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Environmental impact on heavy metals and conventional effluent treatment methodologies in steel industrial waste- A review

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ABSTRACT

Steel industry is the business of processing iron ore into steel. In the process of steel making the industry consume lots of energy and emits lots of waste. The waste which discharge from this industry contain many toxic substances. These industrial wastes pollute our environment hardly. Treated this harmful waste using microorganism to breakdown or neutralize it and carried out *ex-situ* or *in-situ* is called bioremediation. This article reviews the waste management through bioremediation in Steel industries.

Keywords: Heavy metal, Environmental impact, Conventional effluent treatment methodologies, Biodegrading microorganisms.

INTRODUCTION

Steel is the most basic materials which essential for industrialization. It is mainly produced using Blast Furnace or Electric Arc Furnace method. The blast furnaces produced one ton per day. The furnace is that the initiative in producing steel from iron oxides. Even though equipment is improved and better production rates are often achieved, the processes inside the furnace remain an equivalent. The furnace uses coke, ore and limestone to supply iron. To produce of 70 million tonnes of steel in 2010-11, the industry consumed about 60 million tonnes of coking coal equivalent, 111 million tonnes of iron and 700 million tonnes of water (Dianne *et al.,* 2011)

Environmental impact of steel production

Toxic air emissions from Iron and steel industries are a crucial source of pollution. Major pollutants of ambient air quality are Sulphur Dioxide (SO2), Nitrogen Dioxide (NO_2), carbon monoxide (CO) and Particulate Matter (PM) (Chen *et al.,* 2015). The combination of Carbon dioxide (CO_2) and methane (CH_4) headed for the greenhouse gas emission inventory in India. (Tiwari *et al.,* 2016)

According to the International Energy Agency (IEA), the iron and steel industry accounts for approximately four to five percent of total world CO_2 emissions and 10-15% of annual industry energy consumption. (Dianne E *et al.,* 2011) Steel plants emit three tonnes of CO_2 per tonne of steel. (downtoearth.org.in). Blast furnace gas is treated by water spraying to get rid of dust. This waste water contains Ammonia-nitrogen, phenol, cyanide, oil metal ions, ash, slag and ore particles and other organic and inorganic toxic chemicals. (Edward Ketchum 2007). In India, the typical effluent discharged from integrated BF-BOF (blast furnace-basic oxygen furnace) alone is about 1.75 m3 per tonne of crude steel.

Health issue caused by steel industry waste:

The Steel industry waste contains Heavy metals, aromatic compounds, surfactants, cyanides and fluoride. It contains both friendly and toxic heavy metals. Friendly heavy metals like iron and zinc and toxic heavy metals like lead, mercury, cadmium, nickel. These toxic heavy metals are Poisonous interference to the enzyme systems and metabolism of the body. It damage the function of Blood and cardiovascular, eliminative pathways, endocrine, energy production pathways, enzymatic, gastrointestinal, immune, nervous, reproductive, and urinary system (European Commission 2008).

Conventional Effluent Treatment Methodologies and Steel Industry

Physicochemical treatment administered to steel industry wastewater separately addresses the issues of solids removal, oil and grease removal, removal of acids and alkalis, and treatment of toxic metals. The different techniques adopted are coagulation-flocculation, adsorption, Advanced Oxidation Processes, electrochemical techniques, and a combination of one or more of these processes. Amosa *et al.* (2013) have shown how coagulation, before membrane filtration, was effective in decreasing membrane fouling. Where the wastewater was treated with ferric chloride as coagulant and polyacrylamide as the flocculant followed by adsorption, demonstrated 92.8% COD removal, 99.3% color, and 99.9% turbidity removal (Idris *et al.,* 2010). Adsorbents are used to remove selected persistent compounds from effluents, namely, phenols, cyanide from coke oven liquors, surfactants from pickling liquors, and heavy metals from casting operations (Vazquez *et al.,* 2007; Zhang *et al.,* 2010). Wherein a maximum removal efficiency of 84% was reached, corresponding to an adsorbent dosage of 1g adsorbent per mL of solution. Activated carbon based adsorbents have also been successful in the removal of organic matter from effluents. Muyibi *et al.,* (2014) demonstrated successful TSS and COD removal from treated POME in a laboratory scale study. They showed that removal rates were affected by PAC dosage, degree of agitation, and contact on elimination of COD and TSS.

A new class of adsorbents that has been receiving increased attention in recent years are nanomaterials. Carbon nanotubes, as adsorbents, serve to remove organic as well as inorganic components from wastewater. Carbon nanotubes (CNTs) have been effective in removing. Apparently unnameable components from wastewater, like synthetic dyes, and heavy metals like copper (Kabbashi *et al.,* 2008). AlSaadi *et al.,* (2015) synthesized CNTs on PAC impregnated with Fe3þ catalysts, in batches, using fixed catalyst chemical vapor deposition.

In recent years, membrane technology has become the panacea of energy intensive, multistep complex industrial water resource recovery techniques. Iron and steel industry is no exception. Processes like reverse osmosis and nanofiltration were used to treat effluents which showed a separation efficiency of 97% and removal of heavy metal ions, BOD, COD, and total solids, as well as oil and grease, whilst being environmentally friendly at the same time. Membrane processes consume lesser energy with respect to conventional separation processes like evaporation and distillation (Hinchliffe and Porter, 2000; Jevons and Awe, 2010). Biological Treatments. Advances in the fields of biochemistry, biotechnology, genetics, and microbiology in recent years, have made biological treatment a competitive and successful methodology, with respect to water resource recovery. Biological treatment decreases COD and BOD organic loadings, as well as the concentration of inorganics, is ecofriendly and requires less capital investment. Methanogenic bacteria perform the main degradation in these systems, the rate of which is augmented with an increase in temperature. To increase the overall removal efficiency, anaerobic filters and anaerobic hybrid reactors are often added making it a multistage process (Chernicharo and Machado, 1998).

Membrane bioreactors are also used as a tertiary effluent treatment step in some steel plants in India (Harika *et al.,* 2015). Membrane bioreactors (MBRs) with a ceramic membrane demonstrated a COD reduction rate of up to 97% with a substantial reduction of pH from a highly alkaline feed of pH 10 (Kurian and Nakhla, 2006).

Bioremediation

Bioremediation is a waste management method that uses simple microbes to break down or neutralize waste materials and can be carried out ex-situ or in-situ. It can be applied to solid, liquid, and gaseous wastes from the steel industry (Jayapriya *et al.,* 2015). Degradation and the Removal of heavy metals from contaminated domestic-industrial effluent using eight resistant indigenous bacteria isolated from acclimatized activated sludge. The indigenous bacteria are *Enterobacter* sp. (Cu1), *Enterobacter* sp. (Cu2), *Stenotrophomonas* sp. (Cd1), *Providencia* sp. (Cd2), *Chryseobacterium* sp. (Co1), *Comamonas* sp. (Co2), *Ochrobactrum* sp. (Cr) and *Delftia* sp. (M1). Strains Cu1 , Cd1, Co2, and Cr were able to resist 275mg Cu/l, 320mg Cd/l, 140mg Co/l and 29mg Cr/l respectively. Treatment technologies included the proposed activated sludge unit amended with the acclimatized bacterial strains (ASBS), the plain activated sludge unit (AS) and the acclimatized bacterial cultures (BS) alone represented by Cu1, Cd1, Co2 and Cr. The performance of the three procedures was evaluated to determine the most efficient application. On the basis of heavy metal removal. The highest achieved RE(s) % of Cu, Cd, Co and Cr recorded were 6.61, 16.58, 27.58 and 19.83 mg/g sludge, respectively using ASBS technology 4.39, 22.89, 30.38 and 26.52 mg/g biomass, respectively using BS technology and finally 7.09, 15.02, 21.08 and 18.58 mg/g biomass, respectively using AS technology.

Table 1. Heavy metal and its degrading microorganism

S.No	Metals	Degrading Microorganisms	Reference
1.	Cr	*Pseudomonas aeruginosa, Bacillus subtilis, Sacchromyces Cerevisiae*	Benazir *et al.,* 2010
		Pseudomonas fluorescence, Bacillus cereus and Bacillus decolorationis	Ahirwar *et al.,* 2013
		Brevebacterium casei	Das and Mishra 2010
		Pseudomonas stutzeri, Acinetobacter baumannii	Kuppusamy *et al.,* 2017
2.	Cd	*Alcaligenes sp, Psedomonas sp,Moraxella sp*	Springael *et al.,* 1993
3.	Ni	*Bacillus subtilis, Pseudomonas licheniformis*	Holan & Volesky (1994)
		Pseudomonas fluorescens	Arokiasamy J *et al.,* 1996
		Pseudomonas alcaliphila	JunweiQian *et al.,* 2012
4.	Ag	*Streptomyces noursei*	Mattuschka *et al.,* 1993
5.	Au	*Aspergillus niger* *Chlorella pyrenoidosa*	Kuyucak and Volesky, 1988 Darnall *et al.,,* 1988
6.	Co	*Sacchromyces cerevisiae*	Brady and Duncan, 1993
		Pseudomonas aeruginosa Burkholderia cepacia and Corynebacterium kutscheri	Oyetibo *et al.,* 2013
7.	Cu	*Cardida tropicalis* *Bacillus licheniformis*	Mattuschka *et al.,* 1993 Beveridge, 1986
8.	Fe	*Bacillus subtilis*	Beveridge, 1986
9.	Hg	*Penicillum chrysogenum*	Nemec *et al.,* 1977
10.	Mn	*Bacillus licheniformis*	Beveridge, 1986
11.	Pb	*Penicillum chrysogenum*	Niu *et al.* 1993
		Bacillus licheniformis, Salmonella typhi, Pseudomonas fluorescence *Escherichia coli*	Basha and Rajaganesh, 2014
12.	U	*Sacchromyces cerevisiae*	Volesky 1986
13.	Th	*Sacchromyces cerevisiae*	Brierley *et al.,* 1986
14.	Zn	*Rhizopus arrhizus* *Penicillium chrysogenum,Penicillum spinulosum*	Tobin *et al.,* 1984 Niu *et al.,* 1993, Townsley *et al.*1986

Bieszkiewicz and Hoszowski (1978) reported that activated sludge could tolerate up to 0.8, 1.15 and 20 mg/l only of Cu, Cr III and Cr (VI), respectively after which the activated sludge experienced inferior purification and reduced intensity of respiration of its microorganisms. In another study, removal efficiency % of Cu, Cd and Cr using activated sludge recorded only 80, 62 and 46 %, respectively with initial concentrations of 0.8, 20.9 and 0.63 mg/l of the same metals (Petrasek and Kugelman 1983).

A soil bacterial consortia comprising of *Bacillus*, *Pseudomonas, Arthrobacter* and *Micrococcus* species has successfully degraded the steel industry effluent with 95% reduction of BOD and COD (Veni *et al.,* 2013). Mycelium present in some of the most common fungi, Rhizopus and Absidia, have shown removal rates of 25% and good binding characteristics with respect to heavy metals such as lead, cadmium, copper, zinc, and uranium. In fact, bacteria, algae, fungi, and yeast all have demonstrated biosorbent properties especially with respect to the removal of heavy metals like Pb, Zn, Cu, and Fe from different waste streams (Das *et al.,* 2008).

A pure culture of *Pseudomonas putida* MTCC 1194 was isolated and inoculated to remove toxic phenol which present the steel plant waste water. (Omkar A Shinde et.al 2018) The bacteria *Serratia marcescens*, *Aeromonas hydrophila* and *Bacillus cereus* degrade Oil and grease (Valentina *et al.,* 2006). Revealed primary and secondary screening of various 72 acido-thermophilic, autotrophic microbes which were isolated and adapted for metal tolerance and bio absorption potentiality. The multi metal tolerance was developed with higher gradient of concentrations Ag, As, Bi, Cd, Cr, Co, Cu, Hg, Li, Mo, Pb, Sn, and Zn. The selected highly potential isolate showed maximum adsorption Ag 73% followed by Pb 35%, Zn 34%, As 19%, Ni 15% and Cr 9% in chalcopyrite. Japan has reported a circulation rate of over 90% (Nagaswa and Kanaura, 1992), In the Indian Steel Industry specific water consumption varies in the range 10-50 m3/t of crude steel as against the norm of 16m3/t of crude steel (Pandey,1996). Discharge of effluents generated in steel industry into contiguous water bodies viz rivers has resulted in high pollution load and Several places like Salem have high fluoride level in the ground water and this places a severe restraint on the fluoride content of effluents discharged. Waste Water Treatment Technology for Steel Industry using Membrane Bioreactor (MBR). It is the latest technology for biological degradation of soluble organic impurities was studied (Sinha *et al.,* 2014) MBR technology has been in extensive usage for treatment of domestic sewage, but for industrial waste treatment applications, its use has been somewhat limited or selective.

CONCLUSION

It may be summarized from the review of a number of the important literature that basic characterization study of waste generated from steel industry and heavy metal degradation has been either reported to a limited extent. From this above review it is clear that researches be preferred to evaluate environmental impact and bioremediation technique for the treatment of wastes from industries. It is concluded that integrated systems combining effluent treatment methodologies can guarantee a high degree of contaminant removal leading to ensure eco-friendliness and commercial viability. and produces premier quality reusable water with easily disposable minimum sludge generation.

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