chemical properties of water collected from handpumps around Shuklaganj area in postmonsoon

S. N	GPS Location	Location	pH	Temp °C	Hardness mg/l	Alkalinity mg/l	Conductivity μ s/cm	TDS mg/l	Salinity ppt	Cl ⁻
1	N26° 29.925' E080° 27.594'	Ambikapuram (Shuklaganj)	7.5	25	180	128	1086	539	0.6	16.2
2	N26° 29.925' E080° 27.594'	Baunamau (Shuklaganj)	7.5	25	130	76	538	269	0.1	26.3
3	N26° 28.616' E080° 23.046'	Shaheen Market (Shuklaganj)	8.5	25	210	80	712	356	0.2	18.2
4	N26° 28.066' E080° 22.246'	Ganga Pul (Shuklaganj)	7.5	26	140	36	1139	567	0.5	24.3
5	N26° 28.069' E080° 22.248'	Mishra colony (Entrance)	7.5	26	190	76	1202	600	0.6	22.2
6	N26° 28.668' E080° 22.363'	Mishra colony (Ghat ke pass)	8.5	25	170	120	754	376	0.2	32.3
7	N26° 28.659' E080° 22.363'	Mishra colony (Ganga ghat)	8.0	25	170	128	1361	678	0.6	44.5
8	N26° 28.537' E080° 22.468'	Mishra colony (Naveen Badh kendra)	7.5	25	180	128	1340	670	0.6	44.5
9	N26° 28.486' E080° 22.869'	Shuklaganj (Kafibar, Thane ke pass)	7.5	25	130	100	1068	533	0.5	38.4
10	N26° 29.137' E080° 23.542'	Shuklaganj (rajdhani Road Mandir)	7.5	25	210	92	388	194.1	0.1	10.1
11	N26° 29.389' E080° 23.633'	Shuklaganj (Primary School, Netuwa)	7.0	26	150	60	422	211	0.1	20.2
12	N26° 29.331' E080° 23.655'	Shuklaganj (Panchayat Bhawan Netuwa)	8.5	26	170	48	358	181.6	0.1	8.08
13	N26° 29.352' E080° 23.698'	Shuklaganj (Rashmilok Netuwa)	8.0	26	190	124	616	314	0.1	22.2
14	N26° 29.430' E080° 23.844'	Shuklaganj (Sarosi)	8.0	26	170	120	796	398	0.3	24.5
15	N26° 29.391' E080° 20.824'	Shuklaganj (Sarosi, Sulabh Sauchalay)	7.5	25	170	72	495	248	0.1	28.3
16	N26° 27.984' E080° 25.891'	Poni Bazaar, Bypaas road	7.5	25	130	124	511	255	0.1	38.4
17	N26° 27.953' E080° 25.831'		7.5	25	150	60	711	355	0.2	30.3

The data is the mean of three samples collected from each source (N=3)

Table 4. Shows the heavy metals and arsenic present in water collected from handpumps in and around Shuklaganj in premonsoon

S.N	Location	Cu	Cr	Cd	Zn	Fe	Mn	Ni	As
1	Gajiyakheda (Shuklaganj)	BDL	BDL	0.0007	BDL	BDL	BDL	BDL	10
2		BDL	BDL	BDL	BDL	BDL	BDL	0.0018	25
3		0.0178	0.0083	BDL	2.46	16.61	0.1711	BDL	25
4		0.0057	BDL	BDL	2.86	10.56	0.0854	BDL	250
5	Majharapipalkheda (Shuklaganj)	0.0057	BDL	BDL	2.35	12.30	0.2154	0.0009	5
6		0.0009	BDL	BDL	BDL	16.23	0.2791	BDL	0
7		0.0107	BDL	BDL	3.41	4.34	0.235	BDL	10
8		0.0137	BDL	BDL	3.36	5.50	0.2117	BDL	25
9		0.0005	BDL	BDL	1.15	6.56	0.1472	BDL	0
10	Jabbupurwa (Shuklaganj)	0.0005	BDL	BDL	1.23	7.41	0.1208	BDL	0
11	Poni Bajar (Shuklaganj)	0.0012	BDL	BDL	0.0481	5.97	0.0945	BDL	50
12	Poni(Primary school, Shuklaganj)	0.001	BDL	BDL	BDL	3.16	0.1999	0.0014	0
13	Nihalkheda (Shuklaganj)	0.0142	BDL	BDL	3.26	8.93	0.4363	BDL	10
14		0.0048	BDL	BDL	2.77	13.28	0.1957	BDL	25
15		BDL	BDL	BDL	BDL	8.45	0.1585	BDL	50
16		0.0078	0.0062	BDL	3.09	17.82	0.3709	BDL	250
17		0.0107	0.0012	BDL	2.24	17.99	0.4454	BDL	100

The data is the mean of three samples collected from each source (N=3)

The picture of heavy metals and arsenic present in the water collected during premonsoon and postmonsoon periods were also determined and are shown in Table 4,5,6. However, in premonsoon samples Cr, Cd and Ni were absent in most of the samples. It was noticed that Cd and Ni content was almost absent in the samples collected during postmonsoon season. Copper varied from 0.0 to 0.0178 mg/L during premonsoon and 0.0002 to 0.0098mg/L during postmonsoon. Zinc content varied from 0.0 to 3.26 in premonsoon period and from 0.0-3.6 mg/L in postmonsoon period. Iron varied from 0.0 to 17.99 mg/L in pre monsoon

and varied from 0.0692 to 12.53 in postmonsoon samples. Manganese varied from 0.0 to 0.4454 mg/L in premonsoon samples and 0.0018- 4.74 mg/L in premonsoon samples. Arsenic in premonsoon season varied from 0-250 ppb and from 0-250 ppb in postmonsoon.

Arsenic is stable in four oxidation states (+5, +3, 0, -3) under the Eh conditions that occur in aquatic systems. At high Eh values (mostly exist in oxygenated waters), arsenic acid species (i.e., H_3AsO_4 , H_2AsO_4^- , HAsO_4^{2-} , and AsO_4^{3-}) are stable. At mildly reducing conditions, arsenious acid species (i.e., H_3AsO_3 , H_2AsO_3^- , and HAsO_3^{2-}) become

stable[23,24,25]. The speciation of As in aquatic environment is critical in controlling the adsorption/desorption reactions with sediments. Adsorption to sediment particles may remove As(V) from contaminated water, as well as inhibiting the precipitation of As minerals such as scorodite ($\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$) that control the equilibrium aqueous concentration[26]. Under the aerobic and acidic to near-neutral conditions (typical of many aquatic environments), As(V) is adsorbed very strongly by oxide minerals in sediments. The highly nonlinear nature of the adsorption isotherm for As(V) in oxide minerals ensures that the amount of As adsorbed is relatively large, even when dissolved aqueous concentrations of As are low. Such adsorption occurring in natural environments protects water bodies from widespread As toxicity problems. Adsorption of As species by sediments are as follows: $\text{As(V)} > \text{As(III)} > \text{As(II)}$

(II) > DMA[3]. In As-contaminated sediments, Clement and Faust (1981)[27] found that a significant portion of the As was bound in organo-complex forms and indicated that adsorption-desorption equilibrium must be considered as well as the redox effects in examining the dynamics of As in aquatic environment.

4. Conclusions

It is seen that with increase of pH above 8.5, Arsenic desorbs from the oxide surfaces, thereby increasing the concentration of As in solution. It is suggested that the most desirable and significant mechanism for the groundwater As problems due to oxidizing conditions and the desorption of As from As contaminated sediments at high pH [28,29].

Table 5. Shows the heavy metals and arsenic present in water collected from handpumps around Shuklaganj in postmonsoon

S.N.	Location	Cu	Cr	Cd	Zn	Fe	Mn	Ni	As (PPb)
1.	Maheshkheda (Shuklaganj)	0.002	BDL	0.0004	0.2823	8.20	0.4695	0.0012	5
2.	Nayakheda (Shuklaganj)	0.0029	BDL	BDL	0.059	12.53	0.0618	BDL	0
3.		0.0017	BDL	BDL	0.032	0.2378	0.1104	0.0009	5
4.	Panchwati Mandir (Shuklaganj)	BDL	BDL	BDL	BDL	0.0692	0.0598	BDL	0
5.	Swaraswati palace (Shuklaganj)	0.0037	BDL	0.0008	0.2506	6.88	0.025	0.0087	0
6.	Shuklaganj	0.0002	BDL	BDL	0.2709	BDL	0.4954	BDL	250
7.		0.003	BDL	0.0001	0.0564	0.2795	0.2052	0.0027	0
8.		0.0026	0.0053	0.0009	0.0242	0.2655	0.0955	0.0012	0
9.		0.0015	BDL	BDL	BDL	BDL	0.0034	0.0005	250
10.	Mishra colony (Swarg dham)	0.002	0.0107	0.0001	0.0261	0.0206	0.3665	0.0003	250
11.	Mishra colony (Ganga ghat)	0.005	BDL	BDL	BDL	BDL	0.0018	BDL	250
12.	Champapurwa	0.0066	BDL	0.0004	3.60	5.24	4.74	0.003	25
13.	Champapurwa (manshukheda)	0.0018	0.0056	BDL	0.0035	0.0766	0.3665	BDL	0

The data is the mean of three samples collected from each source (N=3)

Table 6. Shows the heavy metals and arsenic present in water collected from handpumps in and around Shuklaganj in postmonsoon

S.N	Location	Cu	Cr	Cd	Zn	Fe	Mn	Ni	As
1.	Ambikapuram (Shuklaganj)	0.0098	0.095	BDL	6.26	0.2213	4.53	0.0138	0
2.	Baunamau (Shuklaganj)	0.0039	0.0363	BDL	5.44	19.3	0.2967	BDL	250
3.	Shaheen Market (Shuklaganj)	0.0017	0.0149	0.0015	5.87	21.33	0.0215	0.0073	0
4.	Ganga Pul (Shuklaganj)	BDL	0.0164	BDL	0.0247	3.25	0.0246	BDL	250
5.	Mishra colony (Entrance)	BDL	0.0169	BDL	0.0485	15.19	0.2328	BDL	25
6.	Mishra colony (Ghat ke pass)	0.0079	0.0135	BDL	BDL	0.0194	0.001	BDL	0
7.	Mishra colony (Ganga ghat)	0.0005	0.0071	BDL	BDL	0.000	0.000	BDL	0
8.	Mishra colony (Naveen Badh kendra)	BDL	0.0282	0.0001	3.82	11.27	0.0185	BDL	50
9.	Shuklaganj (Kafibar, Thane ke pass)	0.0026	0.0329	BDL	0.0849	7.36	0.0295	BDL	0
10.	Shuklaganj (rajdhani Road Mandir)	BDL	0.0051	BDL	5.09	0.0161	0.1002	BDL	50
11.	Shuklaganj Primary School, Netuwa)	0.0007	0.0277	BDL	4.99	10.26	0.1041	BDL	250
12.	Shuklaganj (Panchayat Bhawan , Netuwa)	0.0012	0.0201	BDL	4.91	21.45	0.1052	BDL	25
13.	Shuklaganj (Rashmilok Netuwa)	0.0003	0.0218	BDL	5.81	11.52	0.1370	BDL	250
14.	Shuklaganj (Sarosi ,)	0.0003	0.033	BDL	4.58	19.86	0.1726	BDL	250
15.	Shuklaganj (Sarosi, Sulabh Sauchalay)	0.0052	0.0255	0.0001	4.54	21.41	0.1984	BDL	50
16.	Poni Bazaar , Bypaas road	BDL	0.0204	BDL	3.63	17.89	0.2137	BDL	25
17.		0.0019	0.0019	BDL	0.0652	22.49	0.2636	BDL	100

The data is the mean of three samples collected from each source (N=3)

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