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RESEARCH ARTICLE

CHARACTERISTICS AND IMPACT OF DIFFERENT INDUSTRIAL EFFLUENTS FROM COAL MINES WITH A BIOTECHNOLOGICAL APPROACH OF USING GREEN ALGAE FOR WASTEWATER TREATMENT – AN APPRAISAL

[1]Ansari Iqbal Md. *,[2]Anand Kumar and [3]Khan Md. Imran

[1]CSIR-Central Institute of Mining & Fuel Research, Dhanbad, India
[2]Department of Biotechnology, Vinoba Bhave University, Hazaribag, India
[3]CSIR-Central Institute of Mining & Fuel Research, Dhanbad, India

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ABSTRACT

In mining areas a huge amount of waste water is generated through coal based industries. It is very toxic in nature and contains non–biodegradable substances. On contamination with these water sources there is depletion in water quality, environmental flora, fauna and health hazards to mankind. This waste water is disposed off in the nearby water bodies without treatment. It creates a lot of problem for the aquatic life as well as for the nearby habitats. Many successful methods have been applied for the treatment of waste water. Waste water is needed to be treated through different techniques which enables it to make it potable and for multipurpose uses. Furthermore some biological treatments are also required for this. Biotechnology plays a vital role in reducing hazards of toxic materials and other harmful substances released during various mining processes. Micro-organisms have several uses in the environment in controlling water pollution and in the treatment of toxic wastes present in waste water coming from coal based industries. In mining industries microbes are used to leach metals from mine dumps and treat liquid and solid wastes. Hence this will be the most effective methods of treatment of waste water generated from different coal based industries and it will also provide a platform for sustainable development and an eco-friendly approach for the human kind. The present paper highlights on the different wastes generated by coal based industries and on their treatment through different methods and technologies used in coal mining.

INTRODUCTION

Coal is an important source of energy for the world, particularly for power generation. Demand for coal has grown rapidly over the last decade, outstripping that for gas, oil, nuclear and renewable energy sources. Coal contributes to over 40% of global anthropomorphic CO_2 emissions and more than 70% of CO_2 emissions that arise from power generation are attributed to coal. Mining activities, mineral processing and metallurgical extraction not only involve the removal and processing of rock and the production and disposal of solid wastes, but also the production, use and disposal of mine water. Mine water originates as ground or meteoric water which under goes compositional modifications due to mineral-water reaction at mine site including surface and subsurface water (Morin and Hutt, 1997). Mining activity excavation leads to increase in large piles of spoil and overburden which are often prone to erosion, releasing large amounts of sediments, acid and toxic leachates into water courses (Riley, 1960). Water is called as the elixir of life, because it can naturally renew and cleanse itself, by allowing pollutants to settle out (through the process of sedimentation) or break down, or by diluting the pollutants to a point where they are not in harmful concentrations. However, this natural process takes time, and is difficult when excessive quantities of harmful contaminants are added to the water (Kumar, W.T. Tsai and Manahan).Water is required at various mining sites for dust suppression, mineral processing, coal washing and hydro-metallurgical extraction. Mine water is generated and disposed during various stages of mining. Water of poor quality needs remediation as its uncontrolled discharge, flow drainage or seepage from the mine site may be associated with the release of suspended solids, bases, acids and dissolved solids including metals, metalloids, or salts. Such release has a negative impact on the environment, in and around the mining site (Lottermoser, 2003). Waste water generated from coke-plant contains ammonia, cyanide, thio-cyanate, and many toxic organic contaminants, such as phenols, mono- and poly-cyclic nitrogen-containing aromatics, oxygen- and sulfur-containing heterocyclic compounds and PAHs (Stamoudis and Luthy, 1980; Luthy *et al.,* 1983; Grady, 1990; Wen *et al.,* 1991). These compounds produce long-term environmental impacts,

**Corresponding author: Anand Kumar,*
Department of Biotechnology, Vinoba Bhave University, Hazaribag, India.

and most of the heterocyclic compounds and PAHs are reported to be mutative and carcinogenic (Melcer *et al.,* 1984; Azhar and Stuckey, 1994). It is therefore necessary to remove these substances from coke-plant wastewaters for reducing their harmful effect to environments.

Most environmental problems associated with the use of coal as fuel in thermal power plants are the likely to contaminate air, water and land environment affecting the livelihood of the local peoples. The disposal of fly ash from coal fired power generation, and its possible impacts on the environment, has been a serious environmental problem. The fly ash is disposed off either by dry methods of disposal in landfills or by wet methods of disposal where the ash is mixed with water and removed as slurry for settlement in ponds. The supernatants are discharged into a receiving system and the final effluents discharged into a natural aquatic drainage system like a river. Both these methods of fly ash disposal result in metal contamination of surface and groundwater resources and hence can transfer these contaminants into the food chain causing a serious health hazards (Mehra *et al.,* 1998).

The effluents coming from mines and industries have a great deal of influence on the pollution of the water body. These effluents can alter the physical, chemical and biological nature of the receiving water body (Sangodoyin, 1991). The quality of a river at any point reflects major influences, including the lithology of the basin, atmospheric inputs, climatic conditions and anthropogenic inputs. On other hand, river plays a major role in assimilation or transporting municipal and industrial waste water and runoff from agricultural land. Industrial waste water discharge contributes a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climate within the basin (Singh, 2004). However the untreated waste water may contain toxic compounds, discharge from industries, mining, domestic and commercial areas enter the surface water body they get dissolved or lie suspended in water or get deposited on the bottom of water resources (Panda *et al*., 2006).

The major part of fly ash is disposed off in unmanaged landfills or lagoons. It leads to environmental pollution in the area through fly ash erosion and leachate generation (Gupta *et al.,* 2002). Heavy metals like Arsenic, Lead, Nickel, Cobalt, Chromium, Boron and Antimony found in fly ash are hazardous for living organisms. These elements are released into the soil, surface water, and groundwater by leaching processes and they further affects the biota in an ecosystem. The leaching potential of ash ponds is higher due to diurnal and seasonal variations in temperature, moisture and other parameters (Praharaj *et al.,* 2002). Leaching of soluble ions from ash ponds into the ground water was reported near Vijayawada Thermal Power Station (Suresh *et al.,* 1998). Leachability of metals such as cadmium, chromium, zinc, lead, mercury, and silver (cations) increases with decreasing pH or under acidic conditions (Dwivedi *et al.,* 2008). Al, Fe, Mn and Pb are the major contaminants contributed from the ash pond effluent from the river water in Orissa and their enrichment with respect to the respective prescribed limits confirmed that the river water is contaminated to varying degrees and therefore not potable (Tripathy *et al.,* 2002). Bioaccumulation of heavy metals in plants lead to increased elemental composition that eventually enters the food chain. A study on fly ash contaminated areas in Uttar Pradesh, India showed the bioaccumulation of heavy metals like Fe, Zn, Cu, Mo, B, Si, Al, Cr, Pb, Cd, Hg as in native aquatic, terrestrial and algal species in the vicinity (Rajarshi *et al.,* 2009).

Impact of industrial effluents on living organisms

Coal slurry or sludge is a waste fluid produced by washing of coal with water and chemicals prior to shipping the coal to market. When coal is mined underground or by high wall or auger miners, there are significant amounts of rocks and clays mixed within it. These materials must be removed before the coal can be sold to power plants or steel mills. In a wet washing plant, or coal preparation plant, the raw coal is crushed and mixed with a large amount of water, magnetite, and organic chemicals. The huge volume of waste water left over is coal slurry. In the slurry are particles of rock, clay and coal too small to float or sink as well as all the chemicals used to wash the coal. Testing has shown coal slurry to be highly toxic. Chronic exposure to the metals found in coal slurry can damage virtually every part of the body. Health problems caused by these metals include intestinal lesions, neuropathy, kidney and liver failure, cancer, high blood pressure, brittle bones, miscarriages and birth defects among others. Studies of the effects of coal slurry on human cell tissues have found evidence that coal slurry causes cancerous proliferation, cell death and damage to kidney cells.

Table 1. Characteristics of Coal Washeries effluents

S.No.	Parameter	Maximum value
1.	Total Solids	1000 -25000(mg/l)
2.	Suspended Solids	800- 24700(mg/l)
3.	Dissolved Solids	200- 300(mg/l)
4.	Hardness	230 mg/l as CaCo3
5.	Alkalinity	86 mg/l as Ca Co3
6.	pH	7.4- 7.8
7.	B.O.D(days, 27ºC	30mg/l
8.	COD	250mg/l
9.	Phenolics	1.0mg/l
10.	Oil &grease	10mg/l

Sources: (www.gitam.edu/eresource/environmental/iwm_tsrinivas/steel_ plant.htm)

Table 2. Characteristics of Thermal Power Plants

S.No.	Parameter	Maximum value
1.	pH	6-9
2.	TSS	50(mg/l)
3.	Oil and grease	10(mg/l)
4.	Total residual chlorine$_a$	0.2(mg/l)
5.	Chromium (total)	0.5(mg/l)
6.	Copper	0.5(mg/l)
7.	Iron	1.0(mg/l)
8.	Zinc	1.0(mg/l)
9.	Temperature increase	$\leq$ 3°C$_b$

Sources: (Thermal Power: Guidelines for New Plants: Pollution Prevention and Abatement Handbook WORLD BANK GROUP Effective July 1998)

"Chlorine shocking" may be preferable in certain circumstances. This involves using high chlorine levels for a few seconds rather than a continuous low-level release. The maximum value is 2 mg/l for up to 2 hours, not to be repeated more frequently than once in 24 hours, with a 24-hour average of 0.2mg/l. (The same limits would apply to bromine and fluorine). The effluent should result in a temperature increase of no more than 3° C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, we use 100meters from the point of discharge when there are no sensitive aquatic ecosystems within this distance.

Coke Ovens and their Water Waste:

The production of coke involves the carbonization of bituminous coal by heating in the absence of air at a temperature range of 900°C 1100°C in an oven, which drives off all volatile portions in the coal. The gas which is evolved containing the volatile matters is collected through the stand pipes and is cooled in stages. In the first stage the gas is cooled to about 80°C by spraying cold liquor over the gas, there by producing mainly tar as condensate. In the second stage by a further cooling to about 30°C, condensate containing additional tar and ammonical liquor is produced. These two condensate liquors after the separation of tar, in a tar decanter are recycled as sprays in the first stage. The excess liquor known as *'ammonical liquor'* containing mainly ammonia and various other compounds is subjected to distillation for the recovery of ammonia. The waste is sent for further treatment or other chemical recovery. After the second stage of cooling i.e. in the third stage, the gas is compressed and cooled for further recovery of chemicals. Besides the arrangement for separation of tar and ammonia, this stage may include a benzo washer for the recovery of light oils. The remaining gas may be used or sold as fuel. The coal after being carbonized is removed from the oven and quenched by cold water. About 30% of the quenching water is evaporated while the remaining water containing coke finally comes out as waste. This wastewater is usually recirculated through breeze settling ponds. The largest single source of wastewater from coke oven plant, having the highest pollution potential in an integrated steel plant is the ammonia still from where the waste ammonical liquor comes out.

Treatment of coal waste

Treatment of Coke Owen Waste

All the pollutants of the spent ammonical liquor, affect the ecology of the waste receiving water. In course, the phenol is considered to be the most objectionable pollutant. The other objectionable substances include thiocynate, thiosulphate, cyanide etc. In some plants spent ammonical liquor is utilized for quenching of hot coke, this practice destroys the toxic matters like phenols in the liquor, but as this causes heavy corrosion in the quenching cars and in other quenching equipments, the method is not generally favored. Phenol being a valuable chemical byproduct may be recovered instead of destroying it. Several techniques have been developed for the recovery of phenol by liquid extraction methods. Most of these processes use benzene as a solvent, to extract phenol from the crude ammonicalliquor, before it enters for ammonia stripping. Other solvents used include light oil, petroleum oil etc. The extracted phenols from all absorption process can be recovered by washing with sodium hydroxide solution; the phenol reacts with the caustic solution to produce sodium phenolate. The crude phenol is then liberated from it using gases containing carbon dioxide. Certain microorganisms both bacteria and yeast, are identified which can oxidize biologically the phenols, thiocynates, thiosulphates and ammonia. When optimum pH and temperature are maintained, sufficient nutrients are added, and the reactor is suitably seeded, the proper loading of this phenolic substrate to the reactor may result in the desirable reduction of the pollution load of the waste. Phenol in concentrations as high as 800 mg/l may be treated biologically. In all practical cases, the phenol concentration in the waste ammonical liquor is too high to be treated directly by biological means.

Treatment of Coal Washery Waste

The major pollutant of the coal washery is the suspended solids. As such this waste is usually treated in a clarifier with or without coagulation. However the addition of coagulant reduces both the retention time and surface area of the tank. Several coagulants like lime, starch and indigenous coagulants like Nirmali seed extracts can be used effectively for the clarification of coal washery wastes. The clarified effluent is either recycled or discharged as waste.

Waste water generated from thermal power plant

The effluents discharged by thermal power plants (TPP) require treatment, before they are discharged into the fresh water streams. Effluents from thermal power plants include thermal discharges, wastewater effluents (e.g., cooling tower blow down; ash handling wastewater; wet FGD system discharges; material storage runoff; metal cleaning wastewater; and low volume wastewater), and sanitary wastewater. There is also the release of ash pond decant into the local water bodies from the coal based industries. Such release of ash pond decant tends to deposit ash all along its path thereby causing fugitive dust nuisance when it dries up. Also when such water mixes with a water body, it increases the turbidity of the water body thereby decreasing the primary productivity. This is harmful to the fisheries and other aquatic biota in the water body. The effect of Tuticorin Thermal Power Plant effluents on Tuticorin coastal water reveals an elevated temperature of coolant water resulted in suppression of phytoplankton, zooplankton, fishes and shell fishes (Selvin *et al.,* 2010). For example, The effect of Tuticorin Power plant on the Tuticorin Bay is evident from the enhanced water temperature up to 2 km from discharging point apart from the decline of depth of Bay and increased ash layer and turbidity due to sustained discharge of ash slurry (Selvaraj *et al.,* 2000) leading to eutrophication with higher Biological Oxygen Demand (BOD) and reduced levels of Dissolved Oxygen (DO).

Biotechnological approach for treatment of wastewater

The use of algae for treatment of water (as algae scrubber) was reported firstly by Dr. Walter Adey, in 1970s. Algal species can improve the quality of mine waste water by reduction in pH, temperature, nitrate, iron, chloride, fluoride, total hardness, sulphate, calcium and manganese. Algae support aerobic bacterial oxidation of organic matter producing oxygen through photosynthesis while release carbon-dioxide and nutrients in aerobic oxidation used for growth of algal biomass. Algae have a solution to the emerging environment problems. They remove the excess wastes generated, efficiently at minimal cost. In comparison to common treatment system oxidation of ponds increases dissolved oxygen and pH concentration. It is because algae remove phosphorous, sedimentation, ammonium, hydrogen and sulphur. High pH in algal waste water purification leads to pathogen disinfection (Laliberte *et al.,* 1994). Some species of algae have capacity to remove heavy metals such as chromium by *Oscillatoria*, cadmium, copper and zinc by *Chlorella vulgaris* (Ting *et al.,* 2001), lead by *Chlamydomnas*and molybdenum by *Scendsmus*and *Chlorelloids* (Sakaguchi *et al.,* 1981)

Conclusion

The effluent discharged by various thermal power plants (TPP) requires some treatment, before they are discharged into the fresh water streams. A coal washery effluent contains a large amount of suspended solids and high COD on contamination with water and creates serious problems to the aquatic life existing there and in adjacent localities. Wastewater generated from coke-plant contains ammonia, cyanide, thio-cyanate, and many toxic organic contaminants, such as phenols, mono and poly-cyclic nitrogen-containing aromatics, oxygen- and sulfur-containing heterocyclic compounds and PAHs has negative impacts on living. Fly ash generated in thermal power plants is disposed off in unmanaged landfills or lagoons. It leads to environmental pollution in the area through fly ash erosion and leachate generation. In the present paper a detailed discussion has been made about the various coals based industrial effluents, their characteristics, their impacts on the environment and treatment processes concerned with them. However, the discussed process of treatment could be beneficial to some extent. Treatment of various industrial effluents through biotechnological process would be safe, economical, eco-friendly and for sustainable development.

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