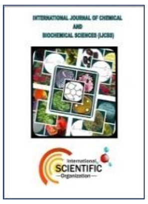
International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html



Geochemical mobilization of Arsenic, Chromium and Uranium in Gangetic Plain of Bihar and Jharkhand

Ashok Kumar Jha*, SubhajitSikdar, SachinVerma, Usha Sharma, Raghbendra Thakur, Sourav Majumder, Amit Anand, Pallavi Kumari

Ashok Kumar Jha – University Department of Chemistry, T.M. Bhagalpur University, Bhagalpur, Bihar, India – 812007
SubhajitSikdar – Department of Chemistry, P.B.S. College, Banka, Bihar, India – 813102
SachinVerma – University Department of Chemistry, T.M. Bhagalpur University, Bhagalpur, Bihar, India – 812007
Usha Sharma – Department of Chemistry, G.B. College, Naugachia, Bihar, India
Raghbendra Thakur – Atomic Minerals Directorate for Exploration and Research Department of Atomic Energy,Bangalore, Karnataka, India.
Amit Anand – University Department of Chemistry, T.M. Bhagalpur University, Bhagalpur, Bihar, India – 812007
SouravMajumder – Department of Chemistry, Kaliaganj College, GourBanga University, West Bengal, India.
Pallavi Kumari-University Department of Chemistry, T.M. Bhagalpur University, Bhagalpur, Bihar, India – 812007.

Abstract

The presence of arsenic, chromium and uranium in the ground water as well as surface water near coal mines may be attributed to the mobilization of uranium in water resources through the ores of uranium such as uranitite, autunite. The diffusion of arsenic and chromium in waterbodies through the ores are causing hazard to the human health. Percolation of toxic elements through soil strata of alluvial to underground water has as well as anthropogenic reasons have increased the level of arsenic and chromium in waterbodies. Heavy metal pollution in general has also occurred due to the effluents of dyeing industries situated near the Gangetic Plain. The highest concentration of chromium and uranium was found 0.092 ppm and 0.00733 ppm near Lalmatia open cast coal mines of Godda district, Jharkhand. Analysis of heavy metals by Induced Coupled Plasma Atomic emission spectroscopy (ICP – AES) showed the presence of 0.004 ppm arsenic and 0.092 ppm chromium in the ground water sample of Lalmatia, an open cast coal mine of Godda, Jharkhand. Analysis of same water sample by LED Fluorimeter and ICP – AES showed the highest concentration of 0.00733 ppm uranium. Thus ion-exchange, diffusion, dissolution and anthropogenic activities account for the heavy metal contamination in waterbodies.

Keywords: ICP – AES, Gangetic Plain, mobilization, LED Fluorimeter, Ion-exchange.

Full length article **Corresponding Author*, e-mail: ashokjha39@gmail.com

1. Introduction

The Rajmahal Hills of Jharkhand possess a variety of ores of rare and rare earth elements, radioactive elements as well as bentonite [1-3]. Few worth mentioning ores are uranitite (UO_2), autunite [Ca $(UO_2)_2(PO_4)_2$. 8-12H_2O], monazite, clay minerals, potash alum, Scheelite, Wolframite. Heavy metals percolate through soil strata and enter into waterbodies through geochemical reactions [4-5]. Ores of arsenic are associated with coal deposits which provide a source of arsenic entry into waterbodies. The migration of contaminated water from the site of coal mines into the waterbodies is considered one of the important reasons of the pollution of the adjoining aquifer. Clay mineral montmorillonite of Rajmahal Hills have been formed from volcanic material. The environment of the basin affects the composition of the mineral and several other ores of metal are present in the Rajmahal hills.

During rock formation, gravel beds, sedimentary alluvial fans, conglomerates are also associated. As a result, rivers also contain sand slit and clay in different proportions. The common mineral found with coal is pyrite, calcite, siderite, quartz and clay minerals such as Kaolinite are found within coal seams. Veins of chalcopyrite, Galena, uranium may also be associated with coal block. The presence of these minerals within coal seams provides an entry pathway into aqueous medium. Heavy metal pollution arising out of ion-exchange, dissolution and anthropogenic activities is causing health hazard to the surrounding population. Lead, cadmium, chromium and arsenic are few hazardous elements causing serious damage to the living systems due to lack of proper remediation strategies [6-9]. Heavy metals enter food chain through irrigation with contaminated ground water. Soil serves as a sink for heavy metal contaminants which ultimately enters the body through food chain causing cancer, neural problems and other complications in the body [10-12]. Radioactive elements also are hazardous to human beings causing kidney damage or bone and liver cancer. Uranium mines release heavy metals and arsenic along with uranium [13-15]. According to Atomic Energy Regulatory Board, radiologically based limit for uranium is 60 μg/L (ppb) of water whereas permissible limit for uranium is 30 ppb according to Beaurau of Indian Standard and WHO.

2. Materials and Methods

2.1. Pre-concentration of water samples for the determination of Chromium, Arsenic and Uranium

Measured amount of water samples was evaporated on hot plate and made the solution in 25 mL volumetric flask containing 3% nitric acid. The solution was aspirated into ICP – OES for chromium, arsenic and uranium analysis. Chromium was determined at 205.552 nm and 267.716 nm. The values at two wavelengths are in good agreement with each other. For arsenic determination, the inert atmosphere was created by using argon gas for 14 hours, then subsequently analysis was carried out the next day in inert condition. Because the sensitivity for uranium is not so high, the result is verified and validated by LED Fluorimeter where the source intensity was generated using combination of many light emitting devices, an in turn, uranium fluorescent intensity is measured at 410 nm. For this, the 10 mL aliquot was evaporated to incipient dryness, and then added 1 mL of sodium pyrophosphate buffer of pH~7, made up to 10 mL volumetric flask and sample readings were taken along with known standard and process blank. ICP – OES (model ULTIMA – 2, Make: Horiba Jobin, YVON, France is used for the analysis of trace elements. Uranium is analyzed by ICP – AES and LED Fluorimeter. Water samples have been collected in sterilized 200 mL plastic bottles near the coal mines in Godda district and the dyeing industries in Nathnagar Block from surface water as well as ground water.

3. Results and discussion

The analysis of chromium shows that the chromium concentrations at 205.552nm and 267.716nm for S13 samples are 0.073 and 0.069 ppm respectively. The highest concentration is for S16 sample having the values 0.088 and 0.092 ppm at 205.552nm and 267.716nm respectively (Figure 1). Arsenic concentrations in all the samples from S1 to S16 are below the permissible limit of 0.05 ppm. Highest concentration of 0.00764 ppm has been recorded for S12 sample (Figure 2). Considerable concentration of uranium has been confirmed in water samples near Lalmatia open cast coal mine in Godda district of Jharkhand (Figure 3). In coal mines, uranium exists in very small quantities and the fly ash of coal also contains uranium. Uranium occurs in many rocks in the form of veins as a result of which extraction of uranium is difficult. Uranium enters waterbodies through coalmines and fly ash of N.T.P.C. Ltd. Kahalgaon in Bhagalpur district of Bihar. Lalmatia coal mines and fly ash of N.T.P.C. Ltd. may be attributed to the presence of uranium in ground water and surface water also. Though the presence of uranium in water samples is well within the permissible limit, it is a significant warning towards adverse health effect in the near future for the surrounding population of tribes in particular. Local combustion increases the concentration of uranium manifold [16]. Water enters the coal swamp during formation stages and ground water interacts with coal seams giving rise to uranium content in water [17]. The concentration of uranium obtained by LED Fluorimeter and ICP – AES are in close agreement (Table 2). Water samples collected near Lalmatia coal mines and dyeing industries in Nathnagar contain chromium more than permissible limit (Table 1). The presence of chromium and arsenic in water samples near Lalmatia coal mine can be explained due to the presence of these elements with coal seam and channelization of ground water with the surface water of the Ganges River. The presence of chromium in surface water of Nathnagar block near the Ganges River may be attributed to the operation of a large number of dying cottage industries by the weavers as well as the geochemical reactions occurring from coal mines. The presence of arsenic in water samples is explained due to the presence of arsenic bearing pyrite in the sedimentary rocks [18]. The presence of iron and sulfur in oxygen depleted environment gives rise to the formation of pyrite in the coal beds. Owing to geochemical reactions, arsenic enters water bodies in trace amounts. Here, in the present study, arsenic concentration is well below the permissible limit of 0.05 ppm. Arsenic gets discharged into the atmosphere also by combustion of coal [19].

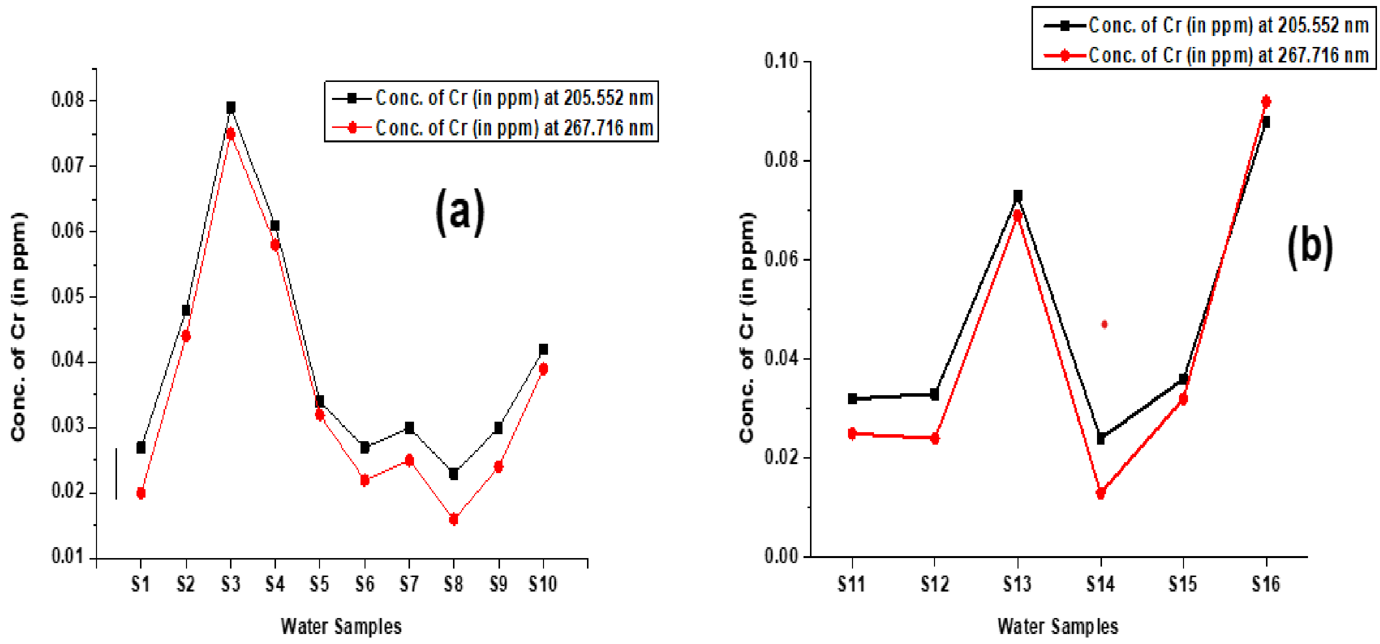


Figure 1: Concentration of Cr (in ppm) at 205.552 nm and 267.716 nm for Samples (a) Near Nathnagar Railway Station (S1 to S10) and (b) Near Lalmatia Open cast coal mines (S11 to S16).

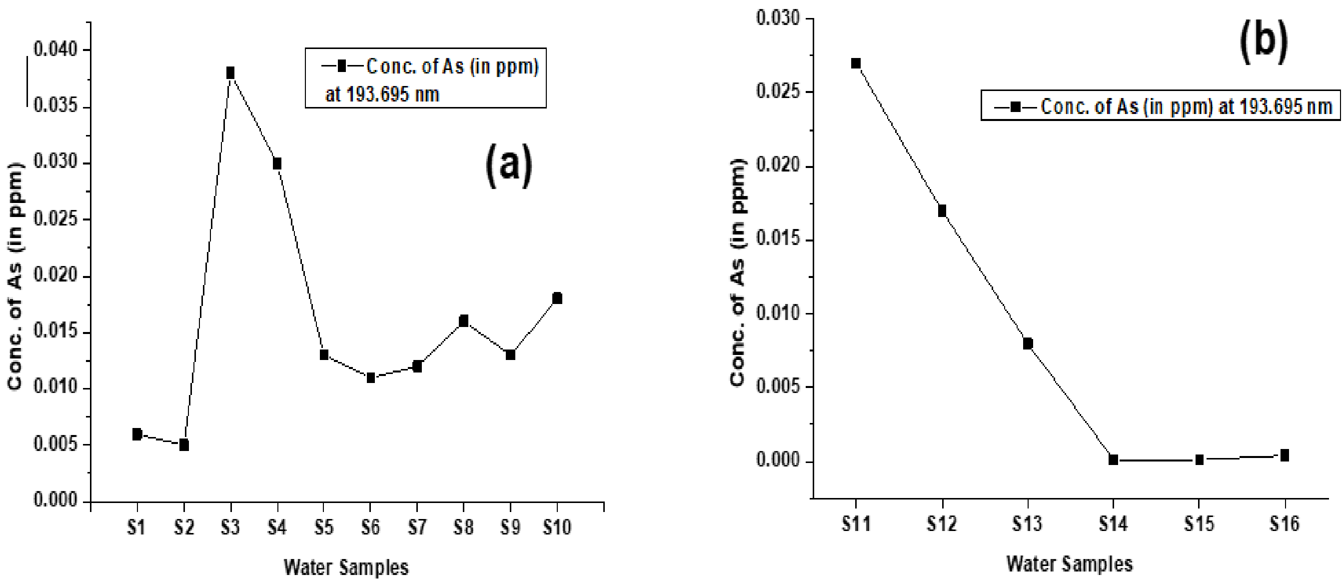


Figure 2: Concentration of As (in ppm) at 193.695 nm for Samples (a) Near Nathnagar Railway Station (S1 to S10) and (b) Near Lalmatia Open cast coal mines (S11 to S16).

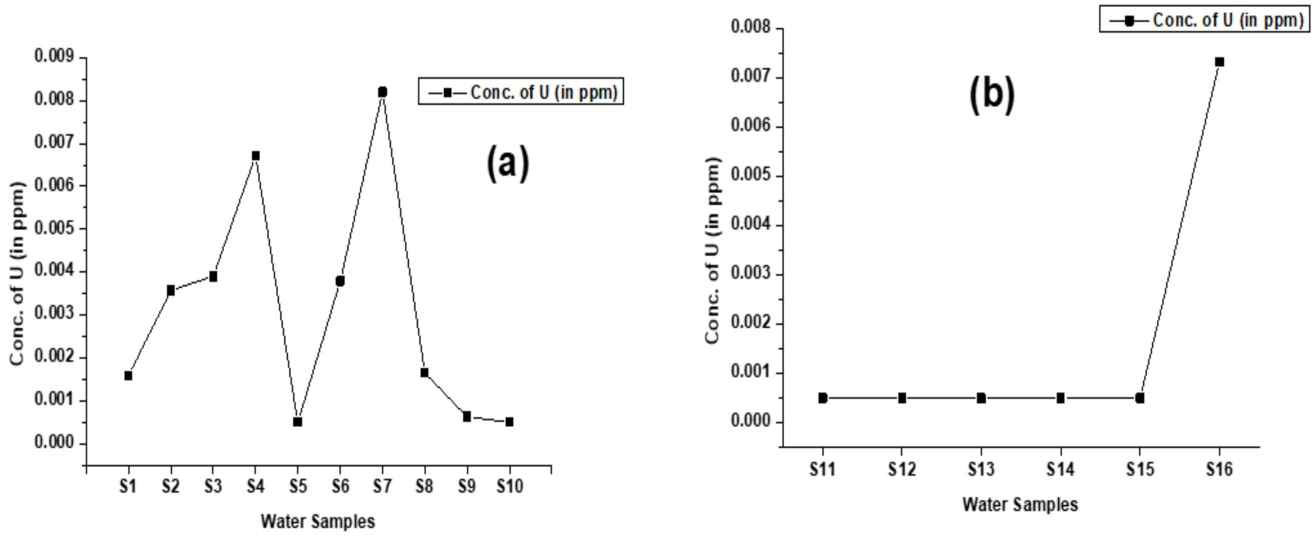


Figure 3: Concentration of U (in ppm) for Samples (a) Near Nathnagar Railway Station (S1 to S10) and (b) Near Lalmatia Open cast coal mines (S11 to S16).

Table 1: Concentration of chromium analyzed by ICP – OES.

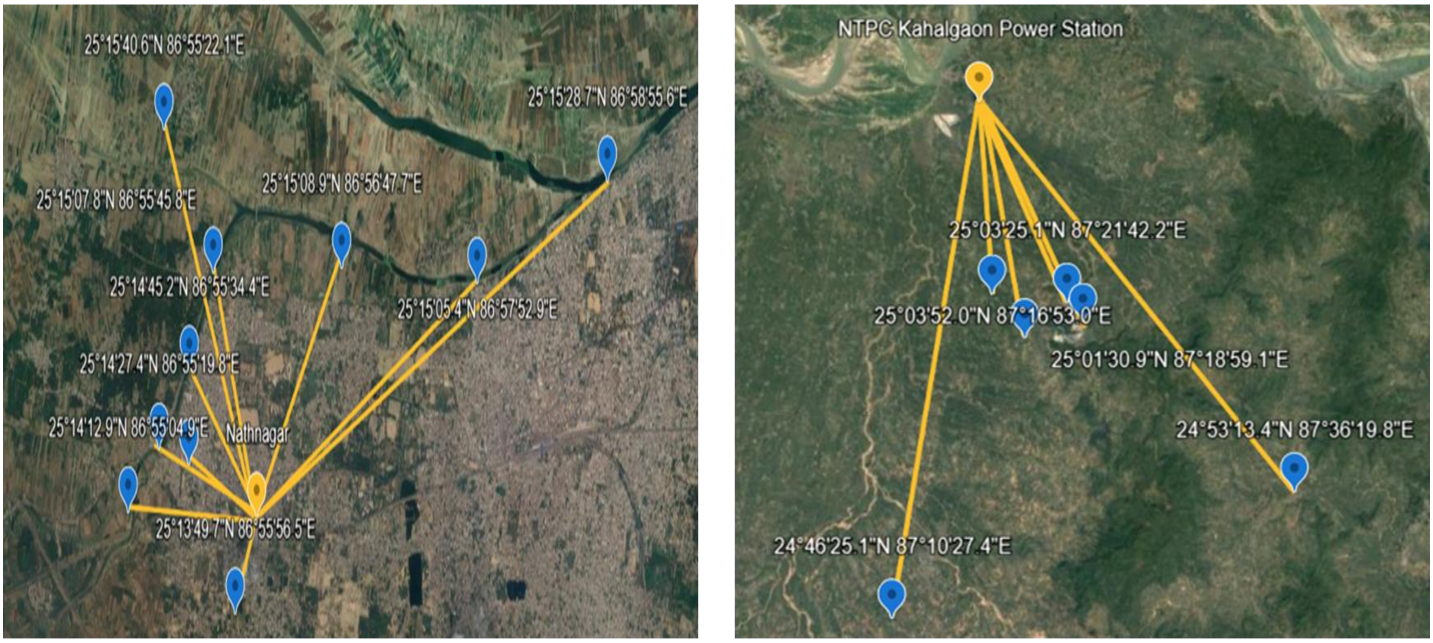
Sample No.	Latitude, Longitude	Distance from reference point and direction	Type of sample	Cr in ppm at 205.552 nm	Cr in ppm at 267.716 nm
S1	25.245881, 86.926207	1.38 KM North West	Surface	0.027	0.020
S2	25.240955, 86.922159	1.47 KM West	Surface	0.048	0.044
S3	25.230484, 86.932360	0.74 KM South	Ground	0.079	0.075
S4	25.252462, 86.946571	2.07 KM North East	Surface	0.061	0.058
S5	25.261283, 86.922813	3.02 KM North	Surface	0.034	0.032
S6	25.252167, 86.929388	1.83 KM North	Ground	0.027	0.022
S7	25.239940, 86.926144	0.99 KM West	Ground	0.030	0.025
S8	25.236907, 86.918028	1.73 KM West	Surface	0.023	0.016
S9	25.251508, 86.964682	3.35 KM North East	Ground	0.030	0.024
S10	25.257963, 86.982110	5.32 KM North East	Surface	0.042	0.039
S11	25.056982, 87.361727	22.23 KM South East	Ground	0.032	0.025
S12	25.038942, 87.378893	25.64 KM South East	Ground	0.033	0.024
S13	24.887052, 87.605486	51.85 KM South East	Ground	0.073	0.069
S14	24.773635, 87.174273	52.26 KM South West	Ground	0.024	0.013
S15	25.025254, 87.316409	23.81 KM South	Ground	0.036	0.032
S16	25.064446, 87.281390	19.12 KM South	Ground	0.088	0.092

* Reference point for S1 to S10 is Nathnagar Railway Stationand for S11 to S16 is N.T.P.C. Ltd., Kahalgaon.

Table 2: Concentration of As analyzed by ICP – OES and U by LED Fluorimeter.

Sample No.	Latitude/Longitude	Distance from reference point and direction	Type of sample	As (in ppm) at 193.695 nm	U (in ppm)
S1	25.245881, 86.926207	1.38 KM North West	Surface	0.006	0.00159
S2	25.240955, 86.922159	1.47 KM West	Surface	0.005	0.00358
S3	25.230484, 86.932360	0.74 KM South	Ground	0.038	0.00390
S4	25.252462, 86.946571	2.07 KM North East	Surface	0.030	0.00671
S5	25.261283, 86.922813	3.02 KM North	Surface	0.013	<0.0005
S6	25.252167, 86.929388	1.83 KM North	Ground	0.011	0.00379
S7	25.239940, 86.926144	0.99 KM West	Ground	0.012	0.00820
S8	25.236907, 86.918028	1.73 KM West	Surface	0.016	0.00165
S9	25.251508, 86.964682	3.35 KM North East	Ground	0.013	0.00063
S10	25.257963, 86.982110	5.32 KM North East	Surface	0.018	<0.0005
S11	25.056982, 87.361727	23.13 KM South East	Ground	0.027	<0.0005
S12	25.038942, 87.378893	25.014 KM South East	Ground	0.017	<0.0005
S13	24.887052, 87.605486	51.89 KM South East	Ground	0.008	<0.0005
S14	24.773635, 87.174273	51.96 KM South West	Ground	<0.0001	<0.0005
S15	25.025254, 87.316409	25.07 KM South	Ground	<0.0001	<0.0005
S16	25.064446, 87.281390	20.14 KM South	Ground	0.0004	0.00733

* Reference point for S1 to S10 is Nathnagar Railway Stationand for S11 to S16 is N.T.P.C. Ltd., Kahalgaon.



(a) (b)

Figure 4: Geographical Map of Sample collection fields of (a) Nathnagar area (S1 to S10) and (b) Lalmatia Open cast coal mines (S11 to S16).

4. Conclusions

The greater concentration of uranium in ground water has been recorded near the coal mines. The higher concentration of chromium in the surface water near Nathnagar block is anthropogenic. Arsenic bearing pyrite along with coal bed is one of the important reasons of arsenic concentration in water. Monitoring of radioactive element uranium, carcinogenic chromium and arsenic in the ground water as well as surface water should take place at regular intervals.

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