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

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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 10µg/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 180-212mg/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 µs/cm in premonsoon and 358-1944µs/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 to 12.1-36.4 mg/L 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 0.0098mg/L during postmonsoon. Zinc content varied from 0.0 to 0.0178 mg/L during premonsoon and 0.0002 to 0.0098mg/L during postmonsoon. Iron varied from 0.0 to 17.99 mg/L in premonsoon and varied from 0.0692 to 12.53 in postmonsoon samples. Manganese varied from 0.0 to 4.454 mg/L in premonsoon samples and 0.0018- 4.74 mg/L in postmonsoon 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 10µg/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 (H2AsO4−)2−, while the dominant As (III) species is neutrally charged (H3AsO3). 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...
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

| 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° 29.925'E| Gajiyakheda (Shuklaganj) | 8.5 | 25      | 200           | 100             | 872               | 438      | 0.3         | 20.2 |
| 2    | N26° 29.925'E| Gajiyakheda (Shuklaganj) | 8.5 | 25      | 180           | 88              | 828               | 412      | 0.2         | 16.2 |
| 3    | N26° 28.616'E| Majhara pipalkheda (Shuklaganj) | 7.5 | 25      | 180           | 112             | 570               | 285      | 0.0         | 12.1 |
| 4    | N26° 28.066'E| Majhara pipalkheda (Shuklaganj) | 7.5 | 25      | 212           | 100             | 538               | 275      | 0.2         | 18.2 |
| 5    | N26° 28.069'E| Majhara pipalkheda (Shuklaganj) | 7.5 | 25      | 180           | 84              | 466               | 229      | 0.2         | 16.2 |
| 6    | N26° 28.668'E| Majhara pipalkheda (Shuklaganj) | 7.5 | 25      | 200           | 92              | 587               | 293      | 0.1         | 32.3 |
| 7    | N26° 28.659'E| Majhara pipalkheda (Shuklaganj) | 8.5 | 25      | 200           | 84              | 320               | 164      | 0.0         | 18.2 |
| 8    | N26° 28.537'E| Majhara pipalkheda (Shuklaganj) | 8.5 | 25      | 212           | 100             | 322               | 163.6    | 0.0         | 14.1 |
| 9    | N26° 28.486'E| Majhara pipalkheda (Shuklaganj) | 8.5 | 25      | 208           | 96              | 676               | 337      | 0.2         | 14.1 |
| 10   | N26° 29.137'E| Jabupurva (Shuklaganj) | 8.5 | 25      | 180           | 88              | 934               | 466      | 0.3         | 32.3 |
| 11   | N26° 29.389'E| Poni Bajar (Shuklaganj) | 7.5 | 25      | 200           | 108             | 1028              | 514      | 0.4         | 12.1 |
| 12   | N26° 29.331'E| Poni (Primary school, Shuklaganj) | 7.5 | 25      | 208           | 108             | 1284              | 643      | 0.6         | 18.2 |
| 13   | N26° 29.352'E| Nihalkheda (Shuklaganj) | 7.5 | 25      | 200           | 100             | 2140              | 1102     | 0.3         | 16.2 |
| 14   | N26° 29.430'E| Nihalkheda (Shuklaganj) | 7.5 | 25      | 180           | 112             | 1094              | 547      | 0.4         | 12.1 |
| 15   | N26° 29.391'E| Nihalkheda (Shuklaganj) | 8.0 | 25      | 200           | 100             | 1242              | 619      | 0.6         | 32.3 |
| 16   | N26° 27.984'E| Nihalkheda (Shuklaganj) | 7.5 | 25      | 212           | 96              | 902               | 452      | 0.3         | 18.2 |
| 17   | N26° 27.953'E| Nihalkheda (Shuklaganj) | 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 hand pumps 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' | Maheshkhera (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 | Panchwati Mandir (Shuklaganj) | 7.3 | 28.2    | 170           | 96              | 861               | 430      | 0.3         | 40.4|
| 4   | N26°29.039'E080°23.750 | Swaraswati palace (Shuklaganj) | 7.3 | 28.4    | 180           | 116             | 1281              | 639      | 0.8         | 38.4|
| 5   | N26°28.580'E080°22.994 | Maheshkhera (Shuklaganj) | 7.4 | 28.1    | 170           | 76              | 488               | 244      | 0.2         | 10.1|
| 6   | N26°29.191'E080°23.601' | Shuklaganj                | 7.3 | 28.2    | 190           | 116             | 467               | 233      | 0.2         | 16.2|
| 7   | N26°29.159'E080°23.560 | Maheshkhera (Shuklaganj) | 7.3 | 28.4    | 210           | 116             | 898               | 427      | 0.5         | 404.0|
| 8   | N26°29.657'E080°24.058' | Shuklaganj                | 7.3 | 28.4    | 180           | 76              | 559               | 279      | 0.2         | 20.2|
| 9   | N26°28.485'E080°22.836' | Maheshkhera (Swarg dham) | 7.3 | 27.0    | 170           | 84              | 847               | 422      | 0.5         | 38.4|
| 10  | N26°28.699'E080°22.382' | Mishra colony (Ganaghat) | 7.3 | 27.4    | 190           | 88              | 1558              | 786      | 1.0         | 32.3|
| 11  | N26°28.832'E080°22.518' | Mishra colony (Ganaghat) | 7.0 | 28.3    | 180           | 76              | 559               | 279      | 0.2         | 20.2|
| 12  | N26°29.096'E080°23.081' | Champapurwa               | 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.
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 Table 1, 2, 3. The parameters determined were pH, hardness, alkalinity, conductivity, TDS, salinity and chloride content. The samples were collected in premonsoon and postmonsoon period 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 180-212 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 to 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 µs/cm | TDS mg/L | Salinity ppt | Cl⁻ |
|-----|--------------|----------|----|---------|---------------|-----------------|-------------------|-----------|-------------|-----|
| 1   | N26°29.925'E080°27.594' | Ambikapuram (Shuklaganj) | 7.5 | 25 | 180 | 128 | 1068 | 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 Bhk kendra) | 7.5 | 25 | 180 | 128 | 1340 | 670 | 0.6 | 44.5 |
| 9   | N26°28.486'E080°22.869' | Shuklaganj (Kafibr, 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 Netwa) | 7.0 | 26 | 150 | 60 | 422 | 211 | 0.1 | 20.2 |
| 12  | N26°29.331'E080°23.655' | Shuklaganj (Panchayat Bhawan Netwa) | 8.5 | 26 | 170 | 48 | 358 | 181.6 | 0.1 | 8.08 |
| 13  | N26°29.352'E080°23.698' | Shuklaganj (Rashmi k Netwa) | 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 Bajaar, Bypass road | 7.5 | 25 | 130 | 124 | 511 | 255 | 0.1 | 38.4 |
| 17  | N26°27.953'E080°25.831' | Poni Bajaar, Bypass road | 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 | 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   |                                 | 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   | Majhara pippalkheda (Shuklaganj) | 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 | 3.16 | 1.999 | 0.0014 | 0    |
| 13  |                                 | 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 | 8.45 | 0.1585 | BDL | 50   |
| 16  | Nihalkheda (Shuklaganj)         | 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 0.0098 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.

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, arsenic acid species (i.e., $H_3AsO_3$, $H_2AsO_3^-$, and $HAsO_3^{2-}$) become...
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 (FeAsO$_4$.2H$_2$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: As(V) > As(III) > As(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    | Panchwati Mandir (Shuklaganj) | 0.0017| BDL   | BDL   | 0.032 | 0.2378| 0.1104| 0.0009| 5        |
| 4    | Swaraswati palace (Shuklaganj) | 0.0037| BDL   | 0.0008| 0.2506| 6.88  | 0.025 | 0.0087| 0        |
| 5    | Shuklaganj                | 0.0002| BDL   | BDL   | 0.2709| BDL   | 0.4954| BDL   | 250      |
| 6    |                             | 0.003 | BDL   | 0.0001| 0.0564| 0.2795| 0.2052| 0.0027| 0        |
| 7    | Mishra colony (Swargdham) | 0.0026| 0.0053| 0.0009| 0.0242| 0.2655| 0.0955| 0.0012| 0        |
| 8    | Mishra colony (Ganga ghat)| 0.0015| BDL   | BDL   | BDL   | BDL   | 0.0034| 0.0005| 250      |
| 9    | Champapurwa               | 0.0002| BDL   | 0.0107| 0.0001| 0.0261| 0.2060| 0.3665| 0.0003  | 250      |
| 10   | Champapurwa (manshukheda) | 0.005 | BDL   | BDL   | BDL   | BDL   | 0.0018| BDL   | 250      |
| 11   |                             | 0.0066| BDL   | 0.0004| 3.60  | 5.24  | 4.74  | 0.003 | 25        |

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 Palli (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 Budh ki Ghat) | 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 Suuchalay) | 0.0052 | 0.0255 | 0.0001 | 4.54   | 21.41  | 0.1984 | BDL    | 50     |
| 16. | Poni Bajaar, Bypass road         | BDL    | 0.0204 | BDL    | 3.63   | 17.89  | 0.2137 | BDL    | 25     |
| 17. | Poni Bajaar, Bypass road         | 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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