ASSESSMENT OF COPPER CONTAMINATION IN SOIL NEAR MALANJKHAND COPPER MINE, MADHYA PRADESH

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN MINING ENGINERING

BY

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CERTIFICATE

This is to certify that the thesis entitled "Assessment of Copper Contamination in Soil near Malanjkhand Copper Mine, Madhya Pradesh" submitted by Sri Deepak Kumar Dhrua (Roll No. 111MN0389) and Sri Shantanu Kumar (Roll No. 111MN0394) in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not formed the basis for the award of any Degree or Diploma or similar title of any University or Institution.

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ABSTRACT

The objective of the study was to examine the copper concentration and soil properties of the area around Malanjkhand copper mine, which is located in north east of Balaghat, Madhya Pradesh which is the largest copper deposit in India producing nearly 2.2 million tonnes of copper tailings annually. The soil was characterized geochemically by taking samples from areas around the mine and the contaminated waste nallas coming out from the mine. Studies were done and the pH, electrical conductivity and the organic carbon content were measured. Copper content of the soil samples were examined. The enrichment factor and index of geoaccumulation were also calculated. On the basis on the enrichment factor and the index of geoaccumulation, the copper concentration was found to be highest near the waste dump and significantly high close to the nallas.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Metals and minerals have become essential for the development of a country. They are required in every industry, manufacturing process, energy generation, construction activities etc. The industrial revolution towards the end of 18th century necessitated expansion of mining of metals on a large-scale (Craddock 1985). The extraction of minerals involve steps like overburden removal, crushing, leaching, milling, smelting and beneficiation. Tailings are left over materials after the refining and beneficiation process. Acid mine drainage results when metals and minerals are extracted from their sulphide ores. It occurs in the open pit mine faces, in underground workings, waste rock dumps, ore stockpiles, tailings deposits, smelting plants etc. Concern towards the environmental pollution caused due to mining activities has led to stricter regulations and inspection. Mine operators now employ several means to reduce and prevent contamination of air, water and land resources.

Copper has been a primary metal since at least 10,000 years. Its demand has been increasing due to spurt in the use of electronic devices by people in general (Kumar and Putnam 2008). Interestingly, about 97% of the copper mined and smelted till date has been extracted only after 1900. The increase in demand is closely related to the growing Indian and Chinese economies (Leonard and Andrew 2006). The annual production of copper in the world is 18 million metric tons (Copper Statistics and Information, Mineral Commodity Summaries 2014). The increase in demand of copper is close to 575,000 tons per year and is accelerating (Leonard and Andrew 2006). As per official records, India produced 689,312 tonnes of copper in 2012. Further the government expects the demand to double by the year 2020 (MPPCB 2011).

The copper contamination of soil can lead to diseases in humans, through crops, like Wilson's disease, chronic anaemia and affects the liver and brain functioning. In plants, excess copper blocks biochemical functions like photosysthetic electron movement, inhibits protein digestion, respiration etc. Contamination of soil by copper affects the shape, size and root growth of crops and being non-biodegradable, copper persists in soil for hundreds of years (Fernandes and Henriques 1991).

The single largest copper deposit in Asia is the Malanjkhand copper deposit. Hindustan Copper limited operates a 2 million tonnes capacity of beneficiation plant for processing the copper ore. Over 70 percent of the known copper reserve of India is located in Malanjkhand. The annual production from the Malanjkhand copper project is 3 million tonnes of ore with 1.05 percent copper content (MPPCB 2011). Tailings deposited due to copper mining is over 2.2 million tonnes annually (Pandey, et al. 2007). The available reserves at 1.28 percent copper in Malanjkhand copper project is 236.4 million tonnes (GMRI 2009).

1.2 OBJECTIVES

The following aspects were studied in the Malanjkhand Copper mining area:-

- To determine the copper content in the soil.
- To determine the copper contamination near Malanjkhand Copper Mine.

2.1 ENVIRONMENTAL ISSUES RELATED TO COPPER MINES

The extraction of minerals from the earth's crust comes with an environmental cost, irrespective of the form of the raw material. The extraction of minerals involve several steps like overburden removal, crushing, leeching, milling, smelting and beneficiation. A huge amount of tailings are released as a result of the above processes (Asokan et. al., 2007). The volume of earth moved, in the form of overburden, is exceptionally high and mining currently strips more of the earth's surface annually compared to natural erosion (Gardner and Sampat 1999). For production of one ton of copper, 350 tonnes of unwanted waste material are generated along with 147 tonnes of tailings and 3 tonnes of slag which exemplifies the damaging nature of copper mining (Menzie 2006). The waste rock, tailings, dump sites, beneficiation process release pollutants which adversely affects the air, water and soil quality of the region. Acid mine drainage results from copper mines as the sulphide containing ores, mostly chalcopyrite, comes in contact with water. Acid mine drainage is a major environmental issue that is often associated with copper mines. Heavy metals cause the plants to decrease water and nutrient uptake, decrease root respiration, constrain cell mitosis in root meristematic regions (Gemmel 1977), and decrease enzymatic activity and microbial communities in soil (Clark and Clark 1981). The local population suffers from various illness due to the degradation of the natural sources of food and water. The ordinary activities of a plant is hindered as the concentration of copper rises and the plants could develop signs of toxicity such as chlorosis, dwarfism and necrosis (Pujari and Shrivastava 2001). A number of cases of environmental disasters linked to copper mines have taken occurred in the past. Copper was mined and processed from the Mount Lyell Mine located in Western Tasmania, Australia from 1893 to 1994. The consequent acid drainage degraded over 40 km of rivers and streams. The ore deposit of the area has over 10% sulphide content and the resultant acidic release into the downstream catchments is over 2 tonnes of copper every day (Custis 1994).

Acid mine drainage happens as sulphide bearing minerals of an ore body is exposed to water and air, which converts the sulfide to sulfuric acid by a chemical reaction. This acid dissolves heavy metals present in tailings and waste rock, for instance copper, mercury, cadmium, arsenic, lead, selenium and zinc, into ground and surface water (Pandey et al. 2007). Certain bacteria which are naturally present significantly intensify the rate of this reaction. Acid mine drainage can take place at numerous areas all through the mining process: open pit mine faces, in underground workings, waste rock dumps, ore stockpiles , tailings deposits etc (Rekacewicz 2005).

Air pollution due to mining is basically due to the fugitive emissions of particulate material, fumes and vapours, which includes sulphur dioxide, particulate matter and dust. The gases jeopardize the lives of the people who are exposed to it through occupation or living close to the polluting mining sites. Respiratory diseases are caused as sulfur dioxide (SO_2) fumes are released from the smelters. Additionally, acid rain resulting from the above, damages trees, streams and rivers (Cunningham and Cunningham 2006).

For example, in the Copperbelt province of Zambia, the copper smelters annually release between 300,000 to 700,000 tonnes in total of $S0_2$ which is very high (The World Bank 2002). Health problems in humans and animals and degradation of environment happens through direct inhalation from the air, soil deposition, or accumulation within a water body. Unregulated copper smelting processes discharge large amounts of particulate matter, trace elements, and sulphur oxides, which lead to adverse effects on health of humans. Sulfur dioxide (SO_2), and the sulfates and sulfuric acid aerosols formed in the atmosphere, can be lung irritants and aggravate asthma (OTA 1988). Additionally, unregulated release of dust from the mines contaminates surface waters and negatively affects crop growth as pores of the plant are blacked (Reza and Singh 2010).

Mining deteriorates the quality of the water as waste water is discharged into the surface drainage arrangement (Figure 1.1). Moreover, U.S. Environmental Protection Agency (1994) noted that waste water discharged from the mineral mining operations have significant negative effect on the quantity and quality of groundwater. Likewise, sediments are deposited in rivers and streams running close by as a result of erosion. Pollutants, which are released from the mines, end up in streams and rivers that has undesirable effect on aquatic biodiversity. For example, in Zambia young Tilapia fish species cannot survive in the water in the Kafue River close to the copper mining area (State of Environment in Zambia 2000).

Notwithstanding the methods and process used for extracting copper, mining always results in massive land disturbance which covers large scale excavation, removal of top soil and dumping of overburden material (Singh et. al., 2004). The waste produced due to mining activities effects the overall land productivity on a long term basis. As a result productive land that could have been used for other economically attractive areas such as agriculture is left barren.

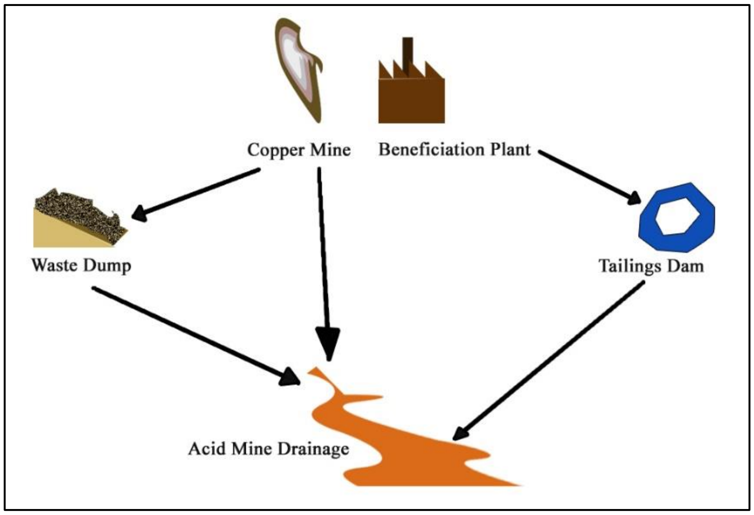

Fig. 1.1 - Mine Waste Generation

Copper can be mined through underground and open cast methods. Currently, most of the copper ores mined are oxide or sulfide ores (Bampton 2003). The next step involves refining of the ore. The copper ore is transported to mills, crushed and ground. The refining method depends on the type of ore. For copper-oxide ores, the copper is typically leached from the ore with a solution of sulphuric acid.

Copper is recovered from the leaching solution through the process of electrolysis (Copper Range Company 1974). Another method can be to pass the solution over scrap iron; a chemical reaction leads the copper to be deposited on the iron. Then the copper is separated from iron by employing methods that are used to refine copper-sulfide ores.

Copper-sulfide ores are treated with the process called Froth Flotation (Pryor 1965). Here, bubbles are produced in a mixture of powdered copper ore, water, and chemical reagents. The particles of copper-bearing minerals in the ore stick to the bubbles and float on the top of the mixture, from where it can be skimmed off.

The copper-bearing minerals are roasted to remove a part of the sulfur. The resulting product is then smelted, which yields a molten combination of copper sulphate and iron sulphide called matte (Wilkomirsky et. al., 2014). Some light impurities combine to form slag, which has to be removed. Then matte is poured into a converter; here air is forced through it to burn out the left out sulphur and to oxidize the iron. By this time, most of the impurities, including the oxidized iron, float to the top of the matte to form more slag, which has to be poured off.The metallic copper, left at the bottom of the converter, is called blister copper (Mäkinen 1982). It is very pure but needs further refining to remove impurities, which includes small amounts of gold, silver, and certain other precious metals (Mäkinen 1982). The refining is done through electrochemical process, a process similar to the one used for oxide ores. The impurities, which are generally the precious metals collect at the bottom of the same tank.

The amount of marketable copper produced is very small compared to the ore mined (U.S. Environmental Protection Agency 1994). Copper concentration ranges from 0.5 to 1.0 percent in the copper ores, with ores containing 0.3 percent or less usually rejected as waste rock (USEPA n.d.). Several hundred tons of ore has to be handled for each ton of copper metal produced, thus generating huge waste quantities.

As large volume of ore has to be processed, hence the processing facilities are located close to the mines. Copper production include the following processes; i) Leaching, ii) Solvent extraction, iii) Milling, iv) Physical Separation, v) Smelting. Each of the process leads to generation of large quantity of waste, which needs to be disposed of.

2.2 CASE STUDIES

2.2.1 OK TEDI COPPER MINE, PAPUA NEW GUINEA

The OK Tedi Copper Mine lies in the Star Mountains of the Western Province in Papua New Guinea. The mine has been named after OK Tedi, an upstream tributary of the Fly River, which is one of the world’s major tropical rivers. It has the greatest diversity of fish fauna in Australasian expanse (IUCN 1995:1, 22).

The Ok Tedi ecological calamity gravely affected the environment within 1,000 kilometres of the Fly River and the Ok Tedi River in Papua New Guinea during 1984 to 2013. The tragedy was the result of release of roughly 2 billion tons of unprocessed mining waste into the Ok Tedi River from the Ok Tedi open cast mine. The operator of the mine testified that in during the period, over 90 million mine waste was released into the river. Mine waste had been dumped in excess of an area of 100 square kilometres. As of 2006, mine operators continued to release eighty million tons of tailings, overburden and mining induced erosion into the rivers every year. About 1,588 square kilometres of the forest area in under tremendous strain (Key Statistics 2006).

Tailings get into the surrounding creeks, swamps and rain forest due to regular high rainfall in the region. Dark grey sludge is can be easily noticed in the Fly River and its associated streams (Kirsch 1996). The huge mine wastes dumped into the stream was way more than the carrying capacity of the river. The continuous dumping raised the river bed by 10 m which gradually transformed the river into shallower stream, ultimately disturbing the waterways used for transportation (Hettler et. al., 1997). The copper concentration exceeded the standard level by 30 times, which was still below the WHO standards (Marychurch and Natalie 2006).

2.2.2 RECSK COPPER MINE, HUNGARY

A very strong bearing on the environment can be seen in the Recsk region due to mining. Natural revegetation is hampered as the abandoned mines and the waste rock dumps continue to release acid mine drainage. Modern mining in the Lahóca Mine area has created huge waste dumps and tailings reservoirs that discharge AMD. Sediments contaminated with wastes has badly affected the ecology of the nearby streams. Interestingly, the buffer capacity due to the carbonate-rich geochemistry of the region reduces the metal contamination in the river within 200-250 metres of the cause (Jordan and Anton Van Rompaey 2009). Comprehensive geochemical analysis of sediments and river water shows surprising abnormal values of metal. Mining activity at the Recsk Deep Mine did not cause substantial surface contamination, as groundwater does not recharge surface waters and groundwater chemistry is protected by Triassic carbonate rocks beneath the ground. Analysis of erosion and sediment-transport modelling show that land-use patterns which reduce the overall sediment transfer are not necessarily the similar as those which lessen the bulk of transferred contaminated waste.

2.23 COPPER MINE TAILINGS, DUCKTOWN, TENNESSEE

The shutting down of mining activities released over 800-900 acres of barren copper mine tailings. The copper concentration was established at 2-100 mg/kg, while for Nickel, Zinc, Cadmium and Chromium was found to be 5-500 mg/kg, 20-300 mg/kg, 10-300 mg/kg, 0.6-1.1 mg/kg and roughly 54 mg/kg, respectively. These results show a toxic levels of heavy metal contamination and are deadly for the vegetation. The calcium and magnesium content was under tolerable limits. Unfortunately, copper content was above the acceptable standards. Similarly, cadmium and chromium also crossed the prescribed threshold limit (Branson and Ammons 2004).

2.3 SOIL POLLUTION BY COPPER MINES

Mining and smelting activities effect the geological scenery (development of mines, tons of discarded waste, and tailings dam) and lead to contamination of the surroundings (Brehuv et al. 2005). Pollution is majorly caused by the processing and smelting facilities (Wang et al. 2007). Copper can persist in soil for hundreds of years as it is non-bidegradable (McGrath 1984). They can collect over long periods of time and cross the toxicity levels in air, water and soil (Kumar et. al. 2007). The range of activities related to copper mining contaminate the groundwater resource. Surface water contaminated with heavy metals in dissolved form can be transported over large distances (Frankowski et al. 2009). The contaminated water resources are a major cause of worry as they can be the cause for neurological, cardiovascular or cancer diseases (Galušková et. al. 2010). Contamination of soil by heavy metals, similar to copper, changes the soil qualities and restricts environmental and productive functions. Contaminated soils are not fit for farming (Ensink et al. 2002).

Further, soil contains various functional groups that actively absorb heavy metal (Wang et al. 2007). Their interactions affect the properties and processes in the soil. These interactions are determined by the level of Fe, Al, Cu and Mn oxides and hydroxides (Khalkhaliani et al. 2006), rainfall distribution, erosion, redox potential, texture and organic matter and clay content (Asokan et. al. 2007). The dominant process at any specific time determines the heavy metal retention capacity (Ramirez et al. 2013). However, anomalies in metallic levels occur as a result of heavy metal deposition on the soil surface from various sources such as emissions of metal carrying dust, gases and smoke from industrial undertakings through atmospheric transportation (Ramirez et al. 2013).

The concentration of metals in soil, water and plants depends on the distance of the area from the mine and the form in which the ore is transported. The spatial variation of the contaminants in the topsoil in the mining site indicates their dispersion through wind and erosion. Metals dispersed from mine waste are generally retained in the lower areas used for agriculture (Matthews et. al. 2012).

All phases of copper production from mining and leaching to crushing, smelting and refining have likely influences on surface and groundwater quality. Serious water quality effects are caused chiefly through waste dumping practices (Pretorius and Dennis 2003), as surface water flows through the impoundments and groundwater penetrates these impoundments (Jason Potts 2014). Moreover, the extensive land disturbances linked to open cast mining can upset the regular flow of surface and ground water, and could decrease the water table in the affected area. Lowering of the water table often lead to water shortages, land subsidence, and rupturing; the latter accelerates the transport of contaminants into a water source (OTA 1988).

2.4 EFFECT OF HIGH LEVEL OF COPPER IN SOIL

Heavy metal contamination is amongst the most troublesome ecological issues confronted by humanity these days (Fernandes and Henriques 1991). Copper, specifically, postures difficult issues because of its boundless industrial and agrarian use.

Copper is not promptly bioaccumulated, in contrast to the other heavy metals like lead, cadmium and mercury, and hence is almost harmless to man and different warm blooded animals (Arduini et. al.1995). Interestingly, plants are extremely delicate and sensitive to toxicity from copper (Fernandes and Henriques 1991).

As copper has the characteristic property of strongly binding to organic and inorganic colloids, its freedom of movement is restricted in sediments and earth. This prevents plants which grow on land from copper toxicity. However, aquatic plants and algae are easily contaminated by copper as they are completely exposed to poisonous effects of copper (Maksymiec 1998).

Surplus copper hinders a number of enzymes and obstructs several characteristics of plant biochemistry, which comprises pigment synthesis, photosynthesis, and membrane integrity (Clijsters et. al. 1999). The most vital consequence is associated with the blocking of photosynthetic electron movement (Fernandes and Henriques 1991). Impact of copper on plant physiology is extensive. Excess Cu interferes with fatty acids, protein digestion and restrains nitrogen fixation processes and respiration. At the entire plant level Cu is a viable inhibitor of vegetative development and actuates symptoms of senescence (Ric de Vos et. al. 1993).

Copper smelters and ore-processing facilities are the main culprits for releasing copper particulates into the environment. Liver and brain the main organs where copper accumulates. Wilson's disease is primarily caused by copper toxicity (Mebrahtu and Zerabruk 2011). Drinking water contaminated with toxic levels of copper leads to chronic anaemia (Iqbal et al. 2011). WHO (World Health Organization) has recommended 10 mg/kg as permitted limit of copper in plants. Similarly, 2 mg/l is the maximum permissible limit for drinking water.

Interveinal foliar Chlorosis is one of the typical initial symptom of Copper toxicity in plants (Taylor and Foy 1993; Zhu and Alva 1993). The chlorosis results in the form of cream or white spots or lesions (Lee et al. 1997; O'Sullivan et. al. 1997). As the content increases, leaf tips and margins turn dark colored (Taylor and Foy 1993; Yau et. al. 1991). Acute Cu toxicity results in wilted leaves which ultimately become dark (Yau et. al. 1991).

Copper Toxicity considerably affects root growth, shape and size (Minnich et. al. 1987). High amount of copper result in radicles which can be blunt tipped, short, of dark brown or black colouration (necrotic) and disposition of fungus (Patterson and Olson 1983).

Experiments conducted by Xu and Yang (2006) showed that copper is highly toxic to rice. They concluded that rice grain yields decreased exponentially and significantly with the increase of soil Cu levels. Moreover, a 10% reduction in the rice yield was noticed at 100 mg kg^{-1} Cu soil level. It increased to 50 % reduction at 300-500 mg kg^{-1} and further to 90% when the concentration of copper reached 1000 mg kg^{-1}. Studies concluded that the most Cu toxicity sensitive part of the rice plant was the root (below 300-500 mg kg^{-1}). At higher soil copper levels (above 300-500 mg kg^{-1}), the growth of the entire plant was seriously inhibited. When the copper levels in the soil was below 150-200 mg kg^{-1}, the copper content increased in the rice grain. Surprisingly, the copper content decreased beyond 150-200 mg kg^{-1}. The peak copper content was found at soil copper level of 150-200 mg kg^{-1}. Copper does not get evenly distributed in all parts of rice. Polished rice accumulates 60% of the copper in grain, while cortex (embryo) has 24%, and chaff holds about 12% of the copper. Thus grain processing removes 30% of the copper in the rice grain as chaff, embryo and cortex are removed during the operation.

2.5 MALANJKHAND COPPER DEPOSIT

Malanjkhand copper mineral deposit is an open-cast copper mine positioned in Malanjkhand with coordinates 22º0’54’’N and 80º43’20’’E. The largest base metal copper open-pit mine in India, it is located 90 Km North East of Balaghat in MP (Madhya Pradesh). The altitude of the mine is 576m RL. The copper project was set up in the year 1982. Hindustan Copper Limited (HCL) established the project for exploitation of the deposit through open cast mine. Systematic geological exploration of the deposit was done in the year 1969 was done by GSI (Geological Survey of India). It is the biggest open cast copper mine in entire Asia. Currently the deposit in under the exploitation phase. It is being carried out by M/s Hindustan Copper Limited. The area of mineralization was found in approximately 2.6 Km long arcuate Malanjkhand hill having elevation of roughly 600 m above M.S.L. (GSI 1994).

The basement rock has an overlying Precambrian metasediments of Chilpi Ghat Series with erosional unconformity. The granitic rocks range in composition from a biotite granite to quartz diorite. They are extremely saussuritised, kaolinised and seriticised in the mineralised zone. Metasediments consist of conglomerates, phyllites, grits and shales. The quartz reefs, associated with the granites have a localized copper mineralization (Pandey et al. 2007). The sulphide minerals are generally found along the shear and fracture planes in the quartz reefs.

The order of abundance of minerals are chalcopyrite, pyrite, magnetite, sphalerite, chalcocite, bornite, molybdenite and cobaltite, in the decreasing order. 95% content of sulphide minerals is made up by chalcopyrite and pyrite (GSI 1994). The strike length of the ore zone is nearly 1.9 km with an average width of about 65 m. and dip is 60° towards east. GSI and MECL (Mineral Exploration Corporation Limited) carried out the drilling investigations and HCL carried out the mine development. The reserves available up to 600 m below the surface was 236.4 million tonnes at 1.28 percent copper out of which 145.7 million tonnes were proven, 50.4 million tonnes were categorized as probable and 40.3 million tonnes as possible reserves (GMRI 2009). Copper ore having around 1.05% copper content is subjected to ore processing which involves various processes like grinding, crushing, floatation, thickening, and filtration and it produces a copper concentrate which has around 25% copper. In the beneficiation process 5-7% of ore are transformed into concentrate and the rest are discarded as tailings which counts up to 90-95% of the extracted ore. The copper ore tailings which are the left out materials after extracting copper are stored in the tailing dams constructed at the Malanjkhand Copper Project. And as time progresses the quantity of copper ore tailings keep on increasing.

Hindustan Copper Limited was set up in the year 1967 under the Companies Act, 1956. It is a Mini Ratna GoI (Govt of India) Enterprise. The objective was to take over all activities related to exploration and exploitation of copper mineral deposits from NMDC (National Mineral Development Corporation). It is the sole company in the country which mines copper ore. It also owns all the operating mining lease for copper ore in India. It is a vertically integrated company and is the only integrated producer of refined copper. The major activities of HCL cover mining, ore beneficiation, refining and casting of refined metal. It has four units- one each in Jharkhand, Madhya Pradesh, Rajasthan and Maharashtra. Listed on BSE and NSE, Govt of India owns 90% equity in HCL.

CHAPTER 3

METHODOLOGY

3.1 SAMPLE COLLECTION

Soil Samples were collected from the Malanjkhand copper mining region. Nineteen soil samples were collected and the coordinates of the sampling site was noted with hand-held GPS. Spatula was used to collect the samples and they were stored in self-locking polythene bags. The samples were air dried at room temperature (25°C) for a length of 2 days. This was done to remove the external moisture. Approximately 100 gm soil for each sample was ground and sieved through -200 mesh size. The storage of the samples were done in polyethylene bags for analysis.

3.2 SAMPLE ANALYSIS

The pH was measured by using calibrated ORION 1260 Ion selective electrode from a mixture of 10 g soil with 25 ml of deionised water (conductivity 1 µS/cm) and stirred with a magnetic stirrer. The EC was measured using the same procedure but from a mixture of soil:deionised water at 1:5.Organic carbon in selected soil and sediment samples were determined following Walkley and Black (1934).

The concentrations of Cu in soil was determined by AAS (Perkin Elmer Aanalyst 200) after digestion (Figure 3.1) using combination of concentrate HNO_3, HCL and $HClO_4$ as shown in Figure 3.2.

Fig. 3.1 Heating the soil sample inside Fume Hood during soil digestion

Figure 3.2 Measurement of copper in Atomic Absorption Spectroscopy (AAS)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS AND DISCUSSION

Experiments were done to find out the properties of soil, which includes pH, electrical conductivity and organic carbon content (Table 4.1). The maximum and minimum pH values of the soil samples was found to be 7.1 and 4.29. The average value of pH was 5.87. The acidic pH of the soil is due to the impact of mine drainage which is highly acidic (Pandey, et al. 2007). Similarly, the average value of electrical conductivity (EC) came out to 83.40 µS. cm^{-1}. The maximum value of EC was 876 µS.cm^{-1} while the least EC was 17.42 µS.cm^{-1}. The maximum organic carbon percentage was 1.59 while the least value was 0.66. The range of organic carbon (OC) in soil varied from 0.66 to 1.5 percent. The average OC came out to be 0.97 percent.

It was observed that the copper content in soil ranged between 15120 ppm to 30.46 ppm. It is interesting to note that the soil sample from the site just below the waste dump showed the highest copper concentration. The maximum tolerance limit of Cu in soil is 100 ppm (Kabata-Pendias and Pendias, 1984). Copper concentration in soil near the waste dump and close to nalla carrying the mine effluents has exceeding the maximum tolerance limit while away from the creeks, Cu concentration is within the tolerance limit.

Table 4.1 pH, Electrical Conductivity (EC) and Organic Carbon (OC) values of the soil samples.

Sample	**pH**	**EC (µs/cm)**	**OC%**
MS1	5.48	876	1.60
MS2	5.88	28.1	1.14
MS3	5.59	59.2	1.09
MS4	4.92	34.9	0.99
MS5	5.89	22.23	0.80
MS6	7.06	31.8	1.15
MS7	5.65	56.5	0.78
MS8	6.65	61.1	1.12
MS9	7.1	33.1	0.81
MS10	4.29	21.09	1.26
MS11	6.19	28.11	0.75
MS12	6.02	131.1	1.09
MS13	6.01	21.76	1.08
MS14	6.23	46.8	0.75
MS15	5.45	27.38	0.80
MS16	4.61	39.7	0.71
MS17	6.07	17.42	0.86
MS18	6.77	23.18	0.68
MS19	5.81	33.5	0.67

Index of geoaccumulation (I_{geo}) is used to determine the contamination by comparing the current and pre-industrial concentrations originally used with bottom sediments (Muller 1969). This is also be used to assess the soil contamination of an area. It is calculated using the equation given below:

$$I_{geo} = \mathrm{Log}(C_n / 1.5\ B_n)$$

Here, C_n is the concentration of the element in the sample and B_n has been taken to be 35. B_n can be either directly measured in texturally equivalent uncontaminated soils or taken from literature. The constant in the equation enables the analysis of natural fluctuations in the content of a given substance in the environment and very small anthropogenic influences. I_{geo} consists of seven grades ranging from unpolluted to very seriously polluted (Table 4.2) (Muller 1969).

Enrichment Factor is used to classify mineral ore bodies. It is defined as the minimum factor by which the weight percent of mineral in an ore body is greater than the average occurrence of that mineral in the Earth's crust. It can be used to compare the necessary enrichment of different types of minerals. It is calculated by the following equation:

$$\mathrm{EF} = {}^{C_n}/_{B_n}$$

Where, C_n is the concentration of the element in soil, B_n is the content of examined element in the reference environment. EF consists of five grades ranging from depletion to extremely enriched (Table 4.3) (Sutherland 2000).

Table 4.2 Index of geoaccumulation (I_{geo}) and contamination level (Muller 1969)

I_{geo}	I_{geo}	**Contamination Level**
<0	0	Uncontaminated
0-1	1	Uncontaminated to moderately contaminated
1-2	2	Moderately contaminated
2-3	3	Moderately to strongly contaminated
3-4	4	Strongly contaminated
4-5	5	Strongly to extremely contaminated
>5	6	Extremely contaminated

Table 4.3 Enrichment factor (Sutherland 2000)

Level	**Enrichment Factor**
<2	Depletion to minimal enrichment suggestive for or minimal pollution
2-5	Moderate enrichment, suggestive of moderate pollution
5-20	Significant enrichment, suggestive of a significant pollution signal
20-40	Very highly enriched, indicating a very strong pollution signal
>40	Extremely enriched, indicating an extreme pollution signal

The enrichment factor ranged from 604.8 to 1.21. This highlights that soil closer to contaminating sources, like the waste dump and nallas, are extremely enriched with copper. This indicates alarming level of contamination in these areas. Most of the other areas slightly or far away from the contaminating sources have moderate to strong contamination. Further, the index of geoaccumulation varied between the ranges of -0.23 to 2.45. Using this data of $I_{geo,}$ it can concluded that soil in the area is moderately contaminated.

Table 4.4 Enrichment factor and index of geoaccumulation of soil samples

Sample Name	**EF**	**I_{geo}**
MS-1	604.80	2.46
MS-2	38.83	1.27
MS-3	25.25	1.08
MS-4	10.03	0.68
MS-5	3.63	0.24
MS-6	2.36	0.05
MS-7	1.96	-0.03
MS-8	5.66	0.43
MS-9	45.16	1.33
MS-10	1.87	-0.05
MS-11	1.33	-0.20
MS-12	15.46	0.87
MS-13	1.76	-0.08
MS-14	126.72	1.78
MS-15	1.40	-0.18
MS-16	7.97	0.58
MS-17	1.24	-0.23
MS-18	1.46	-0.16
MS-19	1.22	-0.24

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

The mining and processing activities at Malanjkhand releases large quantities of waste in the form of tailings, waste water, particulate matter and dust. The copper content was excessively high in the area close to the waste dump. The parameters of EF and I_{geo}, both enable us to conclude that soil in the area is moderately to severely contaminated with copper. However, certain sampling sites close to the waste dump and the nallas are extremely enriched with copper. It can also be assessed that the soil is predominantly acidic in nature. The two nallas, carrying the waste water, contaminate soil over a large area surrounding the mine. Thus, the copper contamination has a significant impact on the environment around the Malanjkhand Copper Mine.

CHAPTER 6

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