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DETERMINATION OF ARSENIC IN THE WATER OF COAL MINING AREAS OF ASSAM

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Abstract: The occurrence of Arsenic (As), in various water bodies from the coal mining areas of Assam in the north-eastern part of India has been reported in this work. The coalmines of Assam are a major source of acid mine drainage due to the presence of pyrites along with the coal deposits. Both open cast and underground mining of coal are done in that area. Rainwater runoff carries the acid mine drainage from the waste piles to the nearby water bodies. In the present work, water from three types of sources, viz., ponds, wells and rivers from the area was systematically investigated to determine the concentration of arsenic. Most of the water sources were found to be polluted by arsenic with pond water and well water having much more contamination. The permissibility levels for arsenic was exceeded in a large number of cases and the high arsenic content may be due to the entry of acid mine drainage into the water that contain arsenic, dissolved from coal. The results are discussed in the light of possible adverse effects.

Keywords: coal; acid mine drainage; groundwater; pond water; river water; arsenic

1. Introduction:

The coal mining areas of Assam (North East India) are located in the Borail range extending from northeast to southwest direction in the districts of Dibrugarh and Tinsukia and the coal belong to Oligocene tertiary variety. Two important coalfields present in the area are Dilli-Jaipur and Makum coal fields. Coal generally contains pyrite (FeS_2) as impurities. Pyrites often exist in association with arsenic along with other metallic elements.

Arsenic occurs naturally in the earth's crust at an average concentration of 2–5 mg/kg, and is primarily associated with igneous and sedimentary rocks in the form of inorganic arsenic compounds (Tamak, 1992). While arsenic is released to the environment from natural sources such as wind-blown dirt and volcanoes, releases from anthropogenic sources far exceed those from natural sources. In aquatic systems, inorganic arsenic occurs primarily in two oxidation states, As(V) and As(III) with As(V) predominating under oxidizing conditions and As(III) under reducing conditions. Arsenic may undergo a variety of reactions in the environment, including oxidation-reduction reactions, Ligand exchange, precipitation, and biotransformation (EPA, 1979, EPA 1984a, Pongratz, 1998, Welch, 1988). These reactions are influenced by Eh (the oxidation-reduction potential), pH, metal sulfide and sulfide ion concentrations, iron concentration, temperature, salinity, and distribution and composition of the biota (EPA, 1979). Natural level of As in water is usually less than 10 ppb, although higher levels may occur near mineral deposits or anthropogenic sources. The major anthropogenic sources of arsenic are Industrial wastes, mining residues, pesticides or fertilizers and geological activities (Ozge, 2013).

Transport and partitioning of arsenic in water depends upon the chemical form of arsenic and on interactions with other materials present. Soluble forms move with water, and may be carried long distances through rivers. Under oxidizing and mildly reducing conditions, groundwater arsenic concentrations are usually controlled by adsorption rather than by mineral precipitation. In acidic and neutral waters, As(V) is extensively adsorbed, while As(III) is relatively weakly adsorbed. This is because As(III), which exists as H_3AsO_3 (pKa = 9.23, 12.13, 13.4), is less strongly adsorbed on mineral surfaces than the oxyanions of H_3AsO_4 (pKa = 2.22, 6.98, 11.53) (NRC,2001). Sediment-bound arsenic may be released back into the water by chemical or biological interconversions of arsenic species. Arsenic enters rivers from mining operations and is transported downstream, moving from water and sediment into biofilm (attached algae, bacterial, and associated fine detrital material), and then into invertebrates and fish. The source of arsenic in the water column may be resuspended sediment.

2. Methods and methodology:

Water samples were collected from the coal belt in three seasons, viz, post monsoon (Batch A, November 2002), monsoon (Batch B, Jun 2003,) and pre monsoon season (Batch C, January 2004,) from 30 different sources. Samples were collected in pre-cleaned plastic bottles of 1 litre capacity. The sampling sources were divided into three categories, pond water (10 samples), ground water (10 samples) and river water (10 samples). The sampling sources and their approximate locations are given in Table 1.

Sample collection, filtration, treatment, digestion and analysis for dissolved metals were carried out following standard procedure (APHA, 1998). The estimation of arsenic was done by using AAS spectrophotometer (Varian SpectrAA 220). Hydride generation technique was used for the determination of As. Calibration was done by using AAS standards (E Merck). The experimental conditions for the determination of the As are presented in Table 2.

3. Results and discussion:

At several locations (Fig. 1), Arsenic (As) content of the water samples from the study area exceeds the permissible limit of 50 µg/L for drinking water given by World Health Organisation. The high arsenic content may be due to the entry of acid mine drainage into the water bodies that contain arsenic, dissolved from coal.

Table 1: The sampling stations for water (Distance and direction are measured with reference to Coal India Limited's residential complex at Margherita)

S.N	Locations	Sources	Distance (km)	Direction
Ground water				
G1	CIL Complex, Srimanta Nagar	Tube well	0	--
G2	Polo field at D duara's residence	Tube well	1	S
G3	At CMPF Office CIL	Tube well	1	W
G4	Near Sarbajanin Kali Mandir	Dug well	20	E
G5	Lalpahar Village, Tipong	Dug well	19	E
G6	No. 2 Tirap Gate	Tube well	18	E
G7	Lekhapani Shiva Temple, Tinali	Dug well	15	S
G8	Lido Itakhola near a bridge	Dug well	9	E
G9	Ledu Bazaar, Barua's Hotel	Tube well	7	E
G10	At the Stadium, Tikok Colliery	Tube well	5	E
Pond water				
P1	Shiva Mandir, Tipong	Pond	20	E
P2	Lalpani Village, Tipong	Pond	19	S
P3	No. 2 Tirap Gate	Pond	18	S
P4	Tirap Colliery, a road side pond	Pond	12	E
P5	Ledo Itakhula, near a bridge	Pond	9	E
P6	Ledo	Pond	8	E
P7	Patkai Stadium	Pond	7	E
P8	Ledu Bazaar	Pond	6	E
P9	Borgolai area	Pond	4	E
P10	Changlang Road, Margherita	Pond	3	N

River water				
R1	Tipong River, Colliery Gate	River	22	E
R2	GE Office under airon bridge	Rivulet	16	E
R3	Lekhapani River, Lekhapani Station	River	15	E
R4	Lekhapani Station, ASEB office	River	14	E
R5	Shiva Mandir, Tirap colliery	Rivulet	11	E
R6	Tirap Colliery near a bridge	Rivulet	10	E
R7	Tikak Colliery under a bridge	Rivulet	5	E
R8	New colony near a bridge	River	2	E
R9	Back side of Borgolai	River	4	E
R10	Margherita	River	3	W

Table 2: Analytical conditions for atomic absorption analysis

Element	Wavelength (nm)	Operating range	HCL current (mA)	Slit width (nm)	Type of flame
As	193.7	3 – 150 ppb	10	0.5	Hydride generation and Electro thermal controller

Much more arsenic was measured in the pond water and the ground water than in the river water. For the pond water, the highest value recorded was 91.2 µg/L at the location PW6 for the batch C and the lowest value was 9.2 µg/L at the locations PW10 for the batch B. For the ground water samples, the range of As was found below detection level (GW3, GW4, GW8, GW9, batch B) to 172.4 µg/L (GW10, batch C). In all the cases, the batch B collected during the month of July had the lowest values, which could be attributed to large dilution due to heavy rains during that month. The highest value of arsenic found in the river water samples is 8.8 µg/L (RW3, batch C) which is well within the permissible limit. The Mean values of arsenic content of the present study is given in Table-3.

Large amount of dissolved arsenic in both pond water and ground water (range for the average content, pond water: 36.3 to 61.4 µg/L, ground water: 30.1 to 89.6 µg/L) can be attributed to local accumulation. Arsenic content of the river water was influenced by large dilution effect and the values were much reduced (range for the average content: below detection level to 4.1 µg/L). In all the cases, the values were substantially less during the wet season (Batch B).

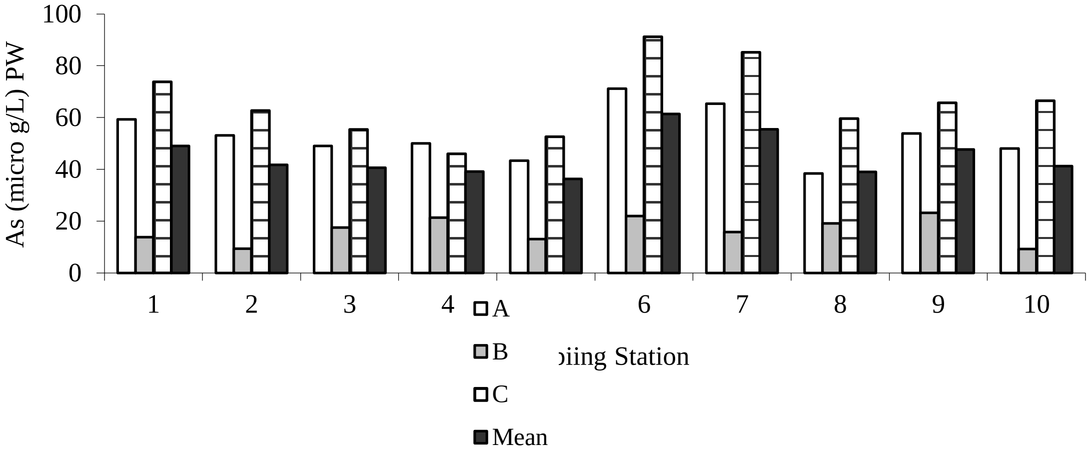
Measurement of arsenic in water is considered extremely important as inorganic arsenic has been recognized as a human poison since ancient times with large oral doses (above 60 ppm in food or water) being fatal. If lower levels of inorganic arsenic (ranging from about 0.3 to 30 ppm in food or water) are swallowed, one may experience irritation of the stomach and intestines, with symptoms such as stomach ache, nausea, vomiting, and diarrhoea. Other effects include decreased production of red and white blood cells causing fatigue, abnormal heart rhythm, blood-vessel damage resulting in bruising, and impaired nerve function causing a "pins and needles" sensation in the hands and feet. Perhaps the single most characteristic effect of long-term oral exposure to inorganic arsenic is a pattern of skin changes. These include a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. A small number of the corns may ultimately develop into skin cancer. Swallowing arsenic has also been reported to increase the risk of cancer in the liver, bladder, kidneys, prostate, and lungs. The International Agency for Research on Cancer (IARC) has determined that inorganic arsenic is carcinogenic to humans.

Table 3: Mean values and standard deviations of As in the water bodies of the coal mining area.

Source	As (µg/L)		Source	As (µg/L)		Source	As (µg/L)	
	Mean	SD		Mean	SD		Mean	SD
PW1	48.97	31.3	GW1	39.24	33.2	RW1	0.54	0.8
PW2	41.70	28.5	GW2	39.93	34.9	RW2	0.36	0.5
PW3	40.63	20.3	GW3	32.07	7.9	RW3	4.13	4.2
PW4	39.10	15.5	GW4	30.83	6.4	RW4	0.25	0.4
PW5	36.33	20.7	GW5	62.40	59.2	RW5	3.11	2.3
PW6	61.40	35.7	GW6	45.10	38.2	RW6	BDL	0.0
PW7	55.43	35.7	GW7	47.33	41.2	RW7	0.97	1.2
PW8	39.03	20.3	GW8	40.70	3.0	RW8	0.91	1.5
PW9	47.60	21.9	GW9	31.63	8.0	RW9	BDL	0.0
PW10	41.23	29.2	GW10	89.60	83.7	RW10	BDL	0.0

Arsenic is widely distributed in surface water, groundwater, and finished drinking water. Surveys of arsenic concentrations in rivers and lakes indicate that most values were < 10 µg/L, although individual samples may range up to 1,000 µg/L (NAS, 1977, Page 1981, Smith 1987). A survey of 293 stations in two nationwide sampling networks on major U.S Rivers found median arsenic levels to be 1 µg/L; the 75th percentile level was 3 µg/L (Jonnalagadda, 1996). River water sampled next to mine dumps during the rainy season in Zimbabwe had an arsenic concentration of 25 µg/L (Jonnalagadda, 1996). Arsenic levels in groundwater average was about 1–2 µg/L, except in some states with volcanic rock and sulfidic mineral deposits, where the arsenic levels up to 3,400 µg/L have been observed (Welch, 1988, Robertson, 1989). In some mining areas, groundwater arsenic concentration up to 48,000 µg/L has been reported (Welch, 1988) . Most arsenic in natural waters is a mixture of arsenate and arsenite, with arsenate usually predominating (Braman, 1973, EPA, 1982)). In a survey of shallow groundwater quality in the alluvial aquifer beneath a major urban centre, Denver, Colorado, arsenic levels in the 30 randomly-chosen wells sampled had minimum levels of < 1 µg/L; the maximum level was 33 µg/L (Bruce, 1996). Areas of the world such as Bangladesh have shallow aquifers composed of arsenic-containing sediment. In four villages of Bangladesh targeted for a recent study, arsenic concentrations in drinking water ranged from 10 to 2,040 µg/L (Tondel, 1999).

In the present work, In many sampling stations, pond and ground water samples exceed the maximum permissible level of 50 µg/L for As (WHO 2008) in one or more of the measurements (excepting the wet season, batch B) and are therefore not suitable for drinking. In case of the river water samples, the values are always much less than the permissible level.



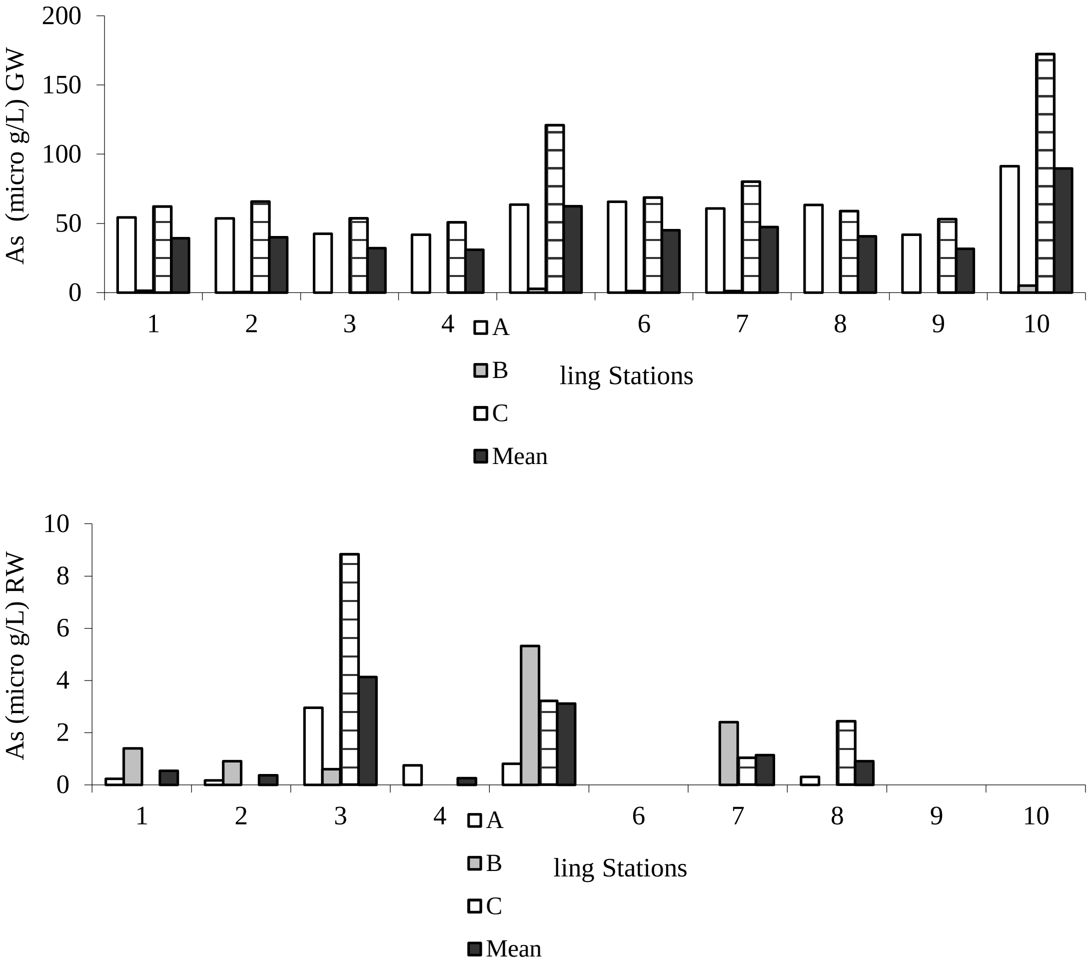


Figure 1: Variation of arsenic content with location for the pond water (top), groundwater (middle) and river water samples (bottom) from the coal-mining area.

4. Conclusion:

From the above data, we can conclude that the water of the coalfield area is polluted by Arsenic. Many sampling sources contain arsenic more than the usual value in natural water (>10 ppb). The high arsenic content may be due to the entry of acid mine drainage into the water bodies that contain arsenic, dissolved from coal. Though river water is free from arsenic in many stations pond and ground water samples exceed the maximum permissible level of drinking water 50 µg/L and are therefore not suitable for drinking.

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