ROLE OF ALGAE IN DISCHARGE FROM MALANJKHAND COPPER MINE

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

BACHELOR OF TECHNOLOGY
IN
MINING ENGINEERING

BY

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Declaration

We hereby declare that this thesis is our own work and effort. This work is being submitted for meeting the partial fulfilment for the Degree of Bachelor of Technology in Mining Engineering at National Institute of Technology, Rourkela for the academic session 2011 – 2015.

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Certificate of Approval

This is to certify that the thesis entitled "**Role of Algae in discharge from Malanjkhand Copper mine**" submitted to the National Institute of Technology, Rourkela by **KEDAR CHANDRA BISOI,Roll No. 111MN0605** and **CHANDAN KUMAR BARIK**, **Roll No. 111MN0581** for the award of the Degree of Bachelor of Technology in Mining Engineering is a record of original research work carried out by them under my supervision and guidance. The results presented in this thesis has not been, to the best of my knowledge, submitted to any other University or Institute for the award of any degree or diploma. The thesis, in my opinion, has reached the standards fulfilling the requirement for the award of the degree of Bachelor of technology in accordance with regulations of the Institute.

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ABSTRACT

Acid mine drainage (AMD) is a potentially severe pollution hazard caused by mining activities and can contaminate surrounding soil, ground and surface water. The AMD effluents contain high concentration of heavy metals which are toxic to aquatic organisms. Various species of algae are the natural residents of AMD and are capable of accumulating and thereby help in removing the metal contents in the AMD affected water bodies. This study aimed at finding the metal contents in discharge from MalanjkhandCopper deposit, located in north east of Balaghat, Madhya Pradesh and to determine the efficiency of algae present in the same discharge with reference to heavy metal accumulation in their biomass. Water and algae samples were collected from the waste rock leachate near the Malanjkhand copper deposit.And were analyzed for iron, copper, zinc, nickel, lead, calcium and magnesium by atomic absorption spectrophotometer (AAS). The algae samples were found to have significantly higher amount of copper, iron, nickel and zinc as compared to the water samples which indicated the accumulation of metals in algae.

KEYWORDS: AMD, heavy metal concentration, algae, water, Malanjkhand, AAS, discharge

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CHAPTER-1

INTRODUCTION

1.1. INTRODUCTION

Mining is one of the most common activities since ancient times and it will continue to remain so in this modern world. It plays a vital role in the economies of many developing and developed nations. Mining operations include practices such as overburden removal, crushing of ores, separation of metal concentratesmill tailings etc leading to environmentalproblems**(Ahmad et al., 1994).**Mining influences the water administration of the zone in number of ways, aggravating the regular seepage example, bringing down of water table, contamination of surface and sub-surface water bodies **(Sheoran et al., 2011).**Acid Mine Drainage (AMD) and the contaminants connected with it is the most constant environmental dilemma worldwide, which can contaminate surrounding soil, surface and ground water **(Singh, 2005).** It generally refers to the outflow of acidic water from coal or metal mines. It is formed when sulphide minerals present in the rocks get oxidized in the presence of water and oxygen to form highly acidic water rich in sulphate content. The effect of AMD on neighboring streams and waterways can be dramatic. AMD contaminated water bodies are characterized by low pH value and high concentration of heavy metals which is toxic to algal organisms **(Ackil et al., 2006).** However they harbor acidophiles. Acidophilic algae can tolerate a high amount of acidity and can grow at a pH as low as 0.05 **(Gross, 2000).Kaonga et al. (2008)** reported higher concentration of heavy metals in algae "*Spirogyra aequinoctialis*" than in corresponding AMD affected water. **Verb and Vis(2005)** reported predominance of algae like "*Microspora sp."* in AMD streams.

Malanjkhand copper deposit is an open cast copper mine situated in Malanjkhand whose coordinates are 22º0'54''N and 80º43'20''E. It is the greatest base metal copper open pit mine in India. It is located at a distance of 90 Km North East of Balaghat in Madhya Pradesh, at an elevation of 576mRL (meters Reduced Level). It is situated in the tehsil of Bihar, which is 22 Km far away from the project, while in transit to the locale town, Balaghat, Madhya Pradesh. Water bodies near this area showed high concentration of heavy metals, low pH, high BOD and low dissolved Oxygen.

The present study deals with concentration of heavy metals in the AMD affected water bodies and accumulation pattern of these heavy metals in the algae present in these water bodies.

1.2. OBJECTIVES-

With the above background in mind, the project work is aimed to:

1. Study the occurrence of algae in AMD environment
2. Find the metal contents in the AMD impacted water and the efficiency of algae to accumulate metal contents in its biomass.

CHAPTER-2

LITERATURE REVIEW

2.1. ACID MINE DRAINAGE

Acid mine drainage (AMD) is a serious environmental problem in many parts of the world. It generally refers to outflow of acidic water from coal or metal mines and is formed when certain sulphide minerals (as mentioned in Table 2.1) present in rocks are exposed to oxidizing condition in presence of water. The acid formed is generally carried from the mine site to the nearby lakes, streams and other water bodies by surface runoff or by rainwater. AMD is generally characterized by low pH values and high concentration of heavy metals which has adverse effects on aquatic ecosytsems, corrosion of mining machineries and other environmental degradation.

The chemical reactions that can represent the entire process of weathering of sulphide minerals such as pyrite to form AMD is as follows (Manahan, 1991):

$$2FeS_2(s) + 2H_2O + 7O_2 \rightarrow 4H^+ + 4SO_4^{2-} + 2Fe^{2+} \quad \text{(a)}$$

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O \quad \text{(b)}$$

$$2FeS_2(s) + 14Fe^{2+} + 8H_2O \rightarrow 15Fe^{3+} + 2SO_4^{2-} + 16H^+ \quad \text{(c)}$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3(s) + 3H^+ \quad \text{(d)}$$

In step (a), S_2^{2-}gets oxidized to form H^+ ions and SO_4^{2-} ions and Fe^{2+} is also formed which is free to react further. In step (b), ferrous ion (Fe^{2+}) is oxidized to form ferric ion (Fe^{3+}) and this oxidation process occurs more slowly at lower pH values. At pH value between 3.5 and 4.5, the oxidation process is catalyzed by a filamentous bacteria*,"Metallogenium"* and at pH value less than 3.5, the oxidation process is catalyzed by a microorganism, "*Thiobacillusferroxidans*". In step (c), ferric ion reacts with pyrite to form more acid. In step (d), ferric ion precipitates as iron hydroxide, which is also known as "yellow boy", as it is recognized as the deposit of amorphous, orange, yellow or red deposit on stream bottoms.

Table - 2.1: Sulphide minerals responsible for acid genearation (**Ferguson and Erickson 1988**)

Sulphide	**Formula**
Pyrite	FeS_2
Pyrrhoite	Fe_xS_x
Chalcopyrite	$CuFeS_2$
Covelite	CuS
Molibdenite	MoS_2
Galena	PbS
Sphalerite	ZnS
Cinnabar	HgS

Lottermoser (2012) reported the factors responsible for the rate of AMD generation. AMD generation depends on

1. **Amount of oxygen present**- Sulphide minerals oxidise more quickly when there is more availability of oxygen. Hence, rate of AMD generation is higher when sulphide minerals are exposed to air than where they are buried in soil or water.
2. **Surface area of sulphide minerals exposed**- Increasing the surface area of sulphide minerals exposed to air and water, increases the rate of sulphide oxidation. Hence, rate of AMD generation is more when exposed surface area of sulphide minerals is more.
3. **Temperature –**Temperature plays a vital role in determiningthe rate of oxidation of sulphide minerals. Not all sulphide minerals oxidize at same rate at a particular temperature. For ex- Pyrite oxidation occurs most quickly at the temperature around 30^0c.

4. **Amount of water available**- Cycles of wetting and drying quicken AMD generation by dissolving and uprooting oxidation products, leaving a fresh mineral surface for

oxidation. In fact, greater volumes of AMD are often produced in wetter areas where there is more water available for reaction.

5. **Types of minerals present-** Not all sulphide minerals oxidize at same rate & neutralization of other minerals present may occur which would slow the rate of production of AMD.
6. **Microorganisms present-** Some microorganisms are able to accelerate the AMD production. For ex- "*Acidithiobacillusthiooxidans*" and "*Acidiithiobacillusferrooxidans*" help in oxidizing Fe^{2+} to Fe^{3+}.

2.3. CHARACTERISTICS AND IMPACTS OF AMD

1) **pH -** It is the measure of concentration of free hydrogen ions in solution and is used to indicate the acidity of the solution. Low pH is the major characteristics of AMD. When the pH of water decreases, solubility of metal ions such as iron, copper etc increases. Low pH causes a disturbance of sodium and chloride ions in the blood of aquatic animals. If pH falls below the tolerance range, then it can cause death due to respiratory or osmo-regulatory failure **(Kimmel,1983).**

2) **Sulphate-** AMD commonly contains high concentration of sulphate content. The problem is it has the affinity to produce strong acids which changes the pH. Also helps in precipitation reactions which affects the solubility of metals and other substances (**Singh, 1992).**

3) **Metal ions-** Heavy metal ions can increase the toxicity of the AMD. Trace metals such as zinc, cadmium & copper are very toxic at extremely low concentration & suppress the growth of aquatic ecosytsems. Most common heavy metals include: copper, nickel, lead, arsenic etc that leads to adverse effects of AMD **(Hoehnand Sizemore. 1977).**

4) **Turbidity-**It refers to haziness or cloudiness of a fluid caused by the individual particles present in large number. Fine particulate mineral matter enters surface water increasing turbidity & dependent upon flow rate & rate of sedimentation (**Kelly,1988).**

5) **Precipitate formation**- As pH increases, dissolved iron and other metals present in the receiving water may precipitate. This occurs when water way is diluted with surface water or at a confluence with less acidic stream **(Niyogi et al., 1999).**

Ex- $Fe(OH)_3$ and $Al(OH)_3$ precipitate above pH 3.5 and 4.9 respectively.

2.4. ACID MINE DRAINAGE IN INDIAN MINING INDUSTRY

AMD is a major environmental concern in Indian mining scenario. Some of them are as follows:

1) **Copper mines:** According to a data published by Multi Commodity Exchange, in 2012, India's production of refined copper is 689,312 MT, which is around 4% of the total world production. The major producers of coper in India are Hindalco, Sterlite and Hindustan Copper Limited. The copper mining is being carried out by Public sector undertaking Hindustan Copper Limited at Khetri in Rajasthan, Masoboni group of mines in Bihar, Malanjkhand (Madhaya Pradesh), Sikkim and in several small mines from Karnataka. (**Pandey et al., 2007)** observed AMD problems at Malanjkhand copper mines. Mine drainage from the mines was found to be highly toxic. Various sources of AMD are heap leaching sites and tailing areas. Here, around $14400m^3$ water per day gets contaminated by liquid effluents. Metal leaching effects result in the elevated level of other heavy metals viz. Au, Ag, Pb, Cr, Cd ,Fe, Cu and base metals like Na and K in AMD impacted water and sediments . AMD at present site is principally caused by the oxidation of pyrite and pyrhotite and the subsequent ferric iron induced dissolution of chalcopyrite etc. The mean concentration of copper was 5892.73 ppm, cadmium was 4.43 ppm, zinc 322.24 ppm, nickel iwas 129.99 ppm, chromium was 123.13 ppm, iron 1.50 ppm, manganese is 161.71 ppm, molybedum 14.14 ppm, silver 0.15ppm and sulphates 3128.57 ppm in AMD

impacted water much above the permissible limits and a mean pH of 2.7. **(Pandey et al.,2007)**

2) **Manganese mines:**India is one of the major produers of Mn. **Choudhary and Kundargi, (1994)**reported highly acidic effluents of pH ranging from 4.5-5.0 with rich in heavy metal ions from DongriBuzurg mine at Bhandara and number of other mines of Balaghat district of central India.

3) **Coal mines:** As on April 1, 2012, India had 293.5 billion metric tons (323.5 billion short tons) of the resource. The production of coal was 532.69 million metric tons (587.19 million short tons) in 2010-11 and lignite production was 37.73 million metric tons (41.59 million short tons) in 2010-11. As on 2011, India ranked 3rd in world coal production. The major source of coal is Coal India Limited (CIL), a public sector undertaking of the Indian Government. **Dubey and Nath, (2007)** reported over one thousand abandoned quarries/subsided areas in the coalmines in India which are still giving continuous rise to AMD. (**Tiwary, 2001)** reported AMD problem in Western coalfields, Northern coalfields and North eastern coalfields. He reported that pH varies from 2.81 to 6.03, sulphate concentration varies from 400 to1948 mg/Land concentration of iron varies in between2.0-51.03 mg/L at Chandmeta colliery. The acidic water problems have been reported in Northern coalfields effluents with pH in the range of 1.53-6.65 and parameters like SO4, TDS and Fe are found to be 418 to 1678 mg/L, 380 to 2324 mg/L and 32.7 to 84.3 mg/L respectively. Water contaminated by AMD in North Eastern Coalfields are highly acidic having pH between 2.85 to 4.30; concentration of SO4, TDS and Fe in the range of 591-881 mg/L, 825-1012,mg/Land86-50.79 mg/L.

4) **Iron mines:** The total recoverable reserves of iron ore in India are about 9,602 million tonnes of hematite and 3,408 million tonnes of magnetite. The major Indian producers of iron ore areMadhya Pradesh, Jharkhand, Odisha, Chattisgarh, Goa, Maharashtra, Karnataka, Andhra Pradesh, Rajasthan,Kerala and Tamil Nadu. The present mining rate of iron ore is 16-21 million tonnes per annum. **Desai, (1990) and Ratha et al. (1994)** reported that the ground water samples from the mining areas of Goa are highly toxic and highly acidic in nature. Sulphate have been reported to be 435 mg/l, on the other hand acidityhas been reported to be 34 mg/l. Iron ore mines

generally produce more than 6.5 million tonnes of waste per year containing high level of metals like iron, manganese, chromium, zinc, lead etc.

5) **Zinc mines**:India's current primary production of zinc is 2,00,000 tonnes per annum and secondary production is 50,000 tonnes per annum. Hindustan Zinc Limited and Vedanta group have several operative mines and smelting facilities. Mining for zinc is carried out in India at Zawar group of mines near Udaipur, Rajpura-Dariba near Bhilwara in Rajasthan, Agnigundla in Andhara Pradesh and Sagipalli in Orissa. At Zawar group of mines about 1.1million tonnes of waste is produced in the form of tailings every year, which is discharged in slurry form in the tailing dams. Zinc was reported to be 80.0mg/l from the seasonal river Tidi.
6) **Gold mines: Krishna and Gejji(2001)** that gold mine at Kolar field generates around 32 million tonnes of tailings from mining and processing of ore. **Rao and Reddy, (2006)** reported that the pyrite mine tailings at Kennedy's line dump area of Kolar gold field are potential source of contamination as they could release acid drainage to the subsurface environment. The low pH of 3.6 is recorded on the surface of Kennedy's linedeposit.Sulphate content is also reported to be higher than the permissible limit.
7) **Lignite mines:** 80% of India's lignite resource is at Neyveli in Cuddalore district of Tamil-Nadu state. AMD problem is reported at the Neyveli lignite mine with high concentration of heavy metals like zinc, lead, mercury, chromium, cobalt, nickel, copper are present in the waste water discharge from the mine pits, fly ash ponds and industrial effluents. The recorded concentration of Hg is 0.084 Mg/L, Cr is 0.275 Mg/L and Co is more than 0.05 Mg/L much above the permissible limit**(Khan et al2005).**

2.5. OCCURENCE OF ALGAE IN ACID MINE DRAINAGE ENVIRONMENT

Low pH of AMD contaminated water is highly toxic to algal organisms **(Bortnikova et al., 2001).** But they harbor "acidophiles" **(Novis and Harding, 2007)**. Acidophiles are the type of algae which can sustain under highly acidic conditions (usually at pH 2.0 or below). Most acidophiles have evolved efficient mechanisms to pump proton out of their intracellular space in order to keep cytoplasm at or near neutalpH. Various mechanisms adapted by acidophiles to sustain in AMD environment are as follows:-

1. **Proton motive force**- Acidophiles harness proton motive force(PMF) caused by the pH gradient across their cell membrane to produce ATP. A large amount of energy is produced by acidophiles through proton movement across their membrane. Inorder to keep the acidity in check in cytoplasm, sodium ions are used as substitute energy transducer instead of H^+ ions **(Barker-Austin and Dopson, 2007).**

2. **Expelling H^+ contain vesicles**- Alternatively, acidophiles use H^+ containing vesicles to avoid cytoplasmic acidity. But H^+ ions must be taken to thrust out after use in electron transport chain (ETC) **(Barker-Austin and Dopson, 2007).**

3. **Improved repair-**Acidophiles also gets benefitted from improved DNA & protein repair systems to sustain in acidic environment **(Barker-Austin and Dopson, 2007).** For ex-"*P.torridus"*contains a large numbers of genes concerned with repair proteins.

2.6. INFLUENCE OF ALGAE IN ACID MINE DRAINAGE ENVIRONMENT

1. **Metal adsorption and absorption**- Heavy metal adsorption and absorption by algae is highly variable and it depends on the metal, age of material, the taxon and other conditions **(Novis and Harding, 2007).**Some species of algae release a range of ligands such as extracellular polysaccharides(EPS_s) under nutrient stress conditions **(Sutherland, 2005)**. EPS_s composed of macro-molecules like polysaccharides,

proteins, nucleic acids and lipids. EPScontains anionic functional groups (ex-carboxyl, hydroxyl, phosphate etc) that promote ionic and electro-static bonding with other cations including metals **(Ford et al., 1995)**.

For example-*"***siderophores***"*, a strategy for microorganisms to escape cu toxicity.

The role of algae in AMD affected environment with reference to heavy metal accumulation is mentioned in Table-2.2. It has been seen that thicker cell walls of algae species has a better modulated toxicity as compared to thinner wall species. Thicker wall species have more abundant of carboxyl, phosphate or other groups that act as a metal binding agent.

2. **Affects acidity of the solution-** Algae can directly affect the acidity of the solution by natural alkalinity generation via assimilation of nitrate and metal hydroxide precipitation **(Koschorreck and Tittel, 2007).**Assimilation of nitrate by algae means direct production of alkalinity. However, this effect can only be used if the inorganic nitrogen is dominated by nitrate. Because assimilation of ammonium produces acidity. **Van Hille et al., (1999)**reported that the alkalinity generation property of algae "*Spirulina sp*." could be used to precipitate heavy metals in continuous system.

3. **Nutrient source for SRB(Sulphur reducing bacteria)-**SRB_S are typically carbon limited in AMD environment **(Koschorreck, 2008).** They require nutrients for survival, growth and for sulphate reduction and metal precipitation. Algae produce algal bio mass and extracellular products that serve as carbon source for SRBs **(Kalin et al., 2004).**

Table-2.2: ALGAE AND THEIR ROLE IN ACID MINE DRAINAGE ENVIRONMENT

ALGAL SPECIES	ROLE	pH RANGE	HABITAT	REFERENCE
Ulothrix Gigas	Absorb up to 3500 mg/l of Cu & 500 mg/l of As	3.0-4.5	Sarcheshmeh Copper Mine, south-eastern Iran	Orandi et al, 2007
Microspora Quadrata	Absorb high concentration of toxic metals like iron and lead	3.13-4.35	Coal mine areas of Jaintia hills, Meghalaya, India	Das and Ramanujam, 2011
Dunaliellasalina	Accumulate high concentration of Zn, Co and Cu (i.e upto 15 ppm)	1.0-5.0	Lake Mariut, Egypt	Magda, 2008
Cladophora Glomerata	Accumulate Uranium concentration (20-400 µg/g dry wt.)	6.0-8.0	Downstream areas of Uranium mines, Neuensalz, Germany	Dienemann et al. 2002; Kalin et al. 2005;Vogel et al. 2004
Sargassum species	Can absorb Cu(II) & Cd(II) from aqueous solution	3.0-5.0	North-eastern coast of Brazil	Antunes et al., 2003; Hashim and Chu, 2004
Scenedesmus bijuga	Can absorb Co^{2+}, Cu^{2+} and Cd^{2+}(ranging from 10^{-3} to 10^{-9}M)	4.0-12.0	River Nile, Egypt	Kuhl, 1962

Chlorella sp.	Can tolerate higher concentration of Ni and Cu	4.0-10.0	Nearby lakes to Sudbury smelter, Ontario, Canada	Stokes et al., 1973
ScapaniaUndulata	Can accumulate high concentration of Pb, Zn and Hg in shoots	6.2-6.5	Stream water at Greenside mines, England	Satake et al., 1988
Klebosormidium	Found to have 4,016 mg/kg(dry wt.) iron concentration	2.9-5.6	AMD waters in South-eastern Ohio, United States	Stevens et al. 2002
Ulva intestinalis	Can accumulate high concentration of Mn(84.49-339.29µg/g dry wt.), Cu(44.65µg/g dry wt.) and As(49.14-69.29µg/g dry wt.)	9.5-10	WadiHanifah stream, Riyadh, Saudi Arabia	Ali et al., 2011
Lemaneafluviatilis	Can accumulate large amount of zinc in filaments	6.0-7.0	River Derwent, England	Harding, 1978
Pinnulariaacoricola	Can tolerate high concentration of As, Cd, Cu, Fe and Mn	2.6-3.3	Acidic Stream (Contamated by coal mine waste), U.K	Kwandrans, 1997
Navicula species	Can absorb high concentration of Zn and Cu	6.0-8.0	Mountain streams, Canada	Benchraka, 2014

2.7. MALANJKHAND COPPER DEPOSIT

Malanjkhand copper deposit is an open cast copper mine situated in Malanjkhand whose coordinates are 22º0’54’’N and 80º43’20’’E. It is the greatest base metal copper open pit mine in India. It is located at a distance of 90 Km North East of Balaghat in Madhya Pradesh, at an elevation of 576mRL (meters Reduced Level). It is situated in the tehsil of Bihar, which is 22 Km far away from the project, while in transit to the locale town, Balaghat, Madhya Pradesh.

Malanjkhand copper venture was secured in the year 1982. Hindustan Copper Limited set up the starting venture for the exploitation of the copper ore through open pit mine. Geological Survey of India took precise exploration at this deposit in the year 1969. It is the biggest open cast copper mine in Asia. The copper deposit in Malanjkhand is presently in the exploitation phase which is carried out by M/s Hindustan Copper Limited. The zone of mineralization could be found in the more or less 2.6 Km long arcuate Malanjkhand slope (height around 600 m above m.s.l.) **(GSI, 1994).**

The cellar rocks have an overlying Precambrian metasediments of Chilpi Ghat Series with an erosional unconformity. The granitic rocks extend in creation from a biotite granite to quartz diorite and they are very kaolinised, seriticised and saussuritised in the mineralised zone. The quartz reefs, connected with the rocks have a restricted copper mineralization **(Pandey et al., 2007).**

The sulfide minerals are seen basically along the shear and crack planes in the quartz reefs. The minerals in decreasing order of abundance are chalcopyrite, pyrite, magnetite, sphalerite, chalcocite, bornite, molybdenite and cobaltite. Chalcopyrite and pyrite make up to 95% of the sulfide minerals **(GSI, 1994).**

The ore zone has a strike length of around 1.9 km with a normal width of about 65 m. and dips at an angle of about 60° towards east. Arout 68,000 m. of drilling has been done along 27 cross section lines spaced 80 mt to 120 mt apart.

The drilling investigations were done by GSI, MECL and the mine development was done by Hindustan copper limited. The reserves accessible upto 600m beneath the surface was 236.4

million tons at 1.28 percent copper out of which 145.7 million tons were proven, 50.4 million tons were regarded as probable and 40.3 million tons as possible reserves **(GMRI, 2009).**

Copper ore having about 1.05% copper content is subjected to ore processing which includes various techniques like grinding, crushing, floatation, thickening, and filtration and it delivers a copper concentrate which has about 25% copper. In the beneficiation process 5-7% of ore are changed to concentrate and the rest are tossed as tailings which checks 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 advances the quantity of copper ore tailings continue to increase**(Pandey et al., 2007).**

CHAPTER-3

METHODOLOGY

3.1 SAMPLE COLLECTION

Water samples and algae were collected from different points from the waste rock leachate near the Malanjkhand copper deposit. Water samples were collected from 7 different locations and at each sampling point, water samples were filtered and collected separately for heavy metal analysis purpose and for analysis of other physio-chemical properties. Water samples collected for heavy metal analysis is acidified with concentratic nitric acid to reduce the pH.Similarly, algae samples were collected from 7 different locations and at each point, some amount of algae were stored in 4% formalin and the remaining amount of algae sample were rinsed with water to remove debris and stored in specimen bottles.

3.2 LABORATORY ANALYSIS

3.2.1. PHYSIO-CHEMICAL PROPERTIES STUDY

Physio-chemical properties such as pH, Eh and EC of water samples were measured by using ORION electrodes. While operating the instrument, the manufacturer's recommendations for the instrument warm up and operation were followed. The electrode was gently shaken to remove air bubbles from the sensing tip of the electrode. The electrode, thermometer and measurement beaker was rinsed with distilled water but excess moisture from the electrode was not wiped. The electrode was calibrated with buffer solution and then set to measurement mode and was placed into sample water to measure the readings.

3.2.2. ELEMENTAL STUDY

Cleaned algal samples were air dried in oven. Total concentration of Cu, Pb, Zn, Fe and Ni was measured using Atomic absorption spectrophotometer (AA-200) after the digestion of algal samplesinside a fume hood using an acid mixture of nitric acid, perchloric acid and distilled water.

Similarly, total concentration Cu, Pb, Zn, Fe and Ni in the sample waters were determined by running samples on AAS (AA-200).

CHAPTER-4

RESULTS AND DISCUSSIONS

4.1. PHYSIO-CHEMICAL PROPERTIES OF WATER SAMPLES

The physio-chemical properties of water samples as determined in the laboratory is mentioned in Table-4.1. The pH value of water samples vary from 4.47 to 6.34. The Eh and ECvalue of water samples vary from 291.6mVto 380.1mV and 281.4μS/cm to 2678μS/cm respectively.

Table-4.1: Physio-chemical properties of sample waters

Sl. no.	**Sample id**	**pH**	**Eh(mV)**	**EC(μs/cm)**
1	MW-1	4.47	380.1	1843
2	MW-2	5.11	367.5	1995
3	MW-3	5.24	363.6	1837
4	MW-4	4.91	382.3	2678
5	MW-5	5.21	367.5	2013
6	MW-6	5.75	339.9	1351
7	MW-7	6.34	291.6	281.4

4.2. HEAVY METAL CONCENTRATION IN SAMPLE WATERS

The heavy metal concentration in water samples is given in Table-4.2. It was observed that the concentration of Cu varied from 17.1 to 160 mg/L, the concentration of Fe varied from 0.039 mg/l to 0.145 mg/l, the concentration of Zn varied from 0.001 mg/L to 0.556 mg/L and the concentration of Ni varied from 0.007 mg/L to 0.122 mg/L.

Table-4.2: Total concentration of heavy metals in sample waters

Sl.no.	Sample id	Cu^{2+}(mg/l)	Fe^{3+}(mg/l)	Zn^{2+}(mg/l)	Ni^{4+}(mg/l)	Pb^{2+} (mg/l)
1	MW-1	29.75	0.094	0.255	0.06	BDL
2	MW-2	32.6	0.129	0.245	0.055	BDL
3	MW-3	30.4	0.073	0.253	0.054	BDL
4	MW-4	159.6	0.062	0.556	0.122	BDL
5	MW-5	44.6	0.145	0.262	0.058	BDL
6	MW-6	17.1	0.039	0.146	0.036	BDL
7	MW-7	0.039	BDL	0.001	0.007	BDL

BDL- below detection limit

4.3. HEAVY METAL CONCENTRATION IN ALGAE SAMPLES

An algae contains Cu (13%), Fe (7.5%), Zn (525 mg/L), Ni (260mg/L). In the present study, it is quite evident that algae samples collected from the AMD affected water bodies have significantly higher amount of copper, iron, nickel and zinc as compared to the water samples which indicated the accumulation of metals in algae. **Rai et al(1981)** reported accumulation of metals in algae in larger amount as compared to its surrounding water. **Lamai et al(2005)** reported lead and cadmium accumulation in algae "Cladophora fracta" at different concentrations. Similarly **Okuo et al (2006)**reported the efficiency of algae "Spirogyra" to remove copper and chromium ions from aqueous solution. All these reports are in favour of the present study that various algae are capable of accumulating different types of metals.

CHAPTER-5

CONCLUSION

It is evident from the present work that water bodies near Malanjkhand copper deposit is characterized by low pH and high concentration of heavy metals.This study has shown that various algae thriving on AMD affected water bodies at Malanjkhand are capable of accumulating different types of metals and have the efficiency to remove toxic metals from the AMD affected water bodies. In the present study, it is quite evident that algae samples collected from the AMD affected water bodies have significantly higher amount of copper, iron, nickel and zinc as compared to the water samples which indicated the accumulation of metals in algae. These algae can be used to extract trace metals through bio-leaching and it also offers solution for the phenomenon of acid mine drainage in mining spoils. The present study has clearly suggested “the influence of algae in AMD environment” with reference to heavy metal accumulation. In addition, identification of metals by algae gives better precision as compared to that of its surrounding water.

CHAPTER-6

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