Iron and Steel Industry-A Review of ETP Technologies

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ABSTRACT: - *This study reviews waste water characterization of Iron and Steel industry and treatment procedure involved in these industries.*
Iron and steel industry is one of the most important and vital industry which is the principal driving force propelling economic and technological growth of a nation. However, since its inception this industry is associated with widespread environmental pollution and enormous water consumption. Different units of a steel plant discharge effluents loaded with, hazardous pollutants, toxic and unutilized components which necessitates mitigation. In this paper, pollutant removal efficiency, effluent volume product quality, and economic feasibility of existing treatments are studied vis-a` - vis their merits, demerits, and innovations to access their shortcomings which can be overcome with new technology to identify future research directions. While conventional methods are inadequate for complete remediation and water reclamation, the potential of advanced treatments, like membrane separation, remains relatively untapped. It is concluded that integrated systems combining membrane separation with chemical treatments can guarantee a high degree of contaminant removal, reusability of effluents concurrently leading to process intensification ensuring Eco friendliness and commercial viability.
KEYWORDS- *Steel Plant Effluent, COD removal, Membrane Treatment*

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I. INTRODUCTION

The steel industry is one of the most important and essential Industry of the present era. It is the asset of a nation. The steel industry's significance for our affluence and growth can be accentuate enough. The steel industry's products also play a crucial role in the development of the sustainable society .World Steel Association, in 2015 alone the world crude steel production was 89.6 Mg. With rising growth, consumption of steel in different sectors is escalating with a commensurate increment in water usage. In India, near about 25 to 60 cubic meters of water are used for producing one metric tons of steel. These statistics tells about the backdrop of the crippling water shortage the world is already facing. It is imperative to have radical progress in water treatment technologies so as to minimize fresh water consumption and shift towards zero effluent discharge.

The development of innovative technologies for treatment of waste from various industries is a matter of alarming concern for us .Although many research papers have been reported on waste water pollution control studies, but a very few research work is carried out for treatment of waste water of steel industries, especially in reference to development of design of industrial effluent Treatment Plant (ETP) system.

Therefore it is necessary to develop effective and inexpensive effluent treatment method to minimize waste water generation and recovery of water .Conventional effluent treatment methods for steel industry are Coagulation – flocculation, APOs, Membrane treatment, Biological treatment, Adsorption and Membrane Bioreactor.

In this paper, we have focussed on iron and steel industry as a whole, critically reviewing the production technology employed for wastes generated in each unit, the role of new technology in decreasing pollution, and the best disposal practices followed. The possible benefits of valuable by-product recovery from the waste streams were explored, so as to enhance water recycling and minimize material consumption. This was substantiated with economic analysis and judicious resource utilization strategies for developing a holistic waste treatment methodology.

II. ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

An environmental Impact Assessment (EIA) is a process of evaluation of various factor such as impact of environment on health of human, ecological health and associated risk with it. It is the title used for the assessment of the environmental consequences (positive and negative) of a plan, policy, program, or concrete

projects prior to the decision to move forward with the proposed action. In this scene, the term "environmental impact assessment" (EIA) is used to concrete projects by individuals or companies and the term "strategic environmental assessment" (SEA) applies to policies, plans and programmers most often proposed by organs of state. Environmental assessments may be governed by rules of administrative procedure regarding public participation and documentation of decision making, and may be subject to judicial review.

2.1   Purpose of EIA

2.1.1 The main aim of Environmental Impact Assessment (EIA) is to identify and assess the potential impacts of development of projects on the environmental system. It is an useful media for decision making based on understanding of the environment implications including social, cultural and aesthetic concerns which could be integrated with the analysis of the project costs and this exercise should be undertaken early enough in the planning stage of projects for selection of environmentally compatible sites, process technologies and such other environmental safeguards.

2.1.2 While all industrial projects may have some environmental impacts all of them may not be significant enough to warrant elaborate evaluation procedures. The need for such exercises will have to be decided after initial evaluation of the possible implications of a particular project and its location. The projects suggested for detailed Environment Impact Assessment include the following:-

1.   Industrial Waste Water Treatment

Industrial waste water treatment includes the mechanisms and processes used to treat wastewater that is produced in industries. After treatment of waste water the effluent may be reused or released to a sanitary sewer or to a surface water in the environment. Industries produce wastewater although in recent trends focused has been given on reduce such production or recycle wastewater within the production process. However it depends upon on processes that produce wastewaters. Every year approximate 1.8 million people die due to suffering from waterborne diseases. Main cause of these deaths can be indirectly imputed to improper sanitation. Wastewater treatment has to be taken more seriously for the betterment of the society and our future. Wastewater treatment involves removal of contaminants from wastewater as well as household sewage, to produce waste stream or solid waste suitable for discharge or reuse.

2.   Effluent Treatment Plants (ETP)

An Effluent Treatment Plants or (ETPs) is a plant in which the treatment of industrial effluents is done. It used by industries to purify water and remove any toxic and nontoxic materials or chemicals from it. These plants are used by all industries for the purpose of environment protection.. Without this treatment, it won't be possible for humans to get clean usable water.

ETP plays vital role in treating industrial wastewater as well as sewages generated from households. Effluent treatment plants help both small- and medium-sized industries by treating of the effluents generated at their facilities. Else ways it would be difficult for them to treat wastewater properly. They might also require to have extra space for contaminated water treatment. Nonetheless, they may need to treat the water for the purpose of solid removal to ensure that the sewer can flow freely. Also, eviction of some toxins is necessary prior to release the wastewater in ETPs.

2.1   Benefits of ETP

Results in clean reusable water: - Effluent Treatment Plants manufactured by any leading packaged ETP manufacturer assure clean and safe water. Before the inception of this incredible treatment plant, people were hardly aware that impure and polluted water can be reused. The treatment method which are followed by ETPs involves the elimination of toxin from the water in order to generate safe and clean water.

Saves Money: It also assure complying with industry regulations and standards.

Saves Planet: ETPs remove hazardous chemical from water in order to treat it and make it ready for reuse. Usually when this treated water will enter the ground, it will leave no negative effect on the planet.ETPs are bliss for the industry owners.

Saves water: By adopting an ETP, water can be save. The plant recycles contaminated water insure less water wastage and that is absolutely good for the earth. If your business might leave the carbon footprint and you are concerned about it, ETPs are the best way to serve Mother Nature in better way.

ETP aid to purify waste water generated from households as well as industry. The treatment process gives reusable clean water, saves your money as well as water and our planet. [42]

III. OVERVIEW OF OPERATIONS, EFFLUENT PRODUCTION AND COMPOSITION

Iron and steel industry discharges huge amount of effluent from different sections. Figure 1 describes pollutants discharges at different levels of a typical steelmaking operation. Ghose studied integrated steel plant and found that the highest water consumption as well as effluent production is cock oven section. Various hydro intensive operations include quenching of hot coke, washing ammonia still, cooling and washing of the coke oven gases, and isolation of the by-products of coke industry such as highly toxic substances like cyanides, thiocyanate, phenol, ammonia, oil, and grease concentrations are generated. [7] Next to the coke oven is the tar and liquor plant, which handles water circulating between the coke oven battery and the by-product recovery section. This water is highly toxic ammoniac AL liquor bearing iron, ammonia, cyanide and phenol. It also includes wastewater from raw material preparation sections and coal handling making it difficult to handle. In terms of water consumption, the blast furnace conquer the major share. An old blast furnace needs around 77 600 liters of water per Mg of pig iron produced. With the introduction of modern technology, water consumption in blast furnaces is reduced but still it can be considered as very high. Utilization of water in the blast furnace of integrated steel plants ranges from 0 to 7.6 m3 per Mg of ingot steel, and for steel processing plants this utilization is up to 1.7 to 49 L/Mg. The pig iron produced is sent to the SMS where furnace is cooled by water. The exit water is at high temperature, with considerable suspended solids loading, in the range of 1000 to 5000 mg/L. Biswas introduced the Continuous Casting process in which the wastewater produced in the apron spray zone contains oil leakages and emulsified solids. An integrated steel plant mainly combines rolling and pickling operations. In hot and cold rolling operation, the primary rolling mill effluent contains scales and debris (10 to 20 mesh size) loading at 100 to 200 mg/L; and oil content varies from 10 to 25 mg/L. [4] At the end of this process, the steel is pickled in acid which give characteristic glossy finish to it. Pickling operations yield SPL (Spent Pickle Liquor) containing dissolved metal salts of iron, copper, zinc, chromium and nickel as well as residual free acid, rinse water, and water used in fume scrubbers. Usually Mild steels are pickled in HCl or H2SO4. Stainless steel is pickled in two steps with acids like, nitric acid hydrofluoric acid and sulphuric acid. Rust and acid resistant chromium-nickel steels are pickled in a bath of HCl and HNO3. When acids other than sulphuric acid or phosphoric acid are used, then wastewater from the fume scrubber is added to the waste. During treatment process of SPL, a large quantity of sludge is generated containing heavy metals.

Table 1—Effluent characteristics of different steel plant units.

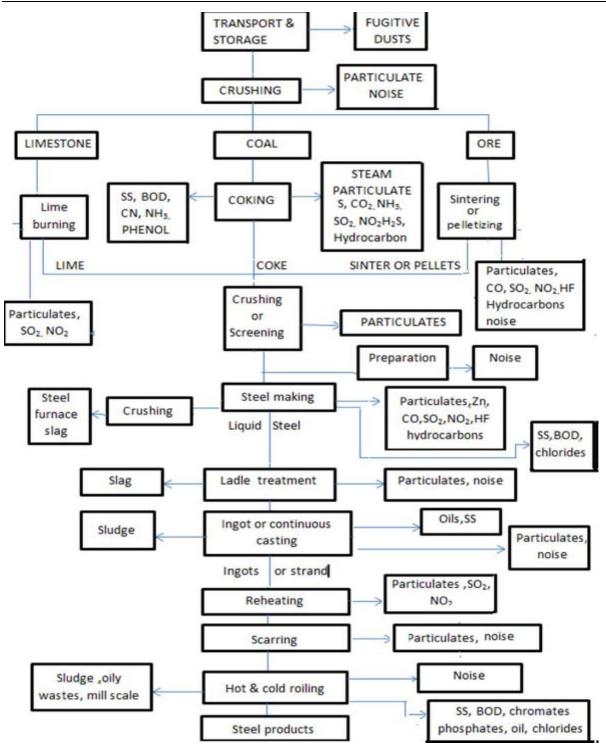| Section	pH	Alk. mg/L	TDS mg/L	TSS mg/L	VSS mg/L	Anions mg/L	Cations mg/L	Phenol (In %)	Others mg/L
Blast Furnace	7–9	-		330–350	<=200	MnO_4^-= 40–15 CN^- = 0.6–1.3 CNS^-= 0–17	Fe^{2+} = 140–180	0.5–1.2	
Slag Crushing	-	3–4	450–550	500–600	30–50	MnO_4^-=100–500 SO_4^{2-}=100–150 CN^- = — CNS^-= 3–4		1.0–2.5	
Rolling Mills		3–4	400–500	1000–1500	10–100	SO_4^{2-}=100–150		-	Lube Oil = 2–50
Coke Oven	7.0– 8.5		800–1200	200–7000		CN^-= 8.2–21	NH_4^+ = 48–1500		Phenol= 82–123 BOD= 64–94
Pig Iron Cooling	7–8		500–2000	500–3500	350	MnO_4^-=60–100 SO_4^{2-}= 20–650 Cl^-= 200–300	———		
Pickling Unit	1.5-4.5					SO_4^{2-}=200–2000	Fe^{2+}= 80–600 Ca^{2+}= 50–200 Al^{3+}= 0–50		

Figure 1- Pollutants emitted from different units of a steel making operation

IV. CONVENTIAL EFFLUENT TREATMENT METHODOLOGY IN IRON AND STEEL INDUSTRY

Physicochemical Processes.

In steel industry Physicochemical treatment separately addresses the issues of solids removal, oil and grease removal, and removal of biodegradable organics, removal of acids and alkalis, and treatment of toxic metals. The different methods used are Coagulation-Flocculation, Adsorption, Advanced Oxidation Processes, Electrochemical techniques, and a combination of one or more of these processes.

4.1 Coagulation-Flocculation

The work carried carried by Amuda et. al focused on Coagulation process followed by flocculation and sedimentation by using ,clarifiers ,settling tanks, and clariflocculators, is one of the most commonly used conventional effluent treatments for the removal of pollutants. These technologies are frequently used to remove emulsified oils present in cold rolling mill residues; to precipitate out the iron and heavy metal residues.[2] Calcium oxide, potash alum, magnesium salts and calcium hydroxide, are the most commonly used flocculants which act through different technique such as bridging ,charge neutralization and electrostatic patch and so forth. Coagulants also help to reduce the total pollutant loading handled by tertiary treatment.

For instance, Amosa et.al prove that how coagulation was effective in decreasing membrane fouling before membrane filtration. [Figure 2] shows how pretreatment and chemical coagulation steps are united for the primary treatment of wastewater. [28]. Recent developments have introduced by Lee C.S.et al .with polymeric coagulants. Different scope of additives, like ionic or nonionic polyelectrolytes and organic molecules, are mixed with a fixed composition, creating composite coagulants with higher pollutant removal efficiency which, in some cases, has shown total dissolved solid(TDS) and total suspended solids (TSS) removal.[20] But in industries, flocculants, coagulants, and sedimentation are primarily used as a pretreatment methods before the main treatment, such as membrane filtration according to Benito et al., As far as lighter particles are considered, such as coke breeze or sinter dust, most coagulants show poor removal efficiency. [30]

4.2 Adsorption

Vazquez et al and Zhange et al used adsorbents to remove selected stubborn compounds from effluents, such as cyanide, phenols, from coke oven liquors, surfactants from pickling liquors, and heavy metals from casting operations [26, 27]. Studies conducted on steel industry waste treatment in Malaysia, using furnace slag as an adsorbent, recorded a substantial reduction of manganese, iron, zinc, and copper content. Beh et al, studied industrially zeolites acting as molecular sieves are act as efficient adsorbents for the selective removal of target compounds. The need for the regeneration of adsorbent is a drawback of nearly all adsorbent based systems, limiting its application in a continuous waste treatment process. Another deterrent is the high cost of adsorbents. Some researchers have utilized inexpensive materials like rice husk, seed coats, and vegetable skins as absorbents. [31] .For instance Li et al., have synthesized boron mud haydite from boron mud, bentonite, flyash, and saw dust, and have applied the same for the removal of turbidity from steel industry wastewater. Maintaining a flow rate of around 1200 L/s and an alkaline medium with a pH of 12, a turbidity removal rate up to 94% was attained in 1 h..[11] An interesting example of waste utilization in the process of waste treatment is presented by Amosa. [2] In the paper, empty fruit bunch (EFB), a discarded material from the palm oil industry, was dried and recycled as a feedstock for powdered activated carbon (PAC) synthesis with carbonization and steam pyrolysis.[2] It was subsequently used for treating POME wherein it showed a removal efficiency of 95% and 90% for manganese (Mn) and hydrogen sulfide (H2S), respectively [4] compared adsorptive strength PACs, prepared from fruit bunch waste activated using steam and CO2 based systems. It was seen that steam activated

PAC outperformed CO2 activated PAC with 81%, 92%, and 89% removal efficiencies for COD, manganese, and hydrogen sulfide (H2S), respectively, versus 67%, 90%, and 87% for CO2- activated PAC. In recent years Choi et al.discovered that adsorbents, granulated activated carbon filters are a technology development that greatly enhance the area available for adsorption. These are synthesized from crude organics, and heated in the absence of oxygen to activate surface porosity, which proves to be economical in the preferential trapping of select chemicals from complex industrial wastewater. These are booming systems capable of removing organic matter and microbial pollutants from wastewater and offering surface areas ranging from 1100 to 1250 m^2/g of adsorbent [32] Modelling, simulation, and economic analysis are some of the important methods to enhance scale-up confidence of these appropriate technologies for real world implementation .Nanomaterials are the new class of adsorbents that has been receiving increased attention in recent years. As adsorbents, Carbon nanotubes, serve to remove organic as well as inorganic components from wastewater. The factors governing adsorptive interfaces between carbon nanotubes (CNTs) and organic pollutants are contact areas, shape, average pore diameter, and volume, morphology, and functional groups of the CNTs; whereas for organic pollutants, hydrophobicity, electron polarizability, size, polarity, functional groups, and environmental conditions (pH, ionic strength) are the dominant factors affecting system performance. Carbon nanotubes (CNTs) have been efficient in removing probably unnamable components from wastewater, like synthetic dyes, and heavy metals like copper proved by Kabbashi. et al., [33]. AlSaadi et. al Synthesized CNTs on PAC impregnated with Fe^{3+} catalysts, in batches, using fixed catalyst chemical vapor deposition. It was concluded that whereas optimization of reaction time, gas flow rates, and reaction temperature could be done successfully, sorption capacity of the adsorbent needed functionalization. Two different methods of functionalization ware tested, namely, sonication with KMnO4 and refluxing with HNO3 at 140^0C. Out of the two, KMnO4 demonstrated a very high cadmium removal efficiency (98.35%) from synthetic wastewater. But the suitability of such a system for industrial upscaling needs to be evaluated. Also research in this direction has to be focused to concretely estimate techno economic feasibility for industrial application.

4.3 Advanced Oxidation Processes (AOP)

The effectiveness of AOP lies in the simultaneous disinfection and lowering of solid content along with COD and BOD. They also aid in volume reduction which is essential as the steel industry generates liters of effluents. Ozonation is a powerful AOP method used for oxidation and disinfection of organic and inorganic compounds, as well as enhancement of sludge degradability. The main restriction for disinfection is the rate of mass transfer of ozone, which is often low as result of its poor solubility. Nava invented that Ozonation degrades toxic compounds like thiocyanate, cyanide,[22]while Kunita studied on degradation of ammonia, [15] all of which are present in high concentrations in steel industry wastewater. Chang et al used this Ozonation method for treating coke oven wastewater, where complete removal of thiocyanate and color was observed, coupled with 80% removal of BOD, in 1 h of ozone dosing.[5] But conduction of tests are to be needed to assess its viability to treat large volumes of the aforementioned compounds. Hydrogen peroxide is another chemical compound that has been extensively used as an oxidant in water resource recovery. Case studies conducted in the Warri petrochemical refining industry showed COD removal of up to 58% with a dosage of 15 ml/L of 30% H_2O_2. Soji Adeyinka and Rim Rukesh integrated setup wherein H_2O_2 dosing was supplemented with an alum treatment, followed by sodium and activated clay ion exchange resin that removed toxic lead present in the effluent. [24] They also found that additives like ultraviolet light and iron salts are mixed with H_2O_2 to increase the removal efficiency. Sindhi and Mehata carried out a experiment by using Fenton's reagent which is a solution of hydrogen peroxide and a ferrous salt as catalyst. They found that due to its high oxidation potential, it oxidizes hazardous components from different complex wastewaters. [43]Though AOP are suitable from the point of view of disinfection and volume reduction, it is yet important to understand that they are used in conjunction with other treatment methodologies to make a complete treatment process. Nevertheless the benefits of ozonation over other modes of disinfection, like chlorination, presently it could not completely replace carcinogen producing chlorination for disinfection, mainly because of the high cost of operation.

4.4 Electrochemical Methods

Farhadi et al studied a class of unit operations where one of the components, as the name suggests, is electricity. Electrochemical oxidation reduces obnoxious bio refractory compounds, as well as markedly decreasing BOD and COD loadings. Generally used electrodes are iron, aluminum, or the hybrid Al/Fe electrodes. Often, electrochemical technique is used in combination with prevailing processes like coagulation (electrocoagulation), flocculation (electroflocculation) , dialysis (electrodialysis) and COD removal efficiencies of electrocoagulation and hybrid associates decreases progressively in the order: peroxi-electrocoagulation > peroxi-photoelectrocoagulation > photoelectrocoagulation > electrocoagulation. Often, electrochemical methods yield hydroxide ion formation which increases surface area for the adsorption of organic ions and colloidal particles from substrate. Consequently, separation of insoluble flocs by electrofloatation is done easily.[8] Inazaki et al. invented that efficiency of treatment is directly proportional to the rate treatment time using by simulated waste water , whereas the electrochemical system size is inversely proportional to the magnitude of electricity passed. [34].

In recent years, Huang demonstrated electrosorption is another channel which is acquiring increased attention and has been industrially scaled up. The parameters which govern system performance in electrosorption are electric voltage, pH, time, temperature and electrode capacity. The frequently used electrode material is activated carbon fiber, due to its high surface area for the adsorption of ions, especially useful when the heavy metal content of wastewaters ranges around 200 ppm[10,11] In China, Zhang et al carried out a WISCO (Wuhan Iron and Steel Group Corporation) on-site test using electrosorption, which demonstrated reduction in conductivity by 70% and removal of chloride and calcium ions by 75% and 68%, respectively, on a continuous basis at a high flow rate of 1000 L/h. [12]

Nonetheless the main risk associated with electrodes is the accidental formation of hazardous mixtures like H_2/Cl_2 and H_2/O_2 as well as pernicious gases such H_2S, CCl_4 , AsH_3, NOx, and SbH_3). Hence, careful design optimization is very much essential for the safe functioning of these systems was studied by Bersier et al. Moreover, he found the need of continuous electricity makes the system energy intensive and, often, economically unattractive. [3]

4.5 Membrane Treatment

In recent years, membrane technology has grown to the remedy of energy intensive, multistep complex industrial water resource recovery techniques. Iron and steel industry is no exception. Membranes offer multifarious benefits such as higher separation efficiency, operational flexibility, modular system design, and easy to maintain process conditions. It is a promising option to change the plethora of equipment used in steel industry effluent treatment (shown in Table 2). The study carried by Jevons K. and Awe was focus on the presence of ions and the high conductivity of steel effluents make them applicable for treatment by reverse osmosis and nanofiltration , which are pressure driven membrane processes. Processes like reverse osmosis and nanofiltration were used to treat effluents having a separation efficiency of 97% and removal of heavy metal

ions, total solid ,BOD, and COD as well as oil and grease, whilst being environmentally friendly at the same time. Membrane processes consume lesser energy as compared to conventional separation processes like distillation and evaporation   [14]. This technology has been utilized in many fields such as upgradation of a process gas stream in a bulk chemical process, enzymes recovery, and the recovery of isopropanol, in a fine chemical process, and so forth. A survey done by Zheng et al. found that near about 580 membrane treatment units of process are operating in industries like power generation, petrochemical and steel industries treating on an average 6.7 million m^3 of waste water per day. [35] Fouling studies separately conducted on the high organic loaded wastes from steel rolling mills their findings revealed high intensity of biofouling on ultrafiltration tank necessitating predisinfection.

The study carried out by Lee et al on the problem of concentration polarization encountered in membrane treatment processes can be minimized significantly by adding a pre-filtration step such as ultrafiltration or microfiltration. An integration of back washable microfiltration and reverse osmosis has demonstrated a conductivity removal of around 95%, which is a direct estimation of solids removal. [19]

Huang et al. invented that Membrane filtration with stabilization and disposal mode of the concentrates gives a complete treatment.[11] Research showed a recovery rate of 75%, with desalination up to 98% by using a integrated ultrafiltration –reverse osmosis and constructed wetland process. In a membrane system, the most crucial factor which affecting separation flux from the process is pore blocking. Solid content present in feed, increases the resistance to filtration by progressively blocking out the effective area offered for filtration. Consequently, the filtrate flow rate diminishes, requiring an increase in overall driving force. He governing equations for constant pressure and constant flux separations in the interstices of a membrane are used for evaluation of the reduced pore size, maximum filtrate volume, and fouling potential.

Amosa et al conducted Fauling studies on a Newtonian fluid (biotreated POME) of three different ultrafiltration membranes which having different molecular weight cut-offs (MWCOs). They measured the extent of fouling using blocking index, which is a dimensionless filtration constant that characterizes the type of fouling model, comprising of four steps of complete blocking, standard blocking, intermediate blocking, and cake filtration, corresponding to a blocking index from 2 to 0. Quite interestingly it was seen that cake filtration prevails, then fouling is not detrimental to the process of membrane filtration.[1]

S. No.	Coke Oven Byproduct Plant Parameter (mg/l)	Concentration in Mg/l Except pH (Not to Exceed)
	Table 2: Integrated Iron and Steel Plant: Wastewater Discharge Standards [2]	
1	pH	6-8
2	Suspended Solid	100
3	Phenol	1
4	Cyanide	0.2
5	B.O.D,3 day 27^{0}C	530
6	COD	25
7	Ammonia Nitrogen	50
8	O& G	10
	Source: Comprehensive Industry Document series (1998)	

4.6   Biological Treatments

Advances in the fields of biotechnology, biochemistry, microbiology and genetics 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, requires less capital investment and is ecofriendly. Microbial action converts colloidal and dissolved carbonaceous organic matter into settleable solids using compounds such as nitrate, carbon dioxide and sulfate as electron acceptors. Broadly speaking, biological treatments are categorized into two types, namely, suspended growth process and attached growth process.

4.6.1   Suspended Growth Process

The most commonly used suspended growth process is activated sludge treatment in which a dense microbial population in suspension converts the soluble and insoluble organic and inorganic components into flocs. Thereafter, the flocs, composed of microbes and oxidized substances, are easily removed by gravity settling. To maintain the microbial concentration a part of the sludge is recycled in the reactor which, in turn, maintains the degree and speed of degradation.
(In presence of bacteria)

257 Organic matters (C,O,H,N,S) + O_2 + nutrients $\rightarrow$ CO_2 + NH_3+ $C_5H_7NO_2$ + end products

(In presence of bacteria)

$5O_2$ + $C_5H_7NO_2$ $\rightarrow$ $5CO2$ + $2H_2O$ + NH_3 + energy

Activated sludge processes are used in both single step and multistep setups, based on the number of stages required for decomposition of the sludge. Numerous design modifications in activated sludge reactor design is done by Kim et al. He mixed activated sludge reactor, plug flow activated sludge reactor, and sequencing batch reactor (SBR).[16] Often different pollutants require different hydraulic residence times, pH conditions and oxygen levels (absence or presence) increasing the number of main reactors required for degradation. Also, cleaning the tanks is quite challenging and this process needs skilled personnel for constant maintenance of all the mechanical equipment.

Xu et al. investigated that Waste stabilization ponds and constructed wetlands gives an alternative to high maintenance treatment systems. By using this consumption of fresh water in steel plant can be minimized by simultaneous removing of high loadings of Iron & Manganese from discharged effluents.

4.6.2 Attached Growth Process
In this process, microorganisms remain adhere to the media in the main reactor which removes organics. The main principle of operation is the growth of predominantly aerobic microorganisms on the media like sand gravel, or plastic screens; which reacts with the organics present in the inflow of wastewater. Trickling filters is the most common attached growth processes which has been utilized for water resource recovery. For biofilm growth Trickling filters provide a support media wherein microorganisms are hold for longer time periods, making it possible for higher hydraulic loadings and toxic content to be handled.

Tekerlekopoulou and Vayenas conducted an experiment to assess performance of nitrifying filters demonstrated a 100% nitrification rate using a dried expanded clay. [25] .A design modification to achieve higher efficiency in the trickling filters is done by Kurner and Rosenthal with three phase fixed media reactors and study characteristics by using granular media filter which allowing secondary treatment in the same unit .[41] Nonetheless Mann and Stephenson carried out study and found that these reactors are not suitable for treating effluents with fluctuating shock loadings or dissolved solids concentrations. [21]

Pozo-Antonio Integrate biological treatment processes with mechanical systems like the fluidized bed reactors which increases separation efficiency to a very high extent. Packed bed reactors are also used as an attached growth system but the fluidized system provides all the advantages of a fluidized system over a packed bed reactor like good mixing and the ability to run in continuous mode for a longer duration and so forth. Design parameters include bed expansion degree, support material (absorptivity, particle density, surface area, shape, size, and distribution), residual sludge and yield of biological solids, concentration of wastewater, rate of circulation, and organic load bearing capacity. In the aerobic fluidized systems, the microbial population is stabilized on glass beads and gravels, which are then fluidized by an incoming jet of air or oxygen. Actually, zeolite has also been used as a possible support material for microbial aerobic fluidized bed reactors. The fluidization process assure uniform mixing, high separation efficiency, and homogenous distribution of the wastewater. After that, treated effluent is withdrawn through an outlet provided at the top, whilst the microbial layer is periodically washed off.[23].Petrozzi and Dunn conducted experiments ,have shown the efficacy of aerobic fluidized bed reactors in removing cyanide, color (89%), and COD (83.3%) removal. [36] Balaji and Poongothai used sulfide with this and found that separation efficiency is directly proportional to the amount of biomass which is attached to the medium used for fluidization, whereas low flow rates correspond to higher separation efficiencies.[9] Xu invented two modes of operation of an aerobic fluidized bed reactor, depending on the target of maximizing removal of contaminants or minimization of the volume of sludge produced at the end of operation. To run the reactor at optimum operating conditions is a challenge, as the amount of biomass governs the rate of endogenous respiration and sludge production, with removal efficiency becoming stagnant at limiting concentrations, even when microbial concentration increases.[6]

4.7 Membrane Bioreactor
Harika et al., carried out investigation and found that Membrane bioreactors are utilize as a tertiary effluent treatment step in some steel plants in India .The technology is a combination of a suspended media bioreactor with the membrane functioning as a secondary settler. The reactors gives several benefits over conventional biological treatment processes because they handle highly variable shock loadings and high BOD/COD loadings with less power utilization Figure 2 illustrate a relative comparison between biological treatments and an MBR. Application of this technology has shown improved nitrification, reduced sludge production (as physical separation by membrane retains almost all the suspended solids) whereas the biological

process create biodegradation of organics and inorganics. The membranes can be in a single stage or present in multiple side tanks, with constant recirculation providing major flexibility in system performance.[37]

Mann and Stephenson studied Membrane bioreactors (MBRs) and show a similar trend of greater fluxes for cross flow modules as a consequence of sweeping action, compared with submerged modules which similar to the dead end modes of membrane filtration.[21].Kurian and Nakhla demonstrated Membrane bioreactors (MBRs) with a ceramic membrane which indicated a COD reduction rate of up to 97% with a considerable reduction of pH from a highly alkaline feed of pH 10.[18]. For sewage treatment operational MBRs are installed in the state of Michigan, U.S.A. have a Capacity to treat 32 000 m3/day of sewage with a final phosphorus concentration as low as 0.2 mg/L, as well as allowing a 40% increase in capacity with the same footprint. Further design modification is the Aqua-EMBR, an external non submerged type MBR which does not require a membrane tank.

Cho et.al., conducted a experiment on pilot by a sequencing anoxic membrane bioreactor, where anoxic conditions were manage for denitrification with internal recycle, whereas, anoxic conditions for phosphorus removal was without internal recycle. It was found that higher flow fluxes and shorter hydraulic residence times achieved higher separation efficiencies .However, MBR's face the problem of fouling which is common to dead-end modules in precise, leading to flux detegration. The high capital cost of existing systems also poses a barrier to large scale application of these systems. In addition, systems using ceramic membranes are represent by the low output flux ad high cost of ceramic membranes, which are significant bottlenecks that have to be overcome [29]
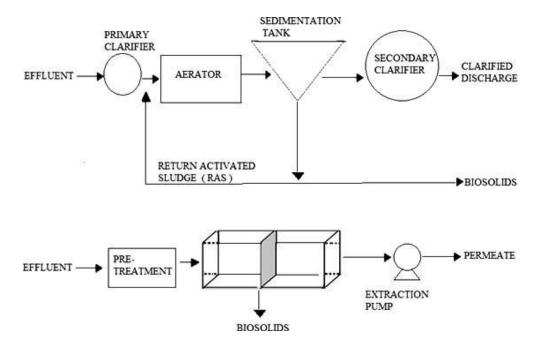

Figure 2- Comparison between biological treatment and membrane bioreactor technology.

4.8   Bioremediation

Jayapriya studied Bioremediation which is a waste management method, utilize simple microbes to break down or neutralize waste materials and can be carried out ex-situ or in-situ. It can be applied to liquid, solid, and gaseous wastes from the steel industry

Bioleaching/biosolubilization of heavy metal loading bearing effluents using fungi or bacteria isolated from polluted sources has the potential to remove heavy metals to a higher degree compared with those isolated from non-polluted pure sources. They found that reclamation of the large volume of water used in steel production is a grey area in which the application of mixed microbial culture can facilitate better water recycling and recovery. [13] A mixed soil bacterial culture comprising of Pseudomonas, Arthrobacter, Micrococcus and Bacillus, has successfully degraded effluents from steel industry with a high COD and BOD of 95%. Bio sorption is another segment of bioremediation in which microbes, or a part of activated biomass, can take up organics as well as inorganics, such as heavy metals, on their surfaces. The microbial cell (solid state) preferentially picks up the materials from effluents (liquid phase) that have a higher affinity for it. Different mechanisms such as cell surface sorption/precipitation, extracellular accumulation/ precipitation and intracellular accumulation manage the location where sorbents will be deposited.

Mycelium present in some of the most common fungi Absidia, and Rhizopus have shown removal rates of 25% and good binding characteristics related to heavy metals such as cadmium, zinc, copper, uranium and lead. In fact, algae, fungi, yeast and bacteria all have demonstrated biosorbent properties especially releated to the removal of heavy metals like Zn,Fe Cu, and Pb from different waste streams. However, there are some pertinent issues such as toxic variation in metal ion removal rates, sludge generation, and high rate of reagent consumption which required to be worked out to progress these processes towards a fully acceptable developed technology. Evaluation of the various technologies tells that focusing on waste load reduction will not sufficient; sustainable waste management must include the following steps: a) recovery and recycling, b) effective utilization of raw materials, and c) minimum waste generation. Only then can zero discharge technologies be established in reality. Process economics play a important role in the selection of waste disposal technologies, so, economic assessment is an essential step in new technology development, focusing on the aforementioned steps

V. TECHNOLOGICAL ADVANCES AND ECONOMIC EVALUATION

Tihansky analyzed the total cost invested by all American Steel plants for pollution control .He discovered that industry effluents contain a host of compounds, some of which, if recovered, will serve as an inducement for the entire waste treatment process by aiding overall process economics. The ammoniacal liquor from coke ovens contains phenol (an Industrial solvent), cyanide (an ingredient in paper, textiles, and plastic manufacture), ammonia (a raw material for fertilizers), all of which have been successfully recovered. Table 3 gives an idea about the profitable recovery of value added products from wastes produced from different units of a steel plant. However, the assessment of process economics is of supreme importance when evaluating the recovery options.[40] Moreover cost analysis for capital, installation, and maintenance costs has to be considered along with the cost of raw materials and production, volume of effluent generated, and final disposal standards fixed by environmental protection agencies. For assessing techno – economic Feasibility the two most important parameters are WPI (Water Price Index) and Energy Consumption Curves, in order to study the performance of water resource recovery facilities.

Kumar et al . calculated the Water Price Index using the following formula.[17]

Water Price Index ($/KL) = (Annual Plant cost / Plant Performance) X Margin   (1)

The annual costs can be calculated by the addition of depreciation and expenses incurred during operation of the equipment:

Plant Cost (in $) = Depreciation + Operational Expenditure   (2)

For waste water treatment plant if "*n*" number of different components where rate of depreciation are different, the total depreciation cost of each component "*i*" was computed

$$\text{Depreciation (\$ / year)} = \sum_{i=1}^{n} \frac{\text{Capital Cost of instruments}}{\text{Projected lofe of instruments}} \qquad (3)$$

To rate the energy efficiency of a technology, energy consumption curves, in this case ''cost of conserved energy'' (CCE), can be constructed, which consider the cost of conserved energy to balance the total cost of new technology and the energy savings obtained from it (Worrell et al., 2001).

The CCE can be calculated from the following equation:

$$\text{CCE} = \frac{\text{Annualized Investment + Annual Chnage in O\&M Costs}}{\text{Annual Energy Savings}} \qquad (4)$$

He redesigning the treatment with simultaneous introduction of new production technologies which is the best approach towards cost optimization and achieving higher water reclamation. Using dry quenching instead of wet quenching slashes energy costs by almost 40%, and decreases the volume of hazardous ammoniacal liquor produced. New steel plants are increasingly bypassing coke ovens by opting for direct reduction processes such as HISMELT where direct smelting of the coal, iron ore, and lime occurs in a smelt reduction vessel (SRV). This decreases process costs by allowing utilization of noncoking coal and Titano-magnetite iron ore, available in India, without compromising on the quality of the steel produced.

Kumar et al. developed Corex which is another developed process technology utilizes a mixture of noncocking coal with a small amount of cocking coal with addition of iron ore in the form of pellets and oxygen gas. In the COREX process two main reactors: Melter Gasifier where reduced iron ore and coal are gasified and Reduction Shaft for reducing iron ore with a counter current stream of reducing gases. The direct tangible benefits from the process include decreased carbon dioxide emissions, energy savings, and higher utilization of noncoking coal reserves. Jindal Steel has successfully implemented making of Iron with a combination of COREX and blast furnace technology, wherein the COREX process can permit more silica and sulfur loadings, yielding almost 2.6 to 2.7 times Higher gas than a blast furnace process, with an approximate 98% gas utilization.[38].Manning and Fruehan gives new innovations such as the replacement of open hearth steelmaking with oxygen furnaces and direct reduction technologies like COREX and HISMELT will decrease total pollutant loadings. [39].

VI. CONCLUSION

Selection of treatment method for effluent should be based on the optimization of various parameters like toxicity level and contaminants discharge standards. This is very much important for steel plant where alloy preparation units yield effluent of varying composition, with discharged heavy metals holding stringent discharge standards. Research needs to be undertaken to develop a broad a broad spectrum technology for treating effluents from different section .Selecting membrane process like microfiltration should be done with a clear aim of final treated water usage and cost benefits analysis.

Accordingly, energy and cost considerations have to be balanced. Alternative sources of energy such as solar cells can be with the separation process ensuring further energy saving and environmental benefits. Conventional low cost treatment options like coagulation, can be coupled with membrane based separation techniques, creating an integrated technology that is robust, simple to operate and produces premier quality reusable water with easily disposable minimum sludge generation.

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