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RESEARCH ARTICLE

Impact of Mining on Water Resources in India

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Abstract

Nowadays acid mine drainage (ADM) or mine water is a very common and serious pollution problem or associated with all coal and metals mines, containing pyrite and sulphide deposits worldwide. Mine water is a major problem on coal and metal mines throughout the world and in India. Various studies that have been undertaken in worldwide and in India itself, have shown that the water discharges from the mining industries is highly acidic, having low pH (2-4) and high Concentrations of heavy metals, pose a serious threat to human health, animals and ecological systems. This is because mine water Very acid stream waters with mobilized heavy metals, such as Cd^{2+}, Cu^{2+}, Fe^{3+},Mn^{2+},$Pb^{2+}$and Zn^{2+},which are not biodegradable and tend to accumulate in all living organisms, causing various diseases and serious disorders problems in living creature .Iron is a common constituent of AMD which can also have detrimental effects on aquatic life The water quality of the Churcha and Gorbi mine in the test area was found below standard due to the presence of acid mine drainage or mine water. The main aim of this review paper is to provide complete awareness of the environmental risk associated with acid mine drainage in our natural environment.

INTRODUCTION

Water is one of the most important and essential natural resources for supporting all life on earth. India receives 4000 km^3 annual rainfall including snowfall. It is estimated that out of the 4000 km^3 water, 1869 km^3 is Average annual possible flow in different rivers available as natural water resource. Out of this, only 1123 km^3 water is available as surface and ground water resources respectively 690 km^3 and 433 km^3.The water demands was 634 km^3 in the year 2000 and it is likely to be increases 1093 km^3 in year 2025. Due to rapid growth of population, industrialization, urbanization and mechanization (Water Resources at a Glance, 2011).There will be continuous increase in demand of water for population and growing economy of the country; due to this it will become scarce in the coming decades. The demand of water is not uniform its demand generally depends on many factors like, hydrological, geological and environmental condition of the country. All opencast and underground mines of coal and metals required lot of water for different mining activities and releases mine waste water with toxic metals, which badly affects the hydrology of the mining area and often affects the availability of water quality and quantity. The water seeping into the mine and collected in the mine sump can be partly reused for spraying on haul roads, conveyors, bunkers and loading and unloading points and the excess amount of water discharged into the surface drainage system. Water draining from coal and metal mines contains sulphuric acid and heavy toxic metals at high concentration which could contaminate natural water resources and agricultural lands. When mine water- affected stream water is used for irrigation purposes. That soil and stream contain heavy metals with acidic pH that properties of heavy metals uptake by plants and different crops, which poses a high health risk to the people and animals who consume the contaminated agricultural products (Kuyucak, 2001). The pollution problem is mostly confined to a mine region surrounding at the source, but may extend to large distances if the acid mine water is allowed to get discharged without any suitable treatment into the main water stream. The all big and small coal mine regions faces a serious water pollution problem due to acid mine drainage in India, like Ambora and Rkhikol (wa); Baragolai (ECL); Churcha, Gorbi (Nu) and rslatka (BCCL), lower Gondwana and West Chirimiri, Presently all Indian and worldwide mines required a growing awareness of the environmental legacy for all mining activities that have been undertaken with little concern for the environment (EMCBC, 2001; Jamal et al., 2015). All coal and metal mining industries, by its nature, consumes, diverts and can negatively impacts on natural water resources surrounding mine areas. The severity of these impacts depend on many factors such as sensitivity of local topography, type of ore/ mineral's mining, used technology, skill workers and mine leaseholder, and legal aspect of environmental regime. Many irresponsible mineral developments can result in a degradation of the natural water quality, through increased pollution and sedimentation loads, which are main causes of reduction of quality and quantity of fresh water availabilities for current and future generations. Mine water affected area required suitable effective treatment technology for mine water to avoid instances of the water-borne diseases such as typhoid, fever and cholera, occur in rural areas. There is a need to ensure that the best pollution prevention strategies are employed. The main aim of this review is to raise effective awareness of the environmental risk associated with mine water in our natural environment especially in case where the environmental risks can be managed (Dhar B.B. and Ahmad, 1993).

MINING INDUSTRY IN INDIA

The history of mineral development and production in India dated back to 6000 years ago (Sheoran et al., 2011). The remains of some of the old mine working are a witness for this fact. In fact, some of these have led to the discovery of several large mineral deposits which are operational today like Lead & Zinc in Zawar, Copper in Khetri, and Gold in Karnataka etc. Despite the active past, the metal mining activities in the country remained dormant over a long period until the beginning of this century. Modern mining industry in India started its journey long back in 1774, when East India Company permitted for coal mining to English Company in Raniganj area. Later in 1880 gold mining was started in Kolar goldfield in Karnataka by M/S John Taylor and Sons. At present India produces nearly 89 minerals under different groups comprising 4 fuels, 11 metallic, and 52 non-metallic industrial and 22 minor minerals (Indian mining industries at glance, 2015; Sheoran et al., 2011; Jamal et al., 2015). In India 80% of mining is coal and 20% in various metals and other raw materials such as gold, copper, iron, lead, bauxite, zinc and uranium. Which is 0.21 percent of the total land mass of 21 states in the country (Jamal et al, 2015).

ACID MINE DRAINAGE

Acid mine drainage or mine water are found throughout the world in a different range of pH, with natural environments and anthropogenic land disturbances such as mining of coal , mineral , metals ore and highway construction, where acid-forming sulphide minerals are exposed at the surface of the Earth(Jamal et al.,2015).

CHEMISTRY OF MINE WATER

Many studies have been carried out to understand the chemistry of mine water in both phases solid and fluid(mas) Acid mine drainage (AMD) forms when sulphide minerals or other sulphide minerals such as sphalerites ($ZnS_{(S)}$), covellite ($CuS_{(S)}$) ,millerites ($NiS_{(S)}$), galena ($PbS_{(S)}$), greenockite ($CdS_{(S)}$) and white pyrites(FeS_2) are directly exposed to oxidizing conditions in metal, coal mining, highway , building construction, and other large-scale excavations(James et al 2000; Yadav,H.L and Jamal A. 2015).

The first important reaction is the oxidation of the sulphide mineral into dissolved iron, sulphate and hydrogen:

$$FeS_2+7/2\,O_2+H_2O \longrightarrow Fe_2++2SO_4^{2-}+2H^+ \qquad (1)$$

Equation (1) show the first important reaction is the oxidation of the sulphide mineral into dissolved iron, sulphate and hydrogen

$$Fe^{2+}+1/4\,O_2+H^+ \longrightarrow Fe^{3+}+1/2H_2O \qquad (2)$$

Equation (2) shows, ferrous iron, released from the oxidation of pyrites, can be oxidise to ferric iron

$$Fe^{3+}+3H_2O \longrightarrow Fe(OH)_3 \text{ solid} +3H^+ \qquad (3)$$

Ferric iron precipitates as ferric hydroxide releasing more acid in water at pH>4 shown in equation (3)

$FeS_2+14Fe^{3+}+8H_2O \longrightarrow 15Fe^{2+}+2SO_4^{2-}+16H^+$ (4)

When the pH<4, the ferric iron remain in the solution, and thus produce more protons with pyrites shown in equation (4)

$FeS_2+15/4O_2+7/2H_2O \longrightarrow Fe(OH)_3 +2H_2SO_4$ (5)

Equation (5) show the oxidation of one mole of pyrite produces two mole of sulphuric acid in the natural Environment. (Kuyucak, 2002; Yadav, H.L and Jamal A. 2015).

TYPES OF MINING ACTIVITIES

Mining methods vary widely and generally depend on the size, type and location of different mineral resources. We have two types of mining namely surface and underground mining. Surface mining methods are more effective and economical method, where mineral deposits occur close to the surface. Generally surface mining activities include: open pit mining and strip mining as well as dredge, placer and hydraulic mining in riverbeds, terraces and beaches. These mining activities always disturb the surface and, underground water, fauna, flora and all alternative types of land-use surrounding mine areas (Kuyucak, 2001).

MINE-LIFE CYCLE:

Mine- life-cycle progresses in open and underground mining through the following stages, Exploration, Mine-Development, Extraction and Processing of minerals, Mine Closure, during different, mining activities mine life-cycle invariably affect the natural water and soil quality as well as water availability near mines regions(AEO2014).

MINE WATER PROBLEMS IN INDIA

India has a long history of coal and metal mining and has huge population which depends on limited natural water resources, leading to a situation there are many challenges. Where the groundwater table is close to surface, due to natural process like capillary rise and evaporation approximately 20 cm upper part of soil profiles are severely polluted by heavy metals of the groundwater. The polluted groundwater is discharging into streams an increase in the acidity of the stream water. The effect of the contaminated water from the mines can persist. It is estimated that 70% of India's groundwater and surface water are doubtful in quality due to mine and other industrial activities (Bobba *et al.*, 1997). AMD is the most difficult mine waste problem to address (Thomas et al; 1994). When mining ceases, pumping of the water will stop and groundwater levels will rise (Report to the Inter-Ministerial Committee on Acid Mine Drainage, 2010). Mine water from coal mining is problematic in the Indian coalfield and has been reflected by media attention on the consequences of severe pollution seen in many water resources surroundings mines area (Dhar et al, 1993). In rain season the rain water directly join the mines, to an uncontrolled level, untreated mine water into surface streams and wetlands, which contaminate the surrounding sensitive areas with groundwater aquifers below surface.

IMPACT OF MINE WATER ON NATURAL WATER QUALITY OF INDIA

Acidic of Mine water has been identified as one of the serious pollution that imposed pressures on freshwater systems and resources (Victor Munnik, 2010). Acid mine drainage or Mine water or acid rock drainage is a growing concern in water quality management. Mine water has serious effects on natural Environment (CPCB, 2011). Which effects on drinking water quality and also disrupted the suitable growth and reproduction of aquatic plants and animals surrounding mines areas? Mine water pollution also disturbed the life cycle of fishes and loss of aquatic life. Due to Mine water, starts corrosion of many mining equipments and engineering structures such as buildings, bridges, highways, drainage system and concrete materials**.** Generally, mine water has high acidic, low ph and high turbidity, iron, sulphate and hardness. Various hazardous toxic metals become soluble in acidic water due to low ph content and may be presenting significant to concentration levels which varies site to site and mine to mines. Mine water is the most persistent pollution problems in all Indian mines. Fortunately the considerable majority of coal mining areas is safe and only in a few localized areas problem of mine water exists. Opencast mining has more potential impact on land than underground mining subsidence as observed in Jharia and Raniganj and NCL Coalfields. Mine Water have negative impacts on the natural water resources by decreasing pH, increasing the levels of total solid, suspended solids, with hazardous toxic metals such as aluminium, cadmium, cobalt, iron, manganese and zinc . The mine water generally effects on water quality in many surface water sources that may direct ally or indirectly impact on the domestic, industrial and agricultural sector's demand of water.

THE ENVIRONMENTAL IMPACTS ON WATER SOURCES NEAR MINE DUMPS

In different mining processing large amounts of hazardous toxic waste generated, which required suitable treatment/ disposal or storage facilities. In many developing counties, due to lack of rules and regulations(Dash ashish,2012) .Large amounts of mine tailings with mine water direct ally discharges into natural water bodies, rivers, lakes, resulting in damage of natural ecosystem system with contamination of natural water supplies. All abandoned mines often have exposed tailing piles that are poorly contained. Mine tailings can be transported by wind to contaminate large areas, including waterways and soil. Modern mines employ a variety of containment methods, like tailing pond storage, which reduced the impacts of toxins into natural water sources near mines area in some extent. Mining activities invariably contaminate surface and ground water resources. Due to different mining activities, toxic material such as sulphur, arsenic, mercury and cyanide , lead, leach into ground and contaminated ground water and soil quality, or in rainy season huge amount of rain water mixed with mines waste unite with rivers, lakes and aquifers. Mine water frequently occurs with coal and metals mines, polluting waterways and destroying terrestrial habitats in very large areas surrounding the mines region (Jamal et al., 2015). While presently mining regulations becomes more stringent, worldwide, this required more improved quality of treated effluent for protection of natural environment, human health and aquatic life in country.

ECONOMIC IMPACT OF ACID MINE DRAINAGE

Mine water become a very serious and highly political issue when all mining activities suddenly stopped, results in loss of huge job and increased unemployment. Mine closure and the associated increase in mine water also have serious consequences for communities previously directly supported by mines owner in the mining sector (George et al, 2010). Mine water may render the available natural water resources for agricultural purposes. Mine water affected area also has severe impacts on aquatic resources and can stunt terrestrial plant growth and harm to natural wetlands (Kadlec, R.H.and Wallace S.D, 2009).

THE NEED FOR ACID MINE DRAINAGE TREATMENT

Water is a finite natural resource and essential for life is ubiquitous and it has a number of important physical characteristics that affect its use. Water play very important role due to its utility of many purposes likes, domestic, industrial, agricultural and environmental. Due to following serious effect mine water required suitable treatment. Mine water has low pH (2-4) (Jamal et al., 2015), and hazardous toxic metals which disrupted the growth and reproduction life-cycle of aquatic plants and animals. Due to low pH, the solubility of toxic heavy metals such as As, Fe, Mn, Zn, Cu, Pb etc increases in water resources. This toxic heavy metal consumes the available oxygen in water for their oxidation process. Mine water disturbed the physical, chemical and biological characteristics of the natural water resources due to toxic metal concentration, which direct ally impacts on soil and vegetation. Acidic mine water leach into neighbouring watercourses, direct ally or indirectly join waterways and disrupts surrounding ecosystems by lowering the pH, increases acidity, turbidity and toxic metal concentration etc . Precipitation of " yellow boy'' Fe $(OH)_3$ changes the colour of natural water bodies and increased turbidity in water resources and decreased photosynthesis properties in green plants. Direct toxicity of mine water (benthic algae, invertebrates, and fish); Harm to fisheries life cycle (Jennings et al, 2008).Mine water acidic in nature and supports only acidic resistant algae and moulds, that algae decomposes, produces hazardous toxic metals in natural water resources. This is not suitable for domestic, agricultural, commercial and other purposes.

TYPES OF ACID MINE DRAINAGE TREATMENTS

Treatment of mine water can be done either active or passive process (Younger, 2001). Active treatment can be successful; however it necessitates a long-term and continuous commitment to treatment. In active system failure of equipment and budget can result in lapses in biological and physical degradation of the streams .Although Active treatment system required less construction area as compare to passive treatment system such as constructed wetland. While passive treatment involves the developing of a self-operating system that can treat the effluent without constant human intervention. The basis for passive treatment is to let nature purify itself over time. An example would be passing the water through series of inter connected ponds (Barton et al., 1999) or an artificial wetland in which organic matter, bacterial and algae work together to remove the heavy metal ions and reduce the acidity by the process of filtrations , adsorptions and precipitation.

LIMESTONE PONDS

Presently some mines are used Limestone ponds for treatment for mine water and utilized mine water for different purposes in different mines activities. Ponds are a new passive treatment system in which a man made pond is constructed on the upwelling of a mine water seep or underground water discharge point. Limestone is placed in the bottom portion of the pond and mine water flows upward through the limestone (Falkenmark, M .1994; Faulkner and Skousen 1995).The design and geometry of the ponds depends on the topography of the area and the geometry of the discharge zone, this system are effectively suitable for low DO contain water and free of Fe^{3+} and Al^{3+}.

WETLANDS

Wetlands utilise naturally available energy sources such as topographical gradient, microbial metabolic energy, photosynthesis to precipitate out the heavy metal ions, constructed wetland is an important engineer's sequence of water bodies to treat and filter the mine water surrounding mine region. Wetlands are estimated to cover approximately 6.4% of the earth surface worldwide; out of these 30% bogs 26% fens, 20% swamps 15% flood plain and 9% other. Generally tropical wetland covers about 2.64 million km^2 worldwide. Indian wetlands are generally distributed from the cold arid zone to hot arid zone respectively Ladakh to Gujarat -Rajasthan associated in different tropical monsoon of central India and the wet, humid zone of the southern peninsula with 4.1 million hectares of wetlands out of these 2.6 million man made and 1.5 million hectares natural made. Natural wetland and Constructed wetlands (CWs) are efficiently used for mine water treatment (Acharya et al; 2009). Today Constructed wetlands (CWs) are effectively used due to its many advantages likes effectiveness in treatment, robust operation, less generation of by-products, less construction cost if chiefly land available comparable to conventional treatment systems, and its minimal operation and maintenance costs(Kuyucak,2002; Hoffmann et al,2011; Udiba,2013) .The design and construction of wetland depends on many factors likes rate of Loading , detention time, surface Slope ,Substrate, types of vegetation ,sediment control etc. Wetlands provide adsorption; neutralization and precipitation need to be incorporated into the hydrology, soil and vegetation. Generally three types of constructed wetlands system (cws) are used for waste water treatment. In most cases, for better results bottom of the cws properly lined with either a polymer geomembrane, concrete or clay depends on its fund availability for protection of the surrounding mines water table. The system required less area for water purification as 5 to 10 m^2, with more efficiency, avoid odorous, mosquitoes problems.

FILTRATION PROCESSES

Some mines also used filtration process for primary treatment of mine water for removal of fine solid particles without addition of chemicals in mine water. It is very effective and simple process compare to the conventional systems in terms of many aspect likes, skilled labour requirement, operation, maintenance, effectiveness and treatment efficiency, roughing filters may be considered as a packed, low-cost and efficient pre-treatment process for mine waste water treatment.

NEUTRALIZATION PROCESSES

Neutralization is the worldwide accepted processes for mine water treatment (Kuyucak, 2008),its treatment efficiency depends on many factors like physical, chemical and biological characteristics of the mine water; the quantity of water in need of treatment; local climate condition; geographical condition, life of plants and sludge characteristics responsible for selection of neutralization process. Mine water treatment management includes ammonia, caustic soda, calcium peroxide, hydrated lime, kiln dust, limestone, soda ash and fly ash. Lime neutralization/precipitation is often used to treat mine water in coal and metal mining industry (Kuyucak, 2001; 2002). In lime treatment, mine water is directly discharge into rapid mixed chamber where hydrated lime is added in dry or slurry form. These neutralization process effectively reduced concentration of ferrous iron at some suitable pH level.

CONTROL OF MINE WATER GENERATION

- Primary prevention of the acid-generating process from different mining sources.

- Secondary control, deployment of acid drainage migration, prevention measures.
- Tertiary control, or the collection and treatment of effluent from different sources of mining.
- Due to acidic in nature mine water supports only acid resistant algae and moulds. This algae decomposes, produces hazardous toxic metals such as As, Fe, Mn, Zn, Cu, Pb, and Se in water resources.
- The toxic metal consumes more oxygen from water for their oxidation process. As a result deficiency of dissolved oxygen (DO) in water stream, due to this it cannot support more aquatics life for long time.
- Due to mine water, a natural water resource becomes more acidic and corrosive which are not suitable for domestic water supply, commercial uses, agricultural irrigation, food supply, industrial production, power generation, navigation purposes and wide natural environment.

WATER POLLUTION CONTROL MEASURE

- Industrial effluent treatment plants: many mines have Effluent Treatment Plants (ETPs) in the down flow line of the workshop as well as mine discharges so effluents have acceptable limit. Many of the mines could reach the zero discharge.
- Silt arrestors/ Siltation ponds/ Sedimentation ponds: Catch drains terminating at sedimentation ponds have been constructed garlanding the overburden dumps to arrest flow of silts to the nalas and rivers which effectively reduced the pollution level in water steam.
- Sewage Treatment Plants (STPs): all mines have STPs and ETP to take care of the domestic and mine effluents. All the colonies of the mine project replacing the conventional treatment arrangement with new technology. The treated effluents are re -used for dust suppression in mines and also utilized for gardening and irrigation purposes (Singh, 2005).

CONCLUSION

In India, the Mining and Water Acts, Rules and Regulations do not contain much provision for protection of the water environment and, thus the bulk of the environment protection task is passed onto the Environmental Laws. Mine-water pollution is different from other types of industrial pollution and hence should ideally be from the foregoing analysis it is evident that the increase of AMD presence in the water resource of India, and as a result, disturbed human, animal health and availability of food security in surrounding mining area, it also provide an opportunity to usable water through suitable treatment technologies such as active or passive treatment process. The water qualities of the Churcha mines areas as well as the water quality discharged by the mine into the natural water resources both exceed the standards set by WHO and USEPA. From this, it is concluded that mine water is a serious threaten to large parts of India’s environment and society, direct effect on local communities and environment.

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