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# Impact of mining due to heavy metal pollution on groundwater resources in Jhansi, Bundelkhand Region of Utter Pradesh, India.

# Impacto de la minería debido a la contaminación por metales pesados en los recursos de aguas subterráneas en Jhansi, región de Bundelkhand en Utter Pradesh, India.

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## ABSTRACT

This study evaluated potential groundwater with toxic metals in and around an abundant granite mines in Jhansi. The pH values for ground waters were neutral, with a slight increase of the values in the mining areas. Higher values of electrical conductivity were observed in the mine area. In these areas, groundwater contamination by Cd, Fe, and Pb were observed. Most of the toxic metals were decreased with distance from mines; some have decreased gradually near the adjoining residential areas which may due to mixing with metal-free waters parameters like EC, TDS, Turbidity, DO, TH were found more in mining site comparison to non-mining site.

Key Words: Mining; Heavy metals; Groundwater and Bundelkhand region.

## RESUMEN

This study evaluated potential groundwater with toxic metals in and around an abundant granite mines in Jhansi. The pH values for ground waters were neutral, with a slight increase of the values in the mining areas. Higher values of electrical conductivity were observed in the mine area. In these areas, groundwater contamination by Cd, Fe, and Pb were observed. Most of the toxic metals were decreased with distance from mines; some have decreased gradually near the adjoining residential areas which may due to mixing with metal-free waters parameters like EC, TDS, Turbidity, DO, TH were found more in mining site comparison to non-mining site.

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## INTRODUCTION

Mining affects water resources, both surface and groundwater, at various stages of life cycle of the mine and even after its closure. The mining process itself, mineral processing sing operations, mine dewatering, seepage of contaminated leachetes, flooding of mine workings, and discharge of untreated water are some important processes with related mine water problems (Younger et al., 2002).

An elevated level of heavy metals can be found in and around disused metalliferous mines due to discharge and dispersion of mine wastes into nearby agricultural soils, food crops and stream systems (Jung, 2001). Heavy metals contained in the residues from mining and metallurgical operations are often dispersed by wind and/or water after their disposal (Adriano, 2001). As a result these areas have severe erosion problems caused by wind and water runoff (Querol et al., 2000; Chopin et al., 2003; Razo et al., 2004) in which soil and mine spoil texture, landscape topography and regional and microclimate play an important role.

The extent and degree of soil and water quality deterioration around mines vary depending upon geochemical characteristics and degree of mineralization of the tailings (Johnson et al., 2000). The metals released by sulfide oxidation are attenuated by precipitation and sorption reactions (Berger et al., 2000) in and around the mining area. Such dispersion of metals and their inputs into receiving systems such as soils, sediments and waters have been the subject of numerous studies (Lee et al., 2001; Kim et al., 2002).

Studies related to contamination problems derived from mining activities have been undertaken, focusing variously on soils, plants, surface or stream waters, or stream sediments (Marques et al., 2001; Younger et al., 2002; Gandy and Younger 2003; Miller et al., 2004). Mining and exploitation of mineral resources generally have a considerable impact on the land, water, air, and biological resources as well as socio-economic setting of the local population. Its foci are the environmental issues being confronted by the surface mining industries of Jhansi (Singh et al., 2010). Mining activities in Jhansi is predominantly comprised of granite mining (Singh et al., 2008). Currently, there are around 327 active granite mining sites in Jhansi alone. The objectives of this study are thus to examine the chemical constituents of groundwater and the extent and degree of toxic metal contamination, to evaluate the differences in chemical compositions of the groundwater samples of mining influenced areas and non-mining areas using statistical analysis and also to provide the basic information needed to identify a suitable remediation approach for the contamination.

## MATERIALS AND METHODS

Regional Hydrology: The study area including active granite mine is located in and around the Jhansi, central part of India. The mines were continuously operated since 1958 to till date. The Bundelkhand massif mainly consists of different granites which occupies in area of 26,000 km$^2$ in southern Uttar Pradesh and north-eastern Madhya Pradesh in central India and forms the northern fringe of the peninsula, Indian shield (Fig-1). Jhansi district lies in southwest portion of Jhansi division of Uttar Pradesh state of India between 25$^0$30´ and 25$^0$57 N´ latitude and 78$^0$40´ and 79$^0$25´E longitude. The present area of the district according to Survey of India is 5,024 km$^2$. Mining is an essential activity that provides the raw materials for society. In Jhansi, granite mining is done mainly through the open cast mining method because of the following underlying main reasons, (i) it requires less mining investment, (ii) mechanization is likely to prove inefficient, (iii) availability of cheap labour, *etc*. The mean annual precipitation was recorded as 1080 mm and annual temperature was uniformly high (over $25^0$ C). The average temperature for last ten years was 30-$47^0$ C, 20-$25^0$ C& 16-$21^0$ C for summer monsoon and winter season respectively.

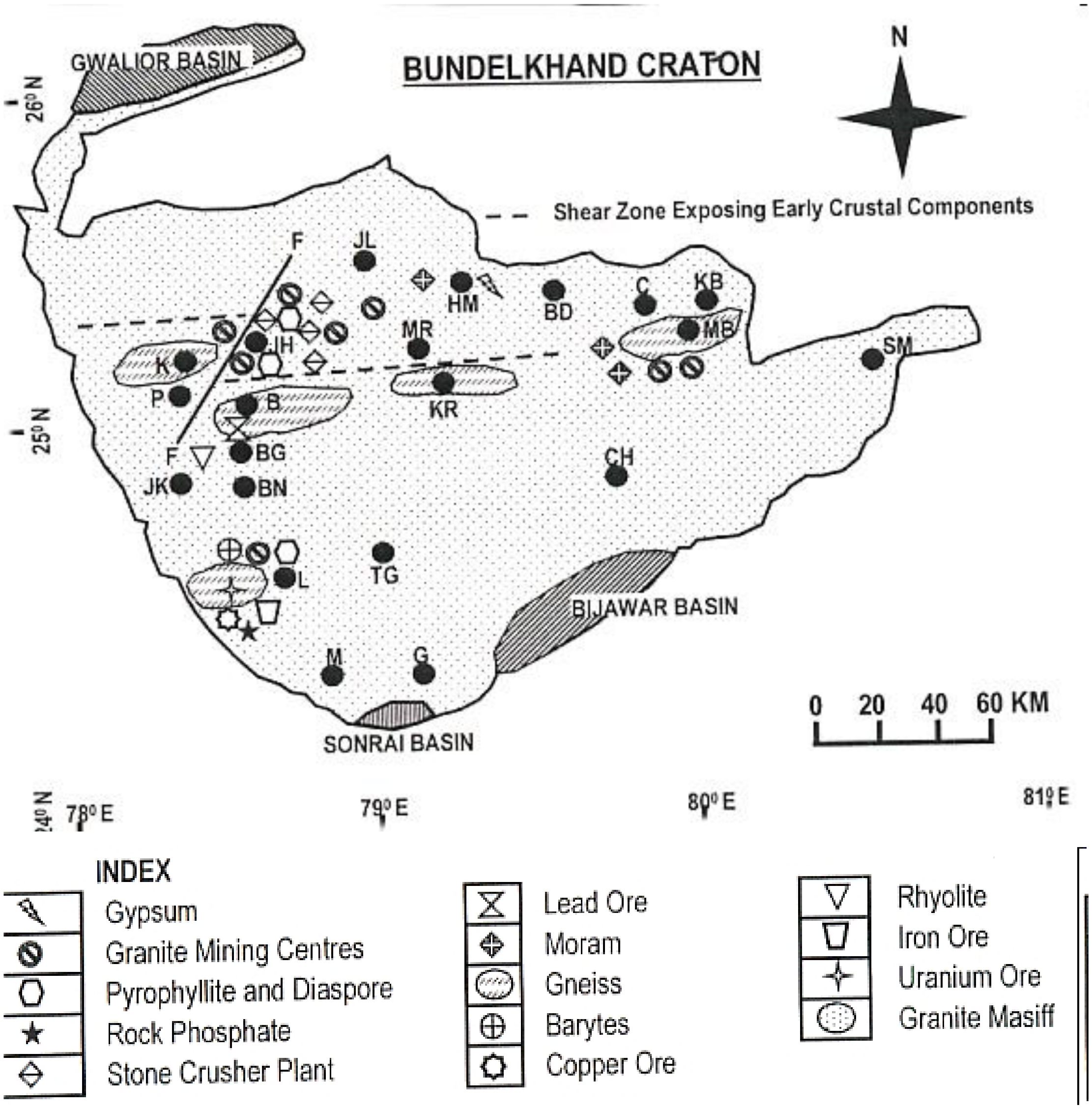

Fig 1: Map showing the mineral and granite deposits in Bundelkhand

Collection of samples: The water samples were collected from wells and hand pumps (January 2010 to June 2010) in and around the Gora Machhia mining area and non-mining area. Gora Machhia mining area is actually an opencast granite mining site whereas non-mining sites includes adjoining residential site. All the chemicals used were of GR/AR grade. Samples were collected according to standard method (APHA, 2005). pH, turbidity, total dissolved solids (TDS), electrical conductivity (EC), alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD), were taken at field site by available analyzing kit. The groundwater samples for analysis of metals were immediately acidified with 1% Merk quality nitric acid. For analysis of anions, another bottle was filled in each solution in the same manner but not acidified.

## RESULT AND DISCUSSION

The average physico-chemical data of bore wells and hand pumps water samples of mining area and non-mining area were presented in Table-1. pH is considered as an important ecological factor and provides an important piece factor and piece of information in many type of geochemical equilibrium or solubility calculations. pH is the measure of acidity or alkalinity. The pH values of mining area and non-mining area 7.96±0.18 and 7.26±0.16 respectively are within the permissible limits given by WHO (6.5-8.5). This may be attributed to different type of buffers normally present in ground water. The variations in pH are relatively small and observed slightly alkaline in ground water of mining areas. The mild alkalinity indicates that the presence of weak basic salts in the soil (Azeez et al., 2000).

Electrical conductivity talks about the conducting capacity of water which in turn is determined by the presence of dissolved ions and solids. The average value of EC in mining area is 811±113.31 µmhos cm$^{-1}$ whereas the non-mining site EC is 530.80±98.46 µmhos cm$^{1}$. As EC exceeds the permissible limit of WHO 300 µmhos cm$^{-1}$, the germination of almost all crops would be affected and it may result in much reduced yield (Srivas et al., 2000). The high conductance in the mining area may be due to the emissions containing metallic ions. The EC values apparently decreased with the distance from mine, which indicated the removal of ions in the flow directions

High levels of TDS value may aesthetically be unsatisfactory for bathing and washing. The total dissolved solids (TDS) values expressed in table-1 are above the permissible limits for mining site and below the permissible limits for non mining site (500 ppm). The high TDS in mining area is due to livestock waste, landfills, hazardous waste and due to dissolve minerals like iron and manganese and give corrosion effects to pipes and fittings. The values obtained for both sites are as 742.10 ± 156.96 and 484.40 ± 117.69 for mining and non mining sites respectively.

The average of turbidity has been found in between 4.05 ± 0.82 NTU in mining area of Gora Machhia and 3.12 ± 0.64 NTU in non-mining area. Turbidity for all samples was reported below the permissible limit given by WHO.

In natural water, DO values are varying according to physicochemical and biological activities. An ideal DO value of 5.0 mg/l is the standard for drinking water. In mining area, the average of dissolved oxygen has been observed between 4.05 ± 0.61 mg/l where as in non-mining site, it has been found between 3.58±0.65 mg/l. The DO values of mining site are more than the non-mining site but below the permissible limits of WHO. This indicates that the effluent of mining containing high organic pollutants have invaded the ground water which decreases the dissolved oxygen content as a result of microbial activities. This is because organic wastes (carbohydrates, proteins, etc.) act as a medium for microbial multiplication.

Table 1: Statistical summary of chemical parameters of groundwater samples

| | Mining Sites | | | | Non-mining Sites | | |
|---|---|---|---|---|---|---|---|
| | Average with Std. Dev(±) | Min | Max | WHO | Average with Std. Dev (±) | Min | Max |
| pH | 7.96±0.176 | 7.13 | 7.69 | 6.5-8.5 | 7.26±0.163 | 7.11 | 7.61 |
| EC (µS/cm) | 811.00±133.313 | 678.00 | 1081.00 | 300 | 530.80±98.46 | 324.00 | 657.00 |
| TDS (mg/l) | 742.10±156.959 | 468.00 | 987.00 | 500 | 484.40±117.69 | 356.00 | 612.00 |
| Turbidity (mg/l) | 4.05±0.828 | 2.90 | 5.10 | 5 | 3.12±0.644 | 1.90 | 4.10 |
| DO (mg/l) | 4.05±0.606 | 3.03 | 5.24 | 5 | 3.58±0.651 | 2.67 | 4.34 |
| BOD (mg/l) | 6.35±1.138 | 4.78 | 7.84 | 6 | 7.53±1.085 | 5.38 | 8.97 |
| Alkalinity (mg/l) | 185.00±50.151 | 100.00 | 256.00 | 200 | 216.40±48.36 | 167.00 | 289.00 |
| TH (mg/l) | 492.70±76.355 | 399.00 | 671.00 | 150-500 | 352.10±49.63 | 287.00 | 456.00 |
| Ca (mg/l) | 194.90±48.356 | 101.00 | 289.00 | 100 | 178.80±47.76 | 100.00 | 278.00 |
| Mg (mg/l) | 124.00±41.601 | 48.00 | 191.00 | 150 | 115.00±38.38 | 72.00 | 177.00 |
| S04 (mg/l) | 214.83±11.382 | 200.35 | 232.36 | 250 | 316.60±8.119 | 300.14 | 324.64 |
| Cl (mg/l) | 805.40±82.073 | 678.35 | 901.35 | 500 | 624.39±35.67 | 589.49 | 711.93 |
| Na | 95.90±101.50 | 38.23 | 135.00 | 200 | 50.70±7.78 | 23.00 | 42.00 |
| K | 75.60±78.50 | 12.31 | 46.00 | 30 | 32.30±8.10 | 30.00 | 21.00 |
| Cd (mg/l) | 0.05±0.020 | 0.00 | 0.08 | 0.01 | 0.04±0.012 | 0.02 | 0.06 |
| Fe (mg/l) | 0.76±0.240 | 0.34 | 0.99 | 0.3 | 0.28±0.09 | 0.18 | 0.46 |
| Mn (mg/l) | 0.19±0.026 | 0.15 | 0.22 | 0.5 | 0.16±0.03 | 0.11 | 0.19 |
| Pb (mg/l) | 0.90±0.313 | 0.07 | 1.22 | 0.05 | 0.58±0.16 | 0.19 | 0.85 |
| Zn (mg/l) | 0.11±0.203 | 0.00 | 0.65 | 3 | 0.28±0.37 | 0.00 | 0.99 |

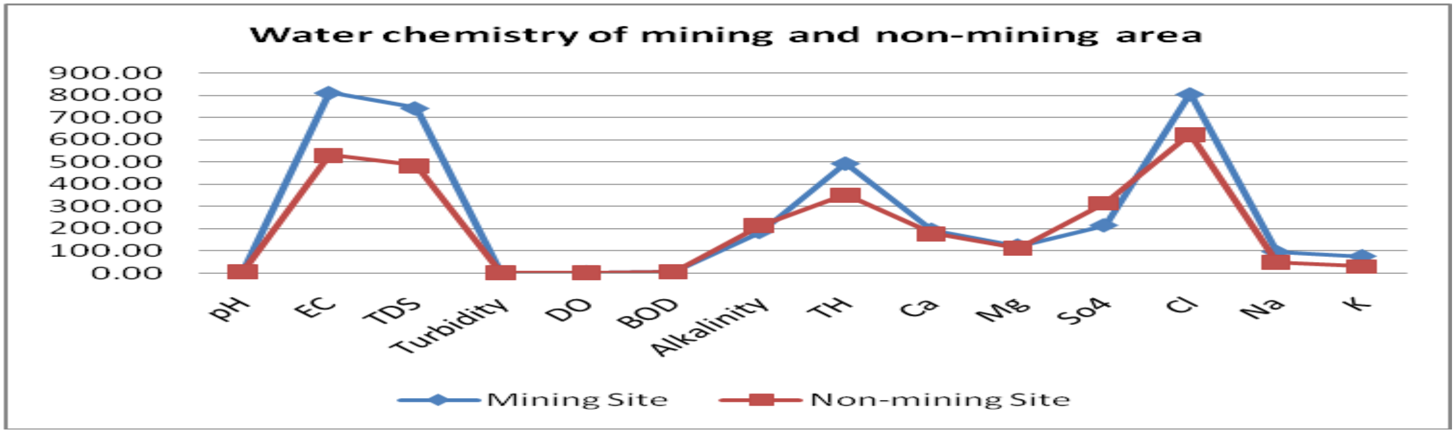

Fig 2: Comparative study of chemical parameters between mining and non-mining site

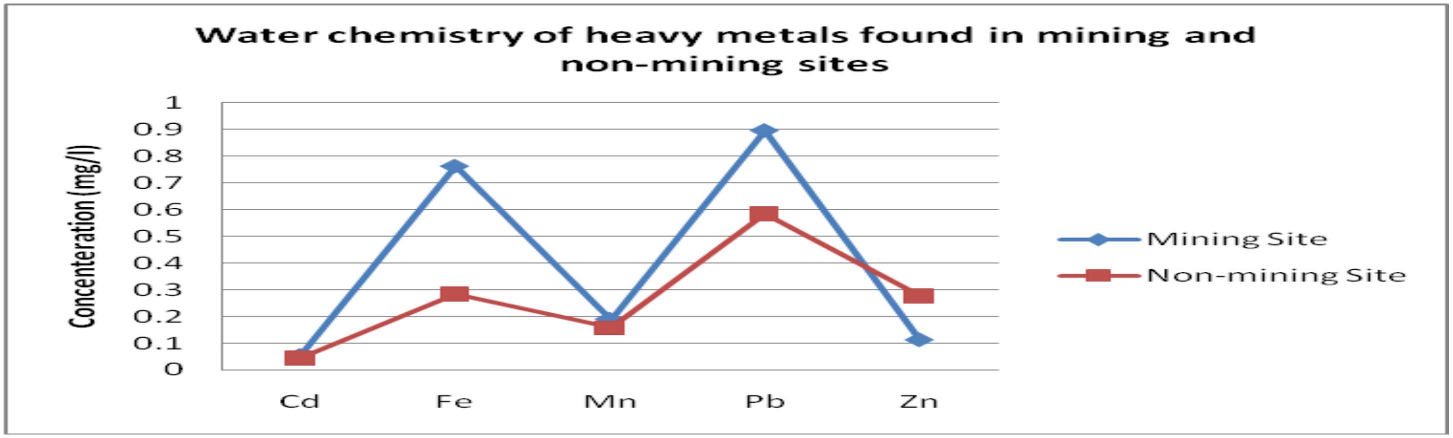

Fig 3: Comparative study of different heavy metals between mining and non-mining site

The values of alkalinity for both mining and non mining sites are exhibited in table-1. The values of alkalinity have been observed 185 ± 50.15 mg/l in mining and in non-mining site it is 216.40 ± 48.36 mg/l.

The average value of total hardness has been determined 492.70 ± 76.35 mg/l (mining site) and 352.10 ± 49.63 mg/l (non-mining site). Water samples collected in the study areas were found within the permissible limit of WHO except two samples. The water samples of the study area are classified according to hardness as suggested by Hem (1985). The high amount of hardness in mining site samples may be due to presence of carbonate rocks. In Bundelkhand region, the groundwater is generally Ca-Mg-$HCO_3$ type, which is mainly due to geology of the area which comprises igneous rocks of crystalline nature, in which the major rock units are granites and gneisses. Groundwater in the study area occurs under water table conditions in the weathered and fractured granite, gneisses.

The most abundant cations found are $Ca^{2+}$ and $Mg^{2+}$ with the average of 194.90 ± 48.36 and 124 ± 41.60 mg/l (mining site), 178.80 ± 47.76 and 115 ± 38.38 mg/l (non-mining site) respectively. The concentration for $Ca^{2+}$ is above the permissible limit (100 mg/l) , but for $Mg^{2+}$, are within the safe limit of WHO (150mg/l) in both the studied sites. High values of calcium hardness in study area may be due to the cationic exchange with sodium. However, the low values do not mean that it is not influenced by the pollutants but it might be due to the reverse cationic exchange with sodium i.e. sodium ions replace $Ca^{+2}$ ions thereby reducing their concentrations in ground water percolation. Magnesium is from natural sources like granite terrain which contain large concentrations of these elements and supposed to be non-toxic at the concentration generally met in natural water.

The average value of $SO_4^{-2}$ and $Cl^-$ was observed 214.83 ± 11.38 mg/l and 805.40 ± 82.07 mg/l (mining site) and 316.60 ± 8.12 mg/l and 624.39 ± 35.67 mg/l (non-mining site). The concentrations of $SO_4^{-2}$ was found within the limit in mining site but above in non-mining site according to WHO (250 mg/l). But the water samples for $Cl^-$ were found above the standard limits of WHO (500mg/l) both in mining as well as non-mining site. This indicates that the high concentrations of $Cl^-$ is due to invasion of domestic wastes and disposals of human activities and describes the chloride pollution in mining as well as non-mining sites.

In the mining site, the average values of the heavy metals i.e. $Cd^{+2}$, $Fe^{+3}$, $Mn^{+2}$, $Pb^{+2}$ and $Zn^{+2}$ were observed 0.05 ± 0.02, 0.76 ± 0.24, 0.19 ± 0.03, 0.90 ± 0.31 and 0.11 ± 0.20 mg/l in the mining site whereas it is 0.04 ± 0.12, 0.28 ± 0.09, 0.16 ± 0.03, 0.58 ± 0.16 and 0.28 ± 0.37 mg/l in non-mining sites respectively. Concentrations of five metal analyses at mine site were higher than those of the non-mining site except Zn respectively according to WHO limits. Heavy metal concentrations at the mining site shows the trend $Pb^{+2}>Fe^{+3}>Mn^{+2}>Zn^{+2}>Cd^{+2}$ while at the non-mining site $Pb^{+2}>Fe^{+3}>Zn^{+2}>Mn^{+2}>Cd^{+2}$. In general, most of the heavy metals decrease gradually with distance from the mine. $Cd^{+2}$, $Pb^{+2}$, and $Fe^{+3}$ from mining site and $Cd^{+2}$ and $Pb^{+2}$ from non-mining site were found above the permissible Limits (WHO, 1994). The high value recorded for $Fe^{+3}$ (0.76 ± 0.24) in mining sites indicating the possibility of acid mine drainage. So large area, in the vicinity of mine would be unfit for agricultural use due to groundwater and soil contamination by the toxic metals. For most toxic metals, contents decreases with distance from the mine, in some cases the decrease was gradual, rather abrupt drop was observed between one sampling point and the next, and there were also some metals found in high concentrations in down gradient or comparison areas. Comparing with the soil contamination levels (Lee et al., 2003; severe soil contamination was extended to 11 km away from the mine dump), levels of groundwater contamination by toxic metals were relatively low, to the contrary of expectation. It has been reported that little heavy metal contamination is produced in the case of tailings with no or little sulphide content (Jung, 2001). Furthermore, the low metal concentrations of metals may be due to high pH of the groundwater (>7) and highly oxygenated conditions, which enhances toxic metal precipitation, although in general the highest concentrations are at mine area. Some physical mechanisms such as mixing with metal free groundwater were expected to play an important role in the low concentrations.

A parametric correlation analysis of melting water throughout the study is given in Table 2 and 3. In the mining site, PH is strongly correlated with alkalinity, EC, $Ca^{++}$, $K^{+}$, $Pb^{+2}$ and $Zn^{+2}$, while EC is correlated with $Ca^{+2}$ only. BOD is correlated to total hardness and Alkalinity is strongly correlated to $K^{+}$, $Fe^{+3}$, $Pb^{+2}$ and $Zn^{+2}$. However, Mg is found to be correlated with $Fe^{+3}$. $Fe^{+3}$ and. Pb is positively correlated with Zn only. In the non-mining site, pH is positively correlated with EC, alkalinity, $Ca^{++}$, $Cd^{+2}$, $Pb^{+2}$ and $Zn^{+2}$ reactively while EC is found to be positively correlated with DO and $Cd^{+2}$. TDS is only correlated with $SO_4^{-2}$ and turbidity its found to be negatively correlated with $Cl^{-}$. However, DO is correlated with BOD and $Mn^{+2}$. Alkalinity is correlated with $Fe^{+3}$ and $Zn^{+2}$ only. TH is correlated with $Cl^{-}$. $Ca^{+2}$ is positively correlated with Mn and Zn and negatively correlated with $Pb^{+2}$. $Mg^{+2}$ is correlated with $Fe^{+3}$ and $Mn^{+2}$. $Cd^{+2}$ is negatively correlated with $Pb^{+2}$ and positively correlated with $Zn^{+2}$. However, $Pb^{+2}$ is correlated with $Zn^{+2}$.

Trilinear explanation/ Piper diagramme: A Piper diagram (Piper 1944), also known as trilinear diagram, provides a convenient method to classify and compare water types based on the ionic composition of different water samples (Hem 1985) using Aqua Chem 5.1 software to plot cation and anion concentrations of (mining and non mining) samples are plotted as percentages of their respective totals in two triangles and then projected into a quadrilateral polygon that describes the water type or hydrochemical faces. Fig 4a and 4b represents Piper diagramme for mining and non-mining respectively. It also shows that $Ca^{2+}$ and $Mg^{2+}$ are the most prevalent cations and $HCO_3^{-}$ is the dominant anions. So, this water could be classified as magnesium- bicarbonate type. From figure it is also clear that most of the samples fall into the normal earth alkaline water group with prevailing bicarbonate and sulphate (Fig 4a and 4b). This type of water originates through natural processes by the dissolution of carbon dioxide ($CO_2$) from the atmosphere and from the soil horizon which causes the dissolution of the carbonate minerals, calcite $CaCO_3$ and dolomite $(Ca/ MgCO_3)_2$ of the aquifer (Suk and Lee 1999).

Table 2: Correlation matrix of chemical parameters of mining sites

| | pH | EC | TDS | BOD | Alkalinity | TH | Ca | Mg | SO4 | Cl | Na | K | Cd | Fe | Mn | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 1 | | | | | | | | | | | | | | | | |
| EC | 0.067 | 1 | | | | | | | | | | | | | | | |
| TDS | -0.665 | 0.062 | 1 | | | | | | | | | | | | | | |
| BOD | 0.515 | -0.281 | -0.615 | 1 | | | | | | | | | | | | | |
| Alkalinity | 0.537 | 0.194 | -0.507 | 0.516 | 1 | | | | | | | | | | | | |
| TH | 0.797 | 0.231 | -0.785 | 0.431 | 0.538 | 1 | | | | | | | | | | | |
| Ca | 0.134 | 0.775 | -0.039 | 0.127 | -0.038 | 0.229 | 1 | | | | | | | | | | |
| Mg | 0.156 | -0.425 | -0.186 | 0.568 | 0.533 | -0.024 | -0.355 | 1 | | | | | | | | | |
| SO4 | -0.241 | 0.497 | 0.086 | -0.259 | 0.153 | -0.114 | 0.3000 | 0.149 | 1 | | | | | | | | |
| Cl | 0.449 | -0.32 | -0.227 | -0.289 | 0.073 | 0.208 | -0.380 | -0.088 | -0.301 | 1 | | | | | | | |
| Na | -0.244 | 0.131 | 0.150 | -0.195 | -0.745 | -0.109 | 0.367 | -0.617 | 0.186 | -0.195 | 1 | | | | | | |
| K | 0.243 | -0.267 | -0.323 | 0.360 | -0.070 | 0.104 | -0.08 | -0.048 | 0.035 | 0.073 | 0.478 | 1 | | | | | |
| Cd | 0.073 | 0.200 | 0.080 | -0.573 | 0.205 | 0.319 | 0.201 | -0.300 | -0.217 | 0.160 | -0.095 | -0.213 | 1 | | | | |
| Fe | -0.752 | 0.254 | 0.704 | -0.578 | -0.517 | -0.595 | 0.128 | -0.125 | 0.506 | -0.436 | 0.299 | -0.477 | -0.192 | 1 | | | |
| Mn | 0.185 | 0.280 | 0.010 | -0.168 | 0.575 | 0.033 | 0.039 | 0.270 | 0.594 | 0.224 | -0.261 | 0.208 | 0.189 | -0.131 | 1 | | |
| Pb | 0.050 | 0.042 | 0.280 | 0.096 | 0.049 | -0.430 | 0.004 | 0.447 | 0.395 | 0.088 | -0.204 | -0.058 | -0.605 | 0.255 | 0.390 | 1 | |
| Zn | -0.116 | -0.070 | -0.262 | -0.008 | -0.152 | 0.198 | 0.041 | -0.544 | -0.423 | -0.077 | 0.313 | 0.343 | 0.426 | -0.387 | -0.321 | -0.860 | 1 |

TDS= Total Dissolved Solids, BOD= Biological Demand, TH= Total Hardness, Ca= Calcium, Mg= Magnecium, K= Potasium, Cd= Cadmium, Fe= Iron, Mn=Mangnese, Pb= Lead, Zn= Zink

Table 3: Correlation matrix of chemical parameters of non-mining sites

| | pH | EC | TDS | BOD | Alkalinity | TH | Ca | Mg | SO4 | Cl | Na | K | Cd | Fe | Mn | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | | | | | | | | |
| EC | 0.503 | 1 | | | | | | | | | | | | | | | |
| TDS | -0.185 | 0.283 | 1 | | | | | | | | | | | | | | |
| BOD | 0.176 | -0.153 | 0.323 | 1 | | | | | | | | | | | | | |
| Alkainity | 0.603 | 0.133 | -0.325 | 0.201 | 1 | | | | | | | | | | | | |
| TH | -0.085 | -0.003 | -0.143 | -0.797 | -0.323 | 1 | | | | | | | | | | | |
| Ca | 0.628 | -0.009 | -0.472 | 0.146 | 0.426 | -0.146 | | | | | | | | | | | |
| Mg | 0.109 | -0.191 | -0.349 | 0.153 | 0.451 | -0.452 | | 1 | | | | | | | | | |
| SO4 | -0.036 | 0.126 | -0.626 | -0.372 | -0.198 | 0.099 | | 0.245 | 1 | | | | | | | | |
| Cl | -0.246 | 0.288 | 0.336 | -0.548 | -0.258 | 0.681 | | -0.416 | -0.049 | 1 | | | | | | | |
| Na | -0.018 | -0.087 | 0.276 | 0.206 | 0.217 | -0.231 | | 0.274 | -0.611 | -0.125 | 1 | | | | | | |
| K | -0.638 | 0.109 | 0.173 | -0.506 | -0.560 | 0.164 | | -0.294 | 0.198 | 0.191 | -0.147 | 1 | | | | | |
| Cd | 0.644 | 0.635 | 0.048 | -0.078 | 0.428 | -0.201 | | 0.090 | -0.085 | -0.272 | 0.046 | 0.086 | 1 | | | | |
| Fe | 0.153 | 0.013 | -0.252 | 0.011 | 0.642 | -0.095 | | 0.576 | 0.061 | 0.242 | 0.235 | -0.514 | -0.180 | 1 | | | |
| Mn | -0.149 | -0.488 | -0.110 | 0.227 | 0.204 | -0.320 | | -0.070 | -0.324 | -0.505 | -0.041 | 0.163 | 0.172 | -0.325 | 1 | | |
| Pb | -0.737 | -0.325 | 0.437 | 0.123 | -0.552 | -0.042 | | 0.054 | -0.159 | 0.162 | 0.332 | 0.306 | -0.609 | -0.071 | -0.261 | 1 | |
| Zn | 0.887 | 0.452 | -0.32 | 0.058 | 0.858 | -0.087 | | 0.185 | -0.058 | -0.168 | 0.489 | -0.564 | 0.621 | 0.400 | -0.020 | -0.755 | 1 |

TDS= Total Dissolved Solids, BOD= Biological Demand, TH= Total Hardness, Ca= Calcium, Mg= Magnecium, K= Potasium, Cd= Cadmium, Fe= Iron, Mn=Mangnese, Pb= Lead, Zn= Zinc.

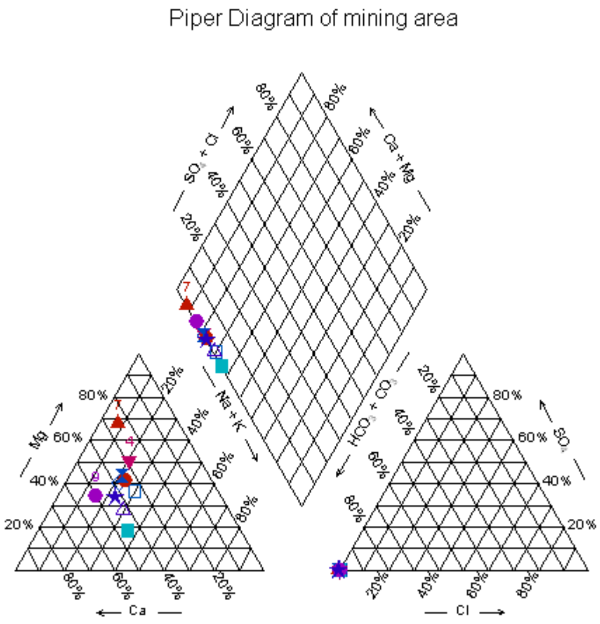

Fig 4a. Piper diagram showing ionic composition of mining area

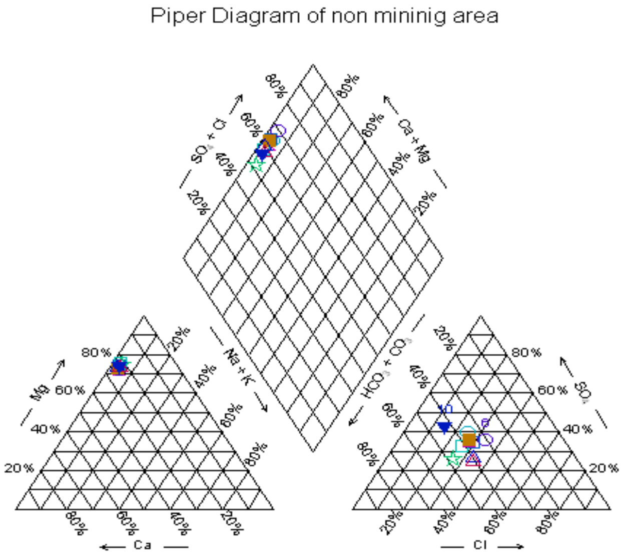

Fig 4b. Piper diagram showing ionic composition of non-mining area

As conclusion, the present study evaluated the hydrological conditions and potential groundwater contamination by toxic metals derived from an abundant mine. The temporarily occurring loosing stream in immediate vicinity the mine waste dump can pose the threat of groundwater pollution. The pH values for groundwater in the mine site were near neutral with slight increase of the values along the downstream flow direction. In comparisons with groundwater in mine site and non- mining sites, higher values of EC were observed and high DO concentrations (mine site) indicated an oxygenated groundwater environment. In the mine site, the groundwater contamination by $Cd^{+2}$, $Fe^{+3}$, $Mn^{+2}$ and $Pb^{+2}$ were observed while less contamination in the non-mining site except in $Zn^{+2}$. The low concentrations may be due to mixing with metal- free waters.

Based on the studied results, a remedial measure may be recommended including rehabilitation of the refuse and gob pile and water treatment system for the contaminated groundwater which is focused on the only mine site.

## REFERENCES

Adriano, DC.; (2001). Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability and Risks of Metals, 2nd edition. Springer-Verlag. 866 pp

APHA., (2005). Standard methods for the examination of water and wastewater (23rd edn.). American Public Health Association, Washington D.C

Azeez P.A., Nadarajan N.R. and Mittal D.D.(2000). The impact of monsoon wetland on ground water chemistry, Poll. Ress., 19(2), 249-255

Berger, AM.; Bethke, CM.; Krumhansl, LK., (2000). A process model of natural attenuation in drainage from a historic mining district. *Appl. Geochem*., 15, 655-666.

Chopin, EIB.; Black, S.; Hodson, ME.; Coleman, ML.; and Alloway, BJ., (2003). A Preliminary investigation into mining and smelting impacts on trace element concentrations in the soils and vegetation around Tharsis, SW Spain., Mineral. Mag., 67, 279–288

Gandy, CJ.; and Younger, PL., (2003). Effects of a clay cap on oxidation of pyrite within mine spoil., Quarterly Journal of Engineering Geology and Hydrogeology., 36 (3), 207-215.

Hem, JD., (1985). Study and Interpretation of chemical characteristics of natural waters., U.S.G.S. Water Supply Paper. 3rd edition No., 2254, 263

Johnson, RH.; Blowes, DW.; Robertson, WD.; and Jambor, JL., (2000). The hydrogeochemistry of the nickel rim mine tailings impoundment, Sudbury, Ontario., J. Contam. Hydrol., 41, 49–80

Jung, MC., (2001). Heavy metal contamination of soils and waters in and around the Imcheon Au–Ag mine, Korea., Appl. Geochem., 16, 1369–1375

Kim, MJ.; Ahn, KH.; and Jung,Y., (2002). Distribution of inorganic arsenic species in mine tailings of abandoned mines from Korea., Chemosphere., 49, 307–312

Lee, CG., Chon, H.; Jung, MC., (2001). Heavy metal contamination in the vicinity of the Daduk Au–Ag–Pb–Zn mine in Korea., Appl. Geochem., 16, 1377–1386

Lee, M.; Choi, J.; and Kim, J., (2003). Distribution and remediation design of heavy metal contamination in farmland soils and river deposits in the vicinity of the Goro abundant mine., Econ. Environ.Geol., 36, 89-101

Marques, MJ.; Martiniz, CE.; and Rovira, JV., (2001). Heavy metap pollution of aquatic ecosystems in the vicinity of a recently closed underground lead-zinc mine (Basque Country Spain)., Environmental Geology., 40, 1125-1137

Piper, A.M., (1944). "A Graphic Procedure in the Geo-chemical Interpretation of Water Analysis". Trans.Am.Geoph., Washington, D.C. 25, 914-923

Razo, I.; Carrizales, L.; Castro, J.; Díaz, BF.; Monroy, M., (2004). Arsenic and heavy metal pollution of soil, water and sediments in a semi-arid climate mining area in Mexico., Water Air Soil Pollut., 152, 129–152

Remediation. Kluwer Academic, Dordrecht., Environmental Pollution., (5) 21-26

Singh, G.; Pal, A.; and Khoiyanbam, SR., (2008). Impact of mining on human health in and around Jhansi, Bundelkhand region of Utter Pradesh, India., Journal of Ecophysiol. Occup. Hlth., 9, 47-54

Singh, G.; Pal, A.; Niranjan, KR.; Kumar, M., (2010). Assessment of environmental impacts by mining activities: A case study from Jhansi open cast mining site-Uttar Pradesh, India., Journal of Experimental Sciences., (1), 9-13

Srinivas C.H., Ravi Shankar Piska, Venkatesan C., Sathya Narayan Rao M.S. and Ravinder Reddy R. (2000). Studies on ground water quality of Hyderabad, *Poll. Res*., 19(2), 285-289

Suk, H., and Lee, K. (1999). Characterization of a ground water hydrochemical system through multivariate analysis: Clustering into groundwater zones. *Ground Water*, 37, 358-366

WHO (1984). Guidelines for drinking water quality, World Health Organization, Washington DC., 333-335

Younger, PL.; Banwart, SA. and Hedin, RS., (2002). Mine Water Hydrology, Pollution, Remediation. In: Alloway, BJ.& TREVORS, J.T(eds) *Environmental Pollution Series*, Dordrecht.

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