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# Assessment of mine water quality and its utilization (recycle and reuse)

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**A R T I C L E I N F O**

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**A B S T R A C T**

There are tremendous mining activities are being carried out in several parts of India i.e. in Orissa, Jharkhand, Chattisgarh, Karnataka, Rajasthan and Tamil Nadu. Mining activities are generally carried out for the utilization of the resources like coal, minerals, ores, dolomite, lime stone and alumina. These resources are very much essential for the developmental activities connected with the relative industries and economic development of the country as a whole. However, these activities pose environmental implications during the process of exploitations and excavations creating environmental problems in different ways if not carried out in a scientific and sustainable manner. There are many causes arising due to the exploitation and exploration in mining activities related to the creation of environmental pollution *i.e.* starting from deforestation, changes in drainage pattern, emission of dust, subsidence, generation of mine water, erosion, creation of over burden, and also changes in degradation of surface soil, increase in noise level, vigorous transportation activities, creation of ponds (when the activities are for open cast mining). Mining activities disturb the hydrological regime where a lot of water is pumped out during the process of operation and creates water pollution problem. The paper highlights some of the water pollution problem associated with the mining activities, it's recycle and reuse.

**K E Y W O R D S**

Mining | Minerals | Water | Waste Water | Quality | Recycle and Reuse

**C I T A T I O N**

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## Introduction

Water is a prime natural resource (surface and ground), a basic human requirement for the survival of mankind. Considering the global land availability, India accounts for 2.2 % of the global land, 6 % of water resources supporting 16% of the world population based on per capita consumption of water India shows the lowest availability as per the comparison of the major nations like Canada, USA, France, China, Australia and Sweden, however with the increase in population and industrial growth the water requirement has increased tremendously now a days and the resources both surface and ground water are depleting rapidly and emerging the scarcity. Considering the total availability of water in the globe *i.e.* about 97% of all the water is saline, 2.5–2.75% is fresh water, including 1.75–2% frozen in glaciers, ice and snow, 0.5–0.75% as fresh groundwater and soil moisture, and less than 0.01% of it as surface water in lakes, swamps and rivers the fresh water availability is very less.

Out of the availability, the resources are also being polluted due to the industrial as well as domestic waste discharges into the surface water bodies as well as land disposals creating ground water pollution and emerging scarcity of clean and potable drinking water in the recent years. Therefore, it has become essential to look into the limited use of water and also adoption of recycle and reuse of industrial and domestic waste water after treatment.

| **Underground Mine water** | | | | |
|---|---|---|---|---|
| Neutral to Alkaline Mine waters (pH=7.0 and above) | | | Acidic Mine Waters (pH=2.0 to 7.0) | |
| (A-1)<br>Soft Alkaline<br>(pH=7.5 to 8.5) | (A-2)<br>Hard Alkaline<br>(pH=7.0 to 8.5) | (A-3)<br>Highly Saline<br>(pH=6.0 to 8.0) | (B-1)<br>Soft, Slightly Acidic<br>(pH=5.0 to 7.0) | (B-2)<br>Hard, Highly Acidic<br>(pH=2.0 to 4.5) |

**Table 1:** Classification of water from Underground mines

As mentioned earlier, in India mining activities are spread up to explore the availability of ores and minerals used for manufacturing of different products required for day to day developmental activities and also for the economic growth of the country. However these mining activities are creating major environmental problems related to air, noise, water and land environmental components. Out of these, water pollution is the major one created during the mining activities. The mine water is produce in large quantity depending on type of ores or minerals to be extracted and also during the processing. The mining industries are discharging millions of litres of water every day to the adjacent water courses creating water pollution problems in and around the mining area. Therefore considering the water scarcity problem all over India it becomes essential to first assess the mine water quality and based on that to put it for beneficial use (recycle and reuse).

## Assessment of mine water quality

Several research papers have been published on assessing mine water quality related to different type if mines. A classification of mine water as arrived at on the basic of analysis of mine waters from various coal mines of India is given below (Table 1) Based on the characteristics these are summarized in different categories as shown in (Table 2). Apart from this acidic mine water also creates

sever water pollution problem. Acid mine drainage refers to the distinctive type of waste water originate from the weathering and leaching of sulphide based minerals present in coal and metalliferous ores and overburden. This acidic mine water creates water pollution problems and harmful effects on aquatic flora and fauna if discharged in water bodies and also to human beings if used for domestic purposes. Based on water quality characteristics, the acid mine water quality is categorized as B1 and B2 and shown in Table 3.

| Water Quality Factors | Category of the Alkaline Mine waters | | |
|---|---|---|---|
| | A-1 | A-2 | A-3 |
| **pH** | 7.7-8.5 | 7.0-8.5 | 6.0-8.0 |
| **Alkalinity (mg/l $CaCO_3$)** | 200-7000 | 100-500 | 10-30 |
| **Hardness (mg/l $CaCO_3$)** | 50-150 | 200-1500 | 1000 |
| **TDS (mg/l )** | 300-700 | 500-1500 | 1500-2500 |
| **TSS (mg/l )** | 5-30 | 12-50 | 10-50 |
| **Bio-Chemical Parameters** | | | |
| **DO (mg/l )** | 5.5-8.0 | 5.0-8.0 | 5.0-8.0 |
| **BOD (mg/l )** | <1 | <1-2 | <1-2 |
| **COD (mg/l )** | 8-30 | 15-50 | 15-60 |
| **Element or Ion Content** | | | |
| **Calcium (mg/l )** | 10-50 | 50-200 | 100-150 |
| **Magnesium (mg/l )** | 10-30 | 40-180 | 80-100 |
| **Total Iron (mg/l )** | 0-2 | 0-5 | 0-5 |
| **Sulphate (mg/l )** | 10-100 | 100-800 | 1000 and above |

**Table 2:** Characteristics of Alkaline Mine waters

| Water Quality Factors | Category of the Acid Mine waters | |
|---|---|---|
| | B-1 | B-2 |
| **pH** | 5.0-7.0 | 2.0-4.5 |
| **Acidity (mg/l $CaCO_3$)** | 25-150 | 100-250 |
| **Hardness (mg/l $CaCO_3$)** | 200-500 | 500-3500 |
| **TDS (mg/l )** | 400-800 | 1000-4000 |
| **Bio-Chemical Parameters** | | |
| **DO (mg/l )** | 5.5-8.5 | 3.8-7.5 |
| **BOD (mg/l )** | 1-2 | 1-5 |
| **COD (mg/l )** | 10-60 | 20-100 |
| **Element or Ion Content** | | |
| **Calcium (mg/l )** | 20-80 | 100-250 |
| **Magnesium (mg/l )** | 10-70 | 50-100 |
| **Ferric Iron (mg/l )** | 0-20 | 10-250 |
| **Ferrous Iron (mg/l )** | 200-600 and above | 100 |
| **Trace Elements Al, Cu, Zn, Mg, Ni, Pb, Cr, Sb, etc** | Present in quantities of 0.5 mg/l depending upon other conditions | |

**Table 3:** Characteristics of Acid Mine waters from NEC

In generalized way, as shown in tables 1 to 7, it is observed that mining water typically in large volume release from aquifers during open cast and underground operations is characterized based on the mineral composition of the ore or mineral to be extracted. Even if there is any change in the mineral composition or the ingredients

present reflects reflect the quality of water *e.g.* few percentage of sulphide content in coal or other minerals may convert mine water in acidic condition.

| Test Parameters | 1101 Coal Phase | 1206 Coal Belt Gate (3-L) |
|---|---|---|
| **pH** | 6.2 | 8.27 |
| **EC (µS/cm)** | 156.8 | 151.60 |
| **Turbidity (NTU)** | 90 | 153 |
| **Total Alkalinity (mg/l $CaCO_3$)** | 128 | 133 |
| **Total Hardness (mg/l $CaCO_3$)** | 45 | 70 |
| **$CO_3$ (mg/l )** | 7.20 | 11 |
| **$HCO_3$ (mg/l )** | 180.15 | 210.45 |
| **Fe (III) (mg/l )** | 0.60 | 0.40 |
| **Ca (II) (mg/l )** | 30 | 40 |
| **Mg (II) (mg/l )** | 15 | 30 |
| **Na (I) (mg/l )** | 7.7 | 5.40 |
| **K (I) (mg/l )** | 3.10 | 2.80 |
| **As (III) (mg/l )** | 0.012 | 0.011 |
| **TDS (mg/l )** | 116 | 115 |
| **$SO_4$ (mg/l )** | 1.33 | 1.70 |
| **$PO_4$ (mg/l )** | 1.20 | 1 |
| **$SiO_2$ (mg/l )** | 35.50 | 36 |
| **$NO_3$ (mg/l )** | 0.18 | 0.12 |
| **Cl (mg/l )** | 5.32 | 5.96 |
| **$NH_3$ (mg/l )** | NF | NF |
| **Cd (II) (mg/l )** | 0.05 | 0.028 |
| **Zn (II) (mg/l )** | 0.21 | 0.24 |
| **Cr (III) (mg/l )** | 0.09 | 0.017 |

**Table no 4:** Characteristics of Underground mine waters

| Test Parameters | 1201 Coal Phase | 1106 Coal Belt Gate (3-R) |
|---|---|---|
| **pH** | 8.03 | 7.33 |
| **EC (µS/cm)** | 91.20 | 174.30 |
| **Turbidity (NTU)** | 28 | 34 |
| **Total Alkalinity (mg/l $CaCO_3$)** | 113 | 125 |
| **Total Hardness (mg/l $CaCO_3$)** | 80 | 71 |
| **$CO_3$ (mg/l )** | 9 | 6 |
| **$HCO_3$ (mg/l )** | 145.65 | 177.3 |
| **Fe (III) (mg/l )** | 0.45 | 0.34 |
| **Ca (II) (mg/l )** | 55 | 45 |
| **Mg (II) (mg/l )** | 25 | 26 |
| **Na (I) (mg/l )** | 6.20 | 7.20 |
| **K (I) (mg/l )** | 2.80 | 3.30 |
| **As (III) (mg/l )** | 0.012 | 0.013 |
| **TDS (mg/l )** | 83 | 127 |
| **$SO_4$ (mg/l )** | 1.30 | 1.23 |
| **$PO_4$ (mg/l )** | 1.20 | 1.10 |
| **$SiO_2$ (mg/l )** | 35 | 35.4 |
| **$NO_3$ (mg/l )** | 0.13 | 0.17 |
| **Cl (mg/l )** | 6.39 | 6.03 |
| **$NH_3$ (mg/l )** | 0.25 | 0.17 |
| **Cd (II) (mg/l )** | 0.030 | 0.026 |
| **Zn (II) (mg/l )** | 0.26 | 0.24 |
| **Cr (III) (mg/l )** | 0.012 | 0.015 |

**Table no 5:** Characteristics of Underground mine waters

| Test Parameters | 1203 Coal Phase (2-L) | 1206 R/W Track Gate (2-R) | Mother Rock (R/W) |
|---|---|---|---|
| **pH** | 7.75 | 7.63 | 7.71 |
| **EC (µS/cm)** | 352 | 323 | 403 |
| **Turbidity (NTU)** | 90 | 198 | 27 |
| **Total Alkalinity (mg/l $CaCO_3$)** | 134 | 111 | 145 |
| **Total Hardness (mg/l $CaCO_3$)** | 55 | 46 | 59.50 |
| **$CO_3$ (mg/l )** | 6 | 21 | 26 |
| **$HCO_3$ (mg/l )** | 135.8 | 225.35 | 255.3 |
| **Fe (III) (mg/l )** | 0.52 | 0.47 | 0.39 |
| **Ca (II) (mg/l )** | 35 | 29 | 38.5 |
| **Mg (II) (mg/l )** | 20 | 17 | 21 |
| **Na (I) (mg/l )** | 4.10 | 3.50 | 5.50 |
| **K (I) (mg/l )** | 2.13 | 1.90 | 2.70 |
| **As (III) (mg/l )** | 0.014 | 0.012 | 0.015 |
| **TDS (mg/l )** | 256 | 241 | 301 |
| **$SO_4$ (mg/l )** | 1.40 | 1.50 | 1.31 |
| **$PO_4$ (mg/l )** | 1.50 | 1.40 | 1.54 |
| **$SiO_2$ (mg/l )** | 42.50 | 53 | 45 |
| **$NO_3$ (mg/l )** | 0.15 | 0.19 | 0.18 |
| **Cl (mg/l )** | 5.04 | 5.68 | 5.54 |
| **$NH_3$ (mg/l )** | 0.13 | 0.18 | 0.14 |
| **Cd (II) (mg/l )** | 0.024 | 0.035 | 0.032 |
| **Zn (II) (mg/l )** | 0.27 | 0.28 | 0.23 |
| **Cr (III) (mg/l )** | 0.017 | 0.016 | 0.014 |

**Table no 6:** Characteristics of Underground mine waters

| | | Post-Monsoon | | Pre-Monsoon | | WHO (1997) | WHO (1997) | BIS 2003 (IS 10500) | BIS 2003 (IS 10500) |
|---|---|---|---|---|---|---|---|---|---|
| **Water Quality Parameters** | **Units** | **Range** | **Mean** | **Range** | **Mean** | **Max. desirable** | **Highest Permissible limits** | **Max. desirable** | **Highest Permissible limits** |
| pH | | 6.5-8.2 | 7.2 | 6.5-8.3 | 7.3 | 7.0-8.5 | 6.5-9.2 | 6.5-8.5 | 8.5-9.2 |
| EC | µS/cm | 480-1300 | 862 | 630-1590 | 1080 | 750 | 1500 | - | - |
| $HCO_3$ | mg/l | 144-357 | 214 | 192-451 | 268 | 200 | 600 | 200 | 600 |
| $F^-$ | mg/l | 0.23-1.5 | 0.7 | 0.46-1.9 | 1.1 | 0.6-0.9 | 1.5 | 1.0 | 1.5 |
| $Cl^-$ | mg/l | 39-198 | 83 | 54-254 | 116 | 250 | 600 | 250 | 1000 |
| $NO_3$ | mg/l | 1.1-30 | 8 | 2.1-46 | 14 | - | 50 | 45 | 100 |
| $SO_4^{2-}$ | mg/l | 47-369 | 193 | 90-397 | 232 | 200 | 600 | 200 | 400 |
| $Na^+$ | mg/l | 14-143 | 48 | 28-189 | 79 | 50 | 200 | - | - |
| $Ca^{2+}$ | mg/l | 28-192 | 92 | 35-205 | 106 | 75 | 200 | 75 | 200 |
| $Mg^{2+}$ | mg/l | 38-129 | 52 | 38-138 | 68 | 30 | 150 | 30 | 100 |
| $K^+$ | mg/l | 1.3-35 | 9.5 | 4-39 | 16 | 100 | 200 | - | - |
| TDS | mg/l | 350-1150 | 705 | 532-1377 | 901 | 500 | 1500 | 500 | 2000 |
| TH | mg/l | 210-752 | 444 | 294-917 | 546 | 100 | 500 | 300 | 600 |

**Table 7:** Analytical data and compare with WHO and Indian Standard (IS: 10500) for domestic purpose

The mine water characteristic both acidic and alkaline mines are depending on the type and nature of mines and also the mineral compositions. The general characteristics and the ranges are shown in tables 4 to 6. The various authors have also reported characteristics of mine water collected from different mines and compared with drinking water quality (IS 10500) and shown in Table 7.

In general the alkaline mine water is having pH 7-8.5 with dissolved solids in the range of

300-2500 mg/l, buffering capacity in the form of alkalinity range from 30-500 mg/l, turbidity in the range of 30-150 NTU with hardness in the range of 50-1000 mg/l. However these are further categorized as A1, A2 and A3 based on the concentration level of the water quality parameter. Further the organic content is also evaluated in the alkaline mine water and expressed in terms of BOD and COD. The DO level is also significant and recorded. The concentration level of demand parameters in the form of DO, BOD and COD ranged from 5.5-8.0 mg/l, < 1-2 mg/l and 10-60 mg/l respectively.The concentration levels of metals content are also given by several authors. It is observed that elemental concentration levels of several metals like calcium, magnesium, iron, zinc, chromium ranged from 20-150 mg/l, 10-100 mg/l, 0-5 mg/l, 0.2-0.3 mg/l, 0.01-0.02 mg/l respectively. Whereas acidic mine water is having pH in the range of 2-5, total dissolved solids 400-4000 mg/l, with hardness 200-3500 mg/l. the demand parameters in the form of DO, BOD and COD ranged from 3.8-8.5 mg/l, 1-5 mg/l and 10-100 mg/l respectively based on the category of mine water. From the characteristics of mine water it is observed that the mine water is contributed by minerals with higher concentration of dissolved solids irrespective of pH and metal concentration. The organic load in terms of BOD was found to be less whereas COD was found to be in higher side might be due to the contamination of oil and grease and phenolic compound.

From the characteristics of both alkaline and acidic mine water it was observed that alkaline water can be put into use or recycle for domestic or irrigation purposes whereas acidic mine water cannot be use for domestic or irrigation purposes. In both cases it becomes very essential to treat the mine water whether it is alkaline or acidic before putting into use or recycle.

**Treatment of mine water**

Alkaline mine water should be neutralized first and treated by applying coagulation and flocculation technique for the removal of suspended load or turbidity followed by pressure filtration with back washing and chlorination treatment along with polishing with activated carbon. For acidic mine water it should be neutralized first with limestone followed by sedimentation and filtration and polishing with activated carbon.

**Recycle and reuse**

The quality of the mine water weather it is alkaline or acidic should be neutralized and treated as mention above and then stored in a mine outpits so that this will be the system of water harvesting and recharging of ground water also. This treated mine water could be used for water sprinkling for dust suppression during excavation and transportation activities. It could be used for gardening also depending on the soil quality and the characteristics of treated water to avoid any soil deterioration, moreover the treated mine water may also be use for domestic or drinking purposes provided all the metal contamination is removed.

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