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SURFACE MINING AND HEAVY METAL POLLUTION OF WATERAND SOIL: A CASE STUDY IN SIMLONG COALFIELD IN SAHEBGANJ DISTRICT, JHARKHAND

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ABSTRACT

This study is an attempt to assess the extent of toxic metals, including Fe, Cu, Zn, Mn, Pb, Cd and Ni in surface water, groundwater, river sediment and crop field soil samples collected from Simlong coalfield area in Sahebganj district of Jharkhand state. The chemical results of water samples show that the mean concentrations of Fe, Cu and Mn exceed the value of ISI (1993) whereas Zn level is within the permissible limit in all water samples except one groundwater sample where it exceeded the ISI value for drinking water. Pb, Cd and Ni are absent in all water samples analyzed. Results reveal wide variation in toxic metal content in river sediment and crop field soil samples. The mean concentrations of Fe, Cu, Zn and Mn in soil samples are far above than their critical limit for crop whereas concentrations of Pb, Cd and Ni ranged from below detection limit to trace amount both in the river sediment and the crop field soil.

KEYWORDS: Coalmines, Groundwater, Heavy Metals, Sahebganj, Soil, Surface Water

INTRODUCTION

Although the coal is very important for the economy of the country and human welfare, the negative effects of today's unprecedented extraction rates threaten to outweigh the benefits. A geological insight to coal formation in basins of plant accumulation indicates that the coal seams and associated sedimentary rocks are repositories of many toxic trace metals. Opencast coal mining operations release a large amount of heavy metals into the aquatic medium from mine drainage. Mining activities pump out in forms of dust, a large amount of heavy metals into the atmosphere which reach back to the earth surface as fallouts or washout and add to the surface water as well as groundwater pollution (1, 2).

Toxic metals pollution of both surface and groundwater cause serious public health hazard (3). Damages like silicosis or carcinogenesis arising out of metal toxicity are well known. Heavy metals can exist in soluble, colloidal and particulate phases and consequently can reach every part of an aquatic ecosystem. Metals that do not remain soluble in water eventually reach the sediment where they become bounded to various components of the sediments. Thus, sediment acts as the sink for most of the trace metals. The bottom sediments serve as a reservoir for heavy metals and therefore deserve special consideration in the planning and design of aquatic pollution research studies. Toxic elements cause chemical contamination of groundwater sources through infiltration processes. Metals toxicity in water and sediment arising out of coal mining operations has been well documented (4, 5, 6, 7, 8 and 9). Coal mining operations cause both surface and ground water pollution by adding toxic metals to water bodies.

The purpose of this study was to quantify the concentrations of heavy metals, including Fe, Cu, Zn, Mn, Ni, Cd andPb, in surface and groundwater, river sediment and crop field soil in the Simlong coalfield area in Sahebganj district of Jharkhand state. This was the first attempt in order to evaluate the suitability of these water resources from potability point of view.

STUDY AREA

Sahebganj district of Jharkhand state is situated on the north-eastern part of Jharkhand, bordering the Katihar district of Bihar in north, Pakur district in the south, West Bengal in the east and Goddadistrict in the west. The Chhotanagpur plateau region of Jharkhand represents a part of Indian Peninsula shield, a stable cratonic block of the earth crust. The most predominant hard rocks in the state comprise of Archeanmetamorphites with associated intrusive and the sedimentaries belonging to Vindhyan and Gondwana super groups and their associated igneous rocks. The Rajmahal hills in the north east extremity of the Chhotanagpur plateau are made up of Jurassic volcanic flows.

The Simlong area is hilly in nature with hard strata rugged with irregular highs and lows. The surface contours within study area range between 100-140m. Simlong is a part of Chuperbita basin of Rajmahal hills on the 24º45’50” N latitude and 87º27’35” E longitude. It is an opencast project. The out crop of main coal seam is exposed all along the Ladariver for a strike length of about 4 km at Simlong and dipping towards north. The solid wastes are being disposed directly and continuously into the Lada river causing considerable contamination of the river which is the only potential source of water for multiple uses available to the local tribal populations. Drinking water is a scarce commodity in the area. Ground water sources, are mainly hand pumps and dug wells in the area. Compared to tube wells, dug wells are more in number. Thus, heavy metals in water and soil have been analyzed to assess heavy metal pollution as affected by mining operations. For this purpose 5 sites were selected from river Lada i.e. site I – upstream, no mining activities at this place, site II – extensive surface mining previously but during present study officially abandoned, site III – illegal manual mining is carried, site IV – official mining is being done and site V – is 3 km downstream from site IV. Groundwater samples were collected from Simlong colony, Simlong and Lada village, Bari Ghaghri village and Jiazore village which are situated at a distance of 0.5 km, 1.5 km, 3 km and 5 km respectively from the active mining site. Crop field soil samples were collected from Simlong office, Lilatari village, Ghaghari village, Jogia village, Japani village, Lada village and Simaldabh village which are situated at a distance of 0.5 km, 5 km, 3 km, 1.5 km, 0.5 km and 1.5 km respectively.

MATERIALS AND METHODS

Surface (Ladariver, 5 samples) and ground water (dug wells and hand pump, 6 samples) samples were collected from below the surface film during February 1992 to January 1994 in 500 ml polyethylene bottles. Hand pump was purged by vigorous pumping for 5 minute before the sample collection. The bottles were washed before water samples collection with concentrated 50% nitric acid (HNO_3) and rinsed with distilled water. Samples were filtered through Whatman No. 42 filter paper and preserved by acidifying the samples with conc. HNO_3 (1:1) to pH < 2. The preserved water samples were brought to the laboratory for digestion. 50 ml of each representative water sample was transferred into long neck digestion flask made up of borosilicate glass. 5 ml of concentrated HNO_3 was added and a few boiling chips were also dropped in the flask. The samples were boiled and evaporated slowly on a hot plate to the lowest possible volume (20 ml). After complete digestion and proper cooling (taken 6 hrs, shown by a light-coloured clear solution) the solution was filtered throughWhatman No. 42 filter paper. The filtrates were transferred to thoroughly cleaned polyethylene bottles, properly stoppered and sealed, and were sent to the chemistry laboratory of the Geological Survey of India, Shillong for the determination of trace heavy metals following the standard method (10).

Soil samples (up to a depth of 15 cm from the surface) were collected from five sites of river Lada and seven from crop fields of Simlong coal mine area. The collected samples were mixed together and kept for drying at room temperature under shade. 10 g of air dried soil was placed in an acid washed and thoroughly cleaned flask and 20 ml of DPTA (Diethylenetriaminepentaacetic acid) reagent was added to it. The flask was shaken on a reciprocating shaker for 2 hrsat 120 cycles/minute with an 8 cm stroke. The soil suspensions were filtered through Whatman No. 42 filter paper and were sent to the chemistry laboratory of the Geological Survey of India, Shillong for the determination of trace heavy metals.

All samples (water and soil) were analyzed for iron, copper, zinc, manganese, lead, cadmium and nickel. The chemistry laboratory of the Geological Survey of India, Shillongused thePyeUnicam S.P.I. series atomic absorption spectrophotometer for the determination of trace heavy metals in all samples.

RESULTS AND DISCUSSIONS

Range and mean concentration of toxic metals in Lada river water are presented in Table1, while Table2, 3 and 4 shows toxic elements concentration in groundwater, river sediment and crop field soilsamples respectively.

Heavy Metals in River Water and Ground Water Samples

Table-1 reveals that mean Fe concentration in river water increases gradually from upstream 3.41mg/l (site I) to the downstream 4.11 mg/l (site V) except site IV (2.97 mg/l) which was probably the result of conversion of soluble Fe^{2+} to insoluble Fe^{3+}. Range of Fe concentration variation in groundwater samples (1.78-21.25 mg/l) was much higher than the surface water. Among the groundwater samples, hand pump (Simlong Colony) water was several times rich i.e. 21.25 mg/l in Fe content than well water i.e. 3.78 mg/l. Fe concentration decreased in groundwater samples at 1.5 km and 3 km distance (1.78 mg/l) and again increased (2.50 mg/l) at 5 km distance from active mining site.KumariRanjana (1) also recorded high value of Fe in Damodarriver and dug wells of Jharia coalfield. Fe concentrations in water samples were higher than the permissible limit of ISI Standard (11) of 0.03 mg /l in drinking water. The primary concern about Fe in drinking water is its objectionable taste and foul odour as a result of H_2S production. Taste of iron can be readily detected at 1.8 mg/l in drinking water.

The Cu levels ranged from 0.07 (site I) to 0.06 mg/l (site V) in river water samples and 0.04 to 0.08 mg/l in groundwater samples which exceed the maximum permissible limit as per ISI (11) specifications of 0.05 mg/l for drinking water. Well water samples had higher Cu concentration (0.04-0.08 mg/l) than hand pump water sample (0.04 mg/l).This result is supported by Ghosh (12) and Dutta (13) in Damodarriver passing through Jharia coalfield and in dug wells of Raniganj coalfield respectively. Excess of copper in drinking water gives unpleasant and astringent taste.

Zn concentrations varied from 0.09 (site III, IV and V) to 0.20 mg/l (site II) in river water samples while 0.06 to 1.65 mg/l in groundwater samples. Zinc concentration in all water samples were well within the permissible limit of ISI (11) i.e. 1.5 mg/l except for hand pump water of Simlong colony (1.65 mg/l) at 0.5 km distance from the active mining site. Zinc concentration was higher in groundwater samples than surface water samples. There is no significant toxicological threat of zinc concentration in drinking water. However, ingestion of 72g Zn produces toxic symptoms like fever, diarrhea, vomiting and other gastrointestinal tract irritation in human beings. The taste threshold for zinc in drinking water is approximately 15 mg/l.

Mn levels ranged from 1.28 to 2.19 mg/l and 0.83 to 2.50 mg/l in surface water and groundwater samples respectively. Mn concentration in all samples was higher than the recommended value in drinking water of ISI (11) i.e. 0.5 mg/l. Compared to surface water and well water samples, Mn was found to be in higher concentration in hand pump water sample. Singh (14) reported manganese concentration in the range of 1.2 to 17 mg/l in the water samples of North-Eastern coalfields. Mn is a known mutagen. The accumulation of manganese may cause hepatic encephalopathy. Moreover, the chronic ingestion of Mn in drinking water is associated with neurologic damage (15).

Table 1 and 2 Reveal that Pb, Cd and Niwere Not Detected in Any of Surface and Groundwater Samples

Heavy Metals in River Sediment and Crop field Soil Samples

Iron is an essential micronutrient and the critical limit for crop is 2.5 to 4.5 mg/100g. It is moderately toxic to plant. It is 4th most abundant element in Earth's crust. The average lowest value for Fe was at upstream and downstream sites (site I, 24.55 mg/100g and site V, 23.85 mg/100g) and maximum (58.04 mg/100g) at abandoned mining site (site II). Fe is often extremely high near mines (16). Iron content in crop field soil showed higher concentration (72.9 mg/100g) at 0.5km and minimum at Simaldabh village on river bank (3.56 mg/100g).

Copper is highly toxic to most species of aquatic plants (17). The critical limit of copper for crop is 0.20 mg/100g. Copper content in river sediment was higher (5.24 mg/100g) at site III and lowest (3.72 mg/100g) at site II. The highest concentration of Cu in crop field soil (9.50 mg/100g) was recorded at 5 km and minimum (1.50 mg/100g) at 1.5 km distance from the active mining sources.The results indicate that copper content was higher in the crop field soil than river sediment. Cu concentration in all river sediment and cropfield soil sample was higher than the critical limit for crop.

Zinc is an essential element for plant growth. It is 24th most abundant element in Earth's crust. The critical level of Zn for cropfield soil is 0.5 to 1 mg/100g. Zinc content in the lowest level was recorded (1.54 mg/100g) at site II and highest (2.17 mg/100g) at active mining site IV. Zinc content in crop field soil varied between (0.30 to 2.20mg/100g) with maximum at 0.5 km and minimum at 3.0 km distance from the active mining sources.

Manganese is slightly to moderately toxic to most species of plant (18). The critical limit for manganese in crop field soil is 1mg/100g. Total environmental flux of manganese is enormous and greater than that of all metal except iron. Maximum concentration was recorded (137.65 mg/100 g) at site I and minimum (75.78 mg/100g) at site II. Manganese content in crop field soil ranged in between 3.32 to 30mg/100g with minimum at river bank soil and maximum at 1.5 km distance from the active mining sources. Oxidation-reduction cycle is important to control the fate of Mn in sediment/soil.

Lead is 36th most abundant element in the Earth's crust. Approximately 96% of all lead originates from anthropogenic sources, particularly fuels and combustion of coal (19). In present study, lead content ranged from below detection limit to 0.04 mg/100g with maximum at site II. In crop field soil, the range varied from below detection limit to trace amount. It is moderately toxic to plants.

Cadmium is the 64th most abundant element in the Earth's crust. It ranged in between below detection limit to 0.04 mg/100g in river sediment and from below detection limit to 0.02 mg/100g in crop field soil in Simlong coalfield area. Cadmium is highly toxic to plant species. The presence of Fe and Mn inhibits the cadmium toxicity.

Nickel concentration ranged from 0.10 to 0.68 mg/100g in river sediment with maximum at site I (0.68 mg/100g) and minimum at site IV (0.10 mg/100g), whereas in crop field soil, it ranged in between 0.10 to 48 mg/100g. Dey et al. (20) also reported higher content of Ni in sediment of river Damodar polluted with coal mining effluent.

Based on the results obtained here, it can be concluded that the level of all tested toxic metals in groundwater and surface water in the study area is in excess of the ISI (11) guideline value and make the water unfit for drinking purposes.

The concentration of Cd, Pb and Ni are not recorded in any of the water sample analyzed. The concentrations of all toxic metals in river sediment and crop field soil are in excess of their critical limit for crop field soil. Other toxic metals (Pb, Cd and Ni) are in below detection limit or in trace amount in river sediment and crop field soil samples. Thus the build-up of toxic metals in water and soil needs to be monitored periodically in view of their significant accumulation.

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APPENDICES

Table 1: Range and Mean Concentration (mg/l) ± S.E. of Trace Elements in Lada River Water Samples in Simlong Coal Mining Area(February, 1992-January, 1994)

Mean Concentration (Range) in mg/l							
Sites	Parameters						
	Fe	Cu	Zn	Mn	Pb	Cd	Ni
I	3.41±0.43	0.07±0.01	0.12±0.02	2.19±0.50	Nil	Nil	Nil
	(1.78-7.50)	(0.02-0.16)	(0.05-0.37)	(0.83-7.26)			
II	3.28±0.18	0.07±0.01	0.20±0.02	1.28±0.10	Nil	Nil	Nil
	(1.78-3.75)	(0.04-0.11)	(0.08-0.38)	(0.83-1.66)			
III	3.70±0.68	0.07±0.01	0.09±0.02	1.72±0.27 N	Nil	Nil	Nil
	(1.78-10.0)	(0.02-0.16)	(0.04-0.32)	(0.83-3.00)			
IV	2.97±0.67	0.06±0.01	0.09±0.02	1.96±0.14	Nil	Nil	Nil
	(1.78-11.25)	(0.04-0.10)	(0.0S3-0.30)	(1.66-3.00)			
V	4.11±0.91	0.06±0.01	0.09±0.02	1.73±0.30	Nil	Nil	Nil
	(1.78-12.46)	(0.04-0.10)	(0.02-0.22)	(0.83-4.50)			

Table 2: Trace Element Contents (mg/l) of Groundwater Samples in and Around the Simlong Coal Mining Area (1992 - 1993)

	Concentrations (mg/l)								
Sampling Location	Sampling Months	Distance from the Active Mining Site (Km)	Fe	Cu	Zn	Mn	Pb	Cd	Ni
Simlong Colony Well	January	0.5 (2)	3.78	0.06	0.33	0.83	Nil	Nil	Nil
Simlong Colony HP	April	0.5 (3)	21.25	0.04	1.65	2.50	Nil	Nil	Nil
Lada Village Well	August	1.5 (4)	3.78	0.05	0.10	1.66	Nil	Nil	Nil
Simlong Village Well	November	1.5 (3)	1.78	0.06	0.08	1.66	Nil	Nil	Nil
Bara-Ghagri Village Well	August	3.0 (6)	1.78	0.04	0.06	0.83	Nil	Nil	Nil
Jiazori Village Well	August	5.0 (10)	2.50	0.08	0.10	1.66	Nil	Nil	Nil

Table 3: Range and Mean Concentration (mg/100g) ± S.E. of Trace Elements in River Sediment Samples in Simlong Coal Mining Area (February, 1992-January, 1994)

Mean Concentration (Range) in mg/l00g							
Sites	Parameters						
	Fe	Cu	Zn	Mn	Pb	Cd	Ni
I	24.55±3.07	5.33±0.28	1.62±0.21	137.65±21.02			
	(8.1-40.5)	(3.56-6.99)	(0.83-3.38)	(16.0-314.0)	(BDL-Tr)	BDL-0.03)	(0.38-0.68)
II	58.04±29.80	3.72±0.49	1.54±0.16	75.78±8.69			
	(16.2-384.48)	(1.12-6.20)	(0.77-2.43)	(34.84-120.0)	(Tr-0.04)	(BDL-0.03)	(0.40-0.48)
III	40.33±4.96	5.24±0.46	1.98±0.23	94.81±20.76			
	(21.36-67.64)	(2.40-7.52)	(1.13-3.90)	(18.0-234.06)	(Tr-0.03)	(BDL-0.02)	(0.40-0.45)
IV	44.97±13.64	3.80±0.70	2.17±0.22	81.36±17.70			
	(7.12-178.0)	(1.78-8.58)	(1.01-4.24)	(12.0-196.0)	(BDL-0.03)	(0.03-0.04)	(0.10-0.38)
V	23.85±4.27	4.24±0.46	1.53±0.17	107.29±19.09			
	(10.24-64.08)	(2.04-7.04)	(0.78-2.64)	(10.0-220.0)	(BDL-Tr)	(BDL-0.03)	(0.22-0.35)

Table 4: Trace Element Contents (mg/100g) in Crop Field Soil Samples at Simlong Coal Mining Area (February, 1992-January, 1994)

Sites	1	2	3	4	5	6	7
Parameters	Simlong Office	Lilatari Village	Ghaghari Village	Jogia Village	Japani Village	Lada Village	Simaldabh Village
Fe	72.9	18.9	10.9	48.6	13.5	13.5	3.56
Cu	8.25	9.5	2.97	8.25	7.85	1.05	2.48
Zn	2.2	0.66	0.30	1.07	0.57	0.63	1.34
Mn	15.0	16.0	12.0	30.0	12.0	16.0	3.32
Pb					BDL		
Cd					0.02		
Ni					0.48		