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Assessment of Groundwater Quality in Granite Mining Areas of Bijauli in Bundelkhand Region of India

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Abstract: ***An assessment of water quality and heavy metal contents in groundwater samples collected from the granite mining areas of Bijauli was carried out, covering, pre-monsoon, monsoon and post-monsoon periods. The physico-chemical variables studied were pH, electrical conductivity, dissolve oxygen, turbidity, calcium hardness, magnesium hardness, alkalinity, nitrate, fluoride, total dissolve solids and chloride contents. The results of the study revealed that parameters such as pH (6.8–8.1), turbidity (1.4 – 2.4 NTU), fluoride (0.31 – 0.99 mg L^{-1}), dissolve oxygen (5.2 – 7.7 mg L^{-1}), and chlorides (36 – 376 mg L^{-1}) contents were within the acceptable limits for drinking water. The electrical conductivity (450–2750 µS cm^{-1}), total dissolve solids (462–1860 mg L^{-1}), calcium hardness (90 – 237 mg L^{-1}), magnesium hardness (40.3 – 134.3 mg L^{-1}), alkalinity (148 – 434 mg L^{-1}), nitrate (15.2 – 89.0 mg L^{-1}) contents were found to have exceeded the prescribed acceptable limits. The results obtained in heavy metal analyses, indicated that the levels of Fe and Zn were within the acceptable limits, whereas Al was below the detectable level. High concentrations of Cd (0.045 – 0.064 mg L^{-1}), Pb (0.045 – 0.630 mg L^{-1}) and Mn (0.250 – 0.613 mg L^{-1}), exceeding the acceptable levels were recorded in the groundwater samples.***

Keywords: Bijauli, granite, groundwater, heavy metals, Jhansi, opencast mining

1. Introduction

Mining is a major anthropogenic activity causing water pollution and environmental degradation [1]-[4]. Groundwater, which is the most important sources of water in semi-arid region of Bundelkhand is currently overexploitation and threatened by mining activities. Groundwater in hard-rock aquifers, particularly in mining areas, is known to be vulnerable to quality problems that may have serious impact on human health. In general, mining has impacts on all elements of the environment, its point and diffuse source pollution presents catchment-scale and transponder impacts. Mine disposals including dumps and tailings piles are a ubiquitous feature of both surface and underground mining. Open cast mining operations and the resultant huge overburden dumps leads to numerous devastating environmental effects, of them water pollution is considered an important one. Water pollution in mining areas can occur in two basic ways – physically and chemically. Physical impact mainly results from silting in the surface water bodies. Deterioration in drinking water quality is a serious human health issue. Mining activities are known to release both major and trace elements into the environment. Trace elements or the heavy metals are classified among the most dangerous groups of pollutants due to their toxicity and persistence in the environment [5], [6]. Metals in the contaminated soils and water may reach human body through agricultural products [7]-[9]. Leaching of heavy metals from the mine spoils is possible during the rainy season thereby contaminating the groundwater. Taking all the above environmental impacts into consideration the current study attempts to assess the groundwater quality in Bijuali mining area in Bundelkhand region of India.

2. Methodology

2.1 Study area

Bundelkhand region occupies almost 70,000 km^2 of the central plains in India. The Bundelkhand massif consists of granite rock which occupies an area of 26,000 km^2 in southern Uttar Pradesh and north-eastern Madhya Pradesh in central India and forms the northern fringes of the peninsula Indian shield. Jhansi is one of the most important districts out of the five districts of Bundelkhand region. The district of Jhansi lies in southwest portion of Jhansi division of Uttar Pradesh state of India between 25° 30′ and 25º 57′ N latitudes and 78º 40′ and 79 º 25′ E longitudes. The present area of the district according to survey of India is 5,024 km^2. Jhansi is one of the important granite mining centres in the region. In Jhansi granite is obtained mainly through the open cast mining. Open cast mining by manual methods is primarily adopted in Bundelkhand because of the following reasons, (i) it requires less mining investments, (ii) mechanization is likely to prove inefficient, (iii) availability of cheap labour, *etc*.

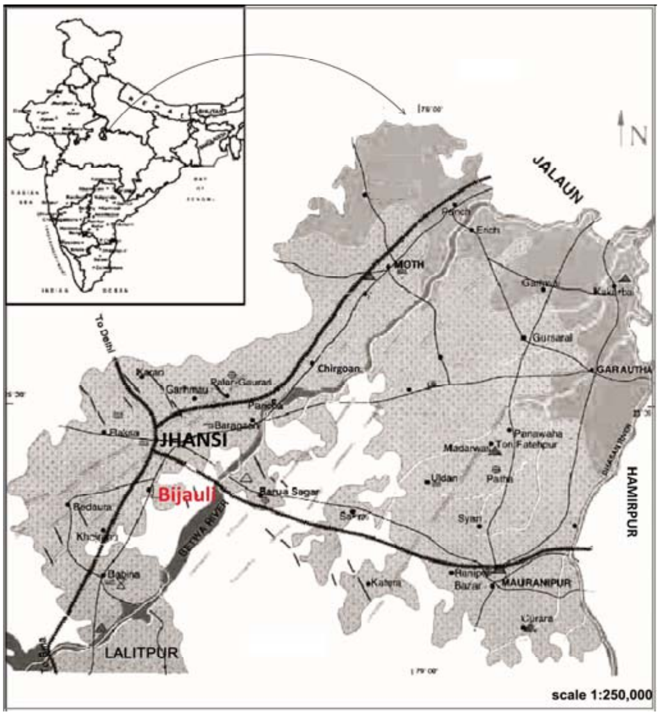

Figure 1: Map showing the study area

2.2 Sample collection and analysis

Water samples were collected from the hand pumps installed in the mining sites and nearby residential areas in Bijauli, Jhansi district, U.P., in Bundelkhand region of India (Fig. 1). The water samplings were carried out in three different seasons covering, pre-monsoon, monsoon and post-monsoon periods. The water samples (500 mL) were collected in plastic bottle. The plastic bottles were thoroughly cleaned and rinsed 3-4 times with the water to be collected and tightly capped immediately after the collection. Water analysis have been done as per A.P.H.A. [10], standards for the following parameters: pH, Electrical conductivity (EC), Dissolve oxygen (DO), Turbidity, Calcium hardness, Magnesium hardness, Alkalinity, Nitrate, Fluoride, Total dissolve solids (TDS) and chlorine contents following standard methods [10]. The EC and pH were determined in the field. All the samples were transportation to the Departmental laboratory and analyzed on the same day within 5 hr of their collection.

The samples were analyzed for heavy metal contents using Atomic absorption spectrophotometer (AAS), Perkin Elmer science, Elan 5000 for Cd, Cu, and Pb. The Ion chromatography (IC), Dionex 2000i was used for the determination of Fe, Mn and Zn.

3. Results Analysis

3.1 Physico-chemical Analyses

The results of the physico-chemical analysis of the groundwater in the mining and residential areas of Bijauli are presented in table 1-3. The results showed that the pH of the water samples in the three seasons; pre-monsoon (ranging between 7.2 and 7.8), monsoon (ranging between 6.8 and 7.5) and post-monsoon (ranging between 7.2 and 8.1) were well within the desirable limits set by Indian Standard specifications for drinking water IS: 10500 (6.5 to 8.5). The electrical conductivity (EC) of the water recorded in the three corresponding seasons ranged between 730 and 2750 μS cm^{-1} (Pre-monsoon) 450 and 1500 μS cm^{-1} (Monsoon) and 558 and 1850 μS cm^{-1} (Post monsoon). The acceptable limits and the maximum limits of EC prescribed by the IS: 10500 are 400 and 1000 μS cm^{-1}, respectively. It was found that in all the sampling sites the EC of the water exceeded the acceptable limits, thereby rendering it unfit for human consumption. In three sampling sites, the EC was found consistently higher exceeding the maximum limits (1000 μS cm^{-1}). This indicates the presence of excessive salts in the groundwater of the region.

Table 1: Groundwater quality in Bijauli during Pre-Monsoon (March-May)
(All values are in mg L^{-1} except for pH, EC and Turbidity)

Sampling Sites	pH	EC (µS cm^{-1})	TDS	Turbidity (NTU)	Ca hardness	Mg hardness	Total Alkalinity	Nitrate	Fluoride	Dissolved Oxygen	Chlorides
Mining Area (MA)											
MA - 1	7.6	2750	1790	2.0	237	40.3	366	25.0	0.72	6.2	350
MA - 2	7.2	730	475	1.2	94	72.3	230	78.9	0.27	6.0	36
MA - 3	7.3	790	490	1.4	101	65.7	339	70.0	0.31	6.4	39
MA - 4	7.8	1100	484	1.9	99	89.3	267	17.1	0.39	6.3	38
Residential Area (RA)											
RA - 1	7.3	1123	560	2.4	110	80.2	270	15.2	0.57	6.0	37
RA - 2	7.5	889	489	2.1	113	89.9	332	56.3	0.65	5.9	49
RA - 3	7.7	890	476	1.7	90	90.2	278	60.9	0.31	6.1	47
RA - 4	7.8	987	503	1.9	98	56.7	245	62.0	0.43	6.4	42
WHO Standards	*7.0-8.5*	–	*500*	–	*75*	*50*	–	–	*1.0*	–	*200*
Desirable Limits	*6.5-8.5*	*400*	*500*	*10*	*75*	*30*	*200*	*45*	*0.6-1.2*	–	*250*
Maximum Limits	*9.2*	*1000*	*2000*	*25*	*200*	*100*	*600*	*100*	*1.5*	–	*1000*

In the groundwater, the total dissolve solids as well as EC signifies the levels of inorganic pollution load. The inorganic salts (magnesium, calcium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter comprise TDS. The TDS of the water samples recorded in the present study ranged between 475 and 1790 mg L^{-1} (Pre-monsoon) 462 and 1589 mg L^{-1} (Monsoon) and 498 and 1860 mg L^{-1} (Post monsoon), respectively (Table 1, 2, & 3). It was found that the TDS have exceeded the desirable limits, varyingly in the different seasons (03 sites each during pre-monsoon and monsoon & 06 sites during post monsoon). Concentrations of TDS in water are known to vary temporally and spatially with geographical locations. Water with a TDS of 25-50 mg L^{-1} was described tasteless [11]. The team also recommended that the optimum TDS should be about 200-400 mg L^{-1} for chloride-sulphate waters and 250-500 mg L^{-1} for bicarbonate waters [11]. However, there is no reliable data available on the health effects of the TDS in drinking water.

Table 2: Groundwater quality in Bijauli during Monsoon (June-September)
(All values are in mg L^{-1} except for pH, EC and Turbidity)

Sampling Sites	pH	EC (µS cm^{-1})	TDS	Turbidity (NTU)	Ca hardness	Mg hardness	Total Alkalinity	Nitrate	Fluoride	Dissolved Oxygen	Chlorides
Mining Area (MA)											
MA - 1	7.5	1300	1589	1.7	207	67.2	252	89.0	0.50	5.4	278
MA - 2	7.3	450	456	1.8	178	56.7	171	56.0	0.78	5.2	45
MA - 3	7.0	1132	208	2.1	211	134.3	189	59.7	0.98	6.1	42
MA - 4	7.1	980	462	2.0	151	89.3	221	56.7	0.99	5.7	52
Residential Area (RA)											
RA - 1	6.9	1132	487	2.1	165	92.5	234	66.3	0.78	6.0	44
RA - 2	7.0	739	588	1.7	161	90.4	148	77.2	0.82	6.1	50
RA - 3	6.8	876	582	1.7	110	94.8	198	54.2	0.53	5.9	43
RA - 4	7.1	650	478	1.8	208	97.5	201	68.3	0.41	6.1	49
WHO Standards	*7.0-8.5*	–	*500*	–	*75*	*50*	–	–	*1.0*	–	*200*
Desirable Limits (IS:10500)	*6.5-8.5*	*400*	*500*	*10*	*75*	*30*	*200*	*45*	*0.6-1.2*	–	*250*
Maximum Limits (IS:10500)	*9.2*	*1000*	*2000*	*25*	*200*	*100*	*600*	*100*	*1.5*	–	*1000*

Turbidity of water is caused by suspended matter like clay, silt, organic matter, algae, rust, bacteria and calcium carbonate, *etc.*, or impurities that interfere with the clarity of the water. The drinking water standards prescribed by ISI for turbidity specify 10 NTU as the permissible limit and can be used up to 25 NTU in the absence of other alternative sources. Turbidity of water recorded in the current study ranged between 1.4 and 2.4 NTU (Pre-monsoon) 1.7 and 2.1 NTU (Monsoon) and 1.5 and 2.1 NTU (Post monsoon). It is pertinent to mention that in all the sampling sites throughout the study, turbidity of the water samples falls within the prescribed permissible limits.

In groundwater, hardness is primarily attributed to the presence of carbonates, bicarbonates, sulphates and chlorides of calcium and magnesium. The calcium hardness recorded in the present study ranged between 90 and 237 mg L^{-1} (Pre-monsoon) 110 and 208 mg L^{-1} (Monsoon) and 168 and 210 mg L^{-1} (Post monsoon). Except for four sampling sites (during the pre-monsoonal sampling), calcium hardness was found to have exceeded the acceptable limits (75 mg L^{-1}) in all the sampling sites. In few sampling sites, the water samples were above the maximum limits (200 mg L^{-1}) for the said parameter (Pre-monsoon – 01 site; Monsoon – 03 sites & Post-monsoon – 02 sites). Corresponding magnesium hardness during the same study period ranged between 40.3 and 90.2 mg L^{-1} (Pre-monsoon) 56.7 and 134.3 mg L^{-1} (Monsoon) and 45.0 and 82.8 mg L^{-1} (Post-monsoon). The values recorded in all the various sites exceeded the acceptable limits of 30 mg L^{-1}. In one of the sampling sites (*MA-3,* Monsoon period) the value of magnesium hardness (134.3 mg L^{-1}) was found exceeding the maximum limits.

Table 3: Groundwater quality in Bijauli during Post-monsoon (November-February)
(All values are in mg L^{-1} except for pH, EC and Turbidity)

Sampling Sites	pH	EC (µS cm^{-1})	TDS	Turbidity (NTU)	Ca hardness	Mg hardness	Total Alkalinity	Nitrate	Fluoride	Dissolved Oxygen	Chlorides
Mining Area (MA)											
MA - 1	7.5	1850	1860	1.7	204	76	434	55.1	0.76	7.7	376
MA - 2	7.3	558	565	1.5	189	82.8	339	54.8	0.34	7.2	48
MA - 3	7.6	1100	572	2.1	210	57.2	370	60.3	0.43	7.5	54
MA - 4	7.5	990	498	1.6	177	78.3	289	50.3	0.56	7.1	57
Residential Area (RA)											
RA - 1	7.2	1232	532	2.1	168	73.8	265	57.2	0.49	6.9	52
RA - 2	7.8	899	510	1.9	199	45.0	343	45.2	0.32	6.3	50
RA - 3	7.6	987	499	1.7	178	56.5	421	58.2	0.39	7.8	62
RA - 4	8.1	900	543	2.0	168	65.8	361	53.2	0.47	6.6	60
WHO Standards	*7.0-8.5*	–	*500*	–	*75*	*50*	–	–	*1.0*	–	*200*
Desirable Limits (IS:10500)	*6.5-8.5*	*400*	*500*	*10*	*75*	*30*	*200*	*45*	*0.6-1.2*	–	*250*
Maximum Limits (IS:10500)	*9.2*	*1000*	*2000*	*25*	*200*	*100*	*600*	*100*	*1.5*	–	*1000*

The alkalinity of the water samples recorded in the different sampling sites during the study seasons ranged between 230 and 366 mg L^{-1} (Pre-monsoon) 148 and 252 mg L^{-1} (Monsoon) and 265 and 434 mg L^{-1} (Post monsoon). Except for four sampling sites (during the monsoon season), all the other sites recorded higher alkalinity, exceeding the acceptable limits. The nitrate concentrations normally remain low in groundwater but can increase considerably as a result of leaching from the agricultural land. The primary health concern regarding nitrate is the incidences of methemoglobinemia in the young babies, causing cyanosis and asphyxia. The nitrate contents in the water samples in the current study ranged between 15.2 and 78.9 mg L^{-1} (Pre-monsoon) 54.2 and 89.0 mg L^{-1} (Monsoon) and 45.2 and 60.3 mg L^{-1} (Post monsoon). Almost in all the sampling sites the nitrate content exceeded the acceptable level for human consumption. Khoiyangbam et al., [12] reported that the average nitrate content in two surface water bodies in the area were 1.62 mg L^{-1} (Lake Lakshmi) and 2.21 mg L^{-1} (Lake Anitya). Fluoride is present in the Earth's crust and forms a part of number of minerals in the fluoride bearing rocks. The exposure of the human population depends upon the geographical location of the inhabitants. Epidemiological evidence shows that fluoride primarily affects the skeletal tissue. Fluoride contents in the water in the present study ranged between 0.31 and 0.72 mg L^{-1} (Pre-monsoon) 0.41 and 0.99 mg L^{-1} (Monsoon) and 0.32 and 0.76 mg L^{-1} (Post monsoon). It is noteworthy to mention that the fluoride contents in the water were within the prescribed acceptable limits of (0.6 – 1.2 mg L^{-1}).

Dissolve oxygen (DO) is the amount of oxygen dissolved in water at a given space and time. The aquatic life is not suitable at DO in water less than 4ppm. The solubility of atmospheric oxygen in water depends on the atmospheric temperature and pressure. The DO recorded in the waters of the sampling sites ranged between 5.9 and 6.4 mg L^{-1} (Pre-monsoon) 5.2 and 6.1 mg L^{-1} (Monsoon) and 6.3 and 7.7 mg L^{-1} (Post monsoon) and were within the acceptable limits. Chloride is one of the most abundant anions found in wastewater and is a good marker ion for pollution sources. The detectable limit is 250 ppm. High level of chloride in a water system increases the rate of corrosion of metallic pipe. Chloride in drinking water may come from natural sources and saline intrusion. The chloride contents in the waters of the sampling sites ranged between 36 and 350 mg L^{-1} (Pre-monsoon) 42 and 278 mg L^{-1} (Monsoon) and 48 and 376 mg L^{-1} (Post monsoon). Except for a sampling site in the mining area (MA–1) the chloride contents in the water of all the other sites were within the acceptable limits for human consumption. The chloride contents in the water of MA–1 (Pre-monsoon–350 mg L^{-1}; Monsoon–278 mg L^{-1}; & Post-monsoon–376 mg L^{-1}) were recorded consistently higher throughout the study period.

Table 4: Concentration of Heavy metals (mg L^{-1}) in Groundwater in mining areas of Bijauli

Sampling	Cd	Pb	Mn	Fe	Zn	Al
Mining Area (MA)						
MA - 1	0.041	0.338	0.250	0.133	0.002	ND
MA - 2	0.064	0.045	0.399	0.133	0.009	ND
MA - 3	0.048	0.192	0.613	0.123	0.253	ND
MA - 4	0.056	0.239	0.435	0.131	0.002	ND
Residential Area (RA)						
RA - 1	0.056	0.200	0.328	0.134	0.002	ND
RA - 2	0.041	0.122	0.365	0.143	0.313	ND
RA - 3	0.048	0.161	0.529	0.126	0.046	ND
RA - 4	0.003	0.630	0.342	0.1290	0.489	ND
Desirable	*0.01*	*0.1*	*0.1*	*0.3*	*5.0*	*0.03*
Maximum	*0.01*	–	*0.5*	*1.0*	*15*	*0.20*
ND – Not detected						

3.2 Heavy metal Analysis

Among pollutants, heavy metals have been the subject of particular attention because of their long term toxicity to the biota when exceeding thresholds. The mean concentrations of the metals measured in groundwater samples collected from the mining site and the residential area of Bijauli are presented in Table 4. The values of Cd were between 0.003

and 0.064 mg L^{-1}. At higher concentrations Cd accumulates in the kidneys and has a long biological half-life of 10–35 years, in human. The values of Pb and Mn in the water samples were between 0.145 and 0.630 mg L^{-1} & 0.250 and 0.613 mg L^{-1}, respectively. These values are higher than those prescribed acceptable limits for drinking water set by the IS: 10500 (Pb–0.1 mg L^{-1}; Mn–0.1 mg L^{-1}). The values of iron were between 0.123 and 0.143 mg L^{-1} and were well within the acceptable limits. The lowest and highest concentration for iron was recorded at sampling sites MA–3 and RA–2, respectively. Iron in natural water may be present in dissolved, colloidal and suspended forms [13]. The levels of Zn in the water samples varied between 0.002 and 0.489 mg L^{-1}. Zinc concentrations were found below the desirable limits set by IS: 10500 (5.0 mg L^{-1}) at all sampling sites. The metals iron and zinc are characterized as undesirable; lead is characterized as a toxic substance. The presence of the aluminium in the water samples could not be ascertained as it is below the detectable level. Aluminium is the most abundant metallic element and constitutes about 8 % of the Earth's crust. High concentrations of Al have been linked to the development of Alzheimer Disease.

4. Conclusions

The composition of ground water varies widely with local geological conditions. Neither groundwater nor surface water has ever been chemically pure, since water contains small amounts of gases, minerals and organic matter of natural origin. Mining is widely regarded as having adverse effects on environment of both magnitude and diversity. Some of these effects include erosion, formation of sinkhole, biodiversity loss and contamination of groundwater by chemical from the mining process in general and open pit mining in particular. Physico-chemical investigation of the water samples in the mining areas of Bijauli showed that the parameters such as pH, turbidity, fluoride, DO and chloride contents were within the acceptable limits for human consumption. The EC, TDS, hardness, alkalinity and nitrate contents were found to have exceeded the prescribed acceptable limits. Analyses of the water samples for the presence of heavy metals indicated that the groundwater sources in the areas were polluted with lead and manganese. It is thus, evident from the foregoing experimental results that the groundwater quality in the study areas of Bijauli is a matter of great concern as a source of drinking water. Long term use of the water may pose serious health problems for the local residents.

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