Chapter- 3

Experimental Studies

Experimental Studies

3.1 Methodology:

The systematic theoretical analysis of the methods applied to the field of actual study is known as the "Methodology". The important part of the planning & the design process is the reliability of the treatment processes & the facilities for the resources of water, its treatment & the reuse of the wastewater. The development of the membrane technology & the alternative disinfection processes for the treatment of water and wastewater is the recent development in the technology of wastewater treatment processes. And hence, it is therefore needed a common methodology to evaluate the reliability of the alternative processes and treatment facilities. Several treatment aspects must be considered for the reliability assessment of treatment facilities including a methodical evaluation of both mechanical reliability and plant performance. A simple method is described herein along with a description of application of the approach to conduct these types of analysis. After the discussion; the value of such a methodology is highlighted for both the quality engineer and the risk manager of the water treatment process.

3.1.1 Scope of the study:

- A proper record of all the universal best practices used for the industrial waste water technology like for primary treatment, secondary treatment & the tertiary treatment and the other best treated waste matter clearance & reuse practice with a particular reference to the technology and the practices adopted in the technology.
- The cost & economic viability analysis for the technologies in India.

3.1.2 Methodology & Approach:

The water scarcity indicator (WSI) is calculated for each process of making integrated steel in the TATA Steel plant. The different unit process like blast furnace, iron ore sinter plant, basic oxygen plant and lime production of the steel plant is under analysis. From the existing steel plants a record of data was obtained and the in-put and output data were converted to a cast steel functional unit (FU). One Ton of Cast steel produced in the integrated steel plants was the functional units of this study.

Table 3.1: Direct water use and wastewater in integrated steel plants / m^3/FU

Different process Plants	Input		Output
	Tap water	Cooling water circulating	waste water
Iron ore sinter Plant	0	0.53	0.49
Blast furnace	0.45	33.09	0.30
Lime production Plant	0	0	0.49
Basic oxygen Furnace	80.90	0	1.32
Continuous Casting Plant	0.64	9.98	0.85
Hot rolling	13.37	1.60	1.2

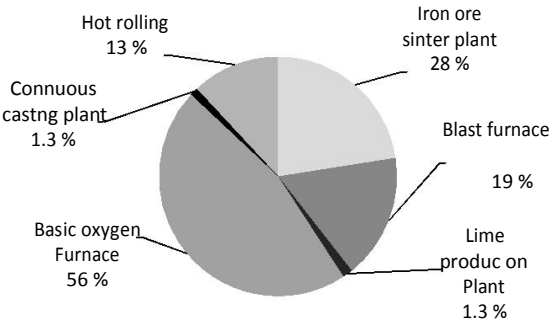

Figure 3.1: water scarcity in the unit processes of integrated steel production

Selected steel industries have been taken for the study of effluent treatment processes, for this a broad literature review and the visits of few sites were carried out. Various data were collected after talking with the ETP operators & members of the industries during the site visits.

3.2 Characterization of Wastewaters of Steel Industries:

A colloidal and dissolved suspended solids, as mineral & organic particles are present in the steel industry wastewater. Additionally, it may be either exceptionally acidic or alkaline & may include colored matter of either high or low concentration and these wastes may also contain some organic or toxic material, inert materials and maybe pathogenic germs and that is why; it

is necessary to retreat the waste prior to discharge into the municipal systems and also very necessary to treat the wastes in all manner when it is being directly discharged to the surface or ground waters.

The treatment facilities, their design & selection criteria is based on the study of the physical, chemical and biological characteristics of the wastewater.

3.2.1Physical Characteristics:

The color, odor solid content & the temperature are the basic physical characteristics of a wastewater.

Total Solids:

The total solids in a wastewater consist of the insoluble or suspended solids and the dissolved soluble compounds in water. After drying the residue removed from the filtering the sample, some suspended solid contents are obtained and all the volatile solids are burned off after igniting residuals. At high temperature some inorganic salts may breakups and the volatile are assumed to be organic matter will not burn. The organic matters mainly contain fats, carbohydrates & the proteins. The suspended solids in average waste water are in between 45% to 70%. By the process of sedimentation the settle able solids in millimeters per liter can be removed. The Set able suspended solids in the urban waste are usually about 65 % (George & Ron, 1998). The solids waste may be classified as the volatile solids (volatile at high temperature i.e 600 °C) and fixed solids, which are not volatile.

- **Color:**

The general condition of wastewater can be assessed by the use of qualitative characteristic like through seeing the color of the material. The waste water having light brown color is less than 6h old and wastewater which have already gone through some degree of decomposition and may have been in a collection system for some time is generally of a light-to-medium grey color is the characteristic. And the wastewater which has been undergone through extensive bacterial decomposition under an aerobic condition, the color becomes dark grey or black. The waste water becomes blacken often, due to various sulphide formation, particularly ferrous sulphide. By doing the comparison with the standards the colour is measured.

- **Odor:**

The determination of odor is very necessary as now a day the general public has become more concerned regarding the proper procedures of waste water treatment facilities. The odor of fresh wastewater is usually not aggressive, in fact; but when it undergo for an anaerobic conditions, the wastewater is decomposed biologically and a variety of odorous compound are released.

.

- **Temperature:**

With the addition of the warm municipal water, the temperature of wastewater becomes higher than that of the water supply. It is very much important to measure the temperature as most of the wastewater handling schemes includes biological processes, are temperature dependent. The temperature of wastewater varies also with the geographical location and in the variation of season. And the temperature varies from about 8 to 19 °C in cold regions and it varies from 14º to 25°C in warmer region (Ron & George, 1998).

3.2.2 Chemical Characteristics:

There are two main classifications of the chemical characteristics of wastewater as the inorganic and organic. They are usually considered separately because of their special importance, priority, pollutants & volatile organic compounds (VOCs).

- **Inorganic Chemicals:**

The tests carried for organic & inorganic phosphorus, free ammonia, organic nitrogen and nitrates are the principal chemical test. The two nutrients nitrogen & phosphorus are important and are responsible for the growth of aquatic plants. Testing of chloride, sulphate, pH & alkalinity are performed to assess the appropriateness of reusing treated wastewater and in calculating the different various treatment processes. In the biological treatment of wastewater the trace elements may be a factor but normally the heavy metals present in traced elements are not determined. For the proper growth of the living being, some trace elements, such as iron, copper, zinc & cobalt, in varying quantity are requiring. It is very much important to determine the quantity of heavy metals, where the further use of treated effluent or sludge is to be evaluated, as this may produce toxic effects. There are many priority pollutants like mercury, cadmium, chromium, arsenic etc.

In a system of operation it is very necessary to take a gas measurement of gases like hydrogen sulphide, oxygen, methane & carbon dioxide; basically made to help the system for their operation. The presence of hydrogen sulphide may cause corrosion & it can also affect the maintenance process of long sewers on flat slopes, as these gases are odorous & very toxic in nature, so it is required to determine the presence of these gases. In order to monitor & control the aerobic biological treatment processes in connection with the operation of anerobic digester, methane & carbon dioxide, the measurement of dissolved oxyzen are made.

- **Organic Chemicals:**

To determine the organic contents in the wastewater, a number of different tests have been developed since past a very long period. These tests are generally divided into the gross concentration of organic matters which are greater than 1mg/L and tests which are used to measure the trace concentrations in the range of 10^{-12} to 10^{-3} mg/ L. The Laboratory methods which are commonly used to measure the gross quantity of organic matters, greater than 1 mg/L in the wastewaters -

(1) BOD (Biochemical oxygen demand),

(2) COD (Chemical oxygen demand)

(3) And TOC (Total organic carbon).

The gas mass spectroscopy & chromatography, basically the instrumental methods are used to decide the trace organics in the range of 10^{-13} to 10^{-2} mg/l. To assess the presence of priority pollutants the specific organic compounds are determined (Metcalf & Eddy 1991). In the various types of biological treatment processes, the gross measure of the organic content of BOD, COD & TOC doesn't reproduce the response of the wastewater. That is why it is therefore desirable to classify the wastewater into different categories as explained in the diagram given below i.e. in Fig. 3.1

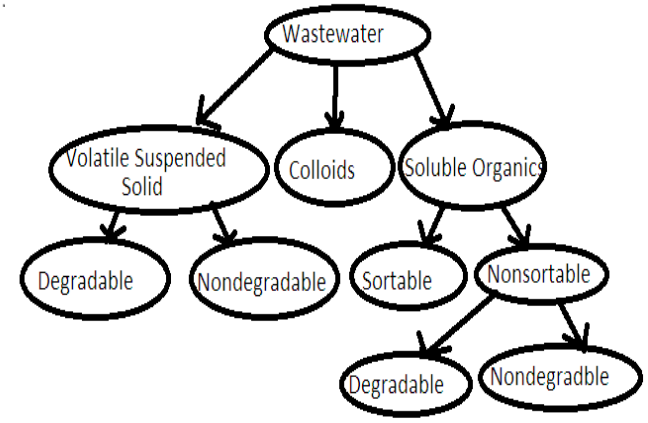

Figure: 3.2 Partition of organic constituents of a wastewater

- **VOC (Volatile Organic Carbons):**

In the area of industries or the other commercial areas, the volatile organic compounds like Tri-chloroethane, Di-chloromethane & Tri-chloroethylene, Benzene, Toluene, Xylenes are the common soil pollutants. The leakage of the underground storage tanks is one of the most common sources of these types of contaminants. The volatile organic carbon (VOC); a significant source of soil is unacceptably discarded solvents & landfills. There are many priority pollutants of organic substances like Acetaldehyde, Formaldehyde, Polychlorinated Biphenyls (PCBs), polycyclic aromatic; 1, 3-Butadiene, 1,2-Dichloroethane, Dichloromethane, Hexachloro Benzene (HCB) etc.

- **Heavy Metals and Inorganic Species:**
  - **Heavy Metal Discharges:**

Chromium is the most widely used heavy metal in the several industries and these industries are discharging these heavy metals to the environment from different sources. The pollutants entering into the aquatic ecosystem are very toxic to the living organism & these pollutants are mainly mercury lead, pesticides & herbicides. This may affect the reproductive success and can stop the proper growth and cause death.

Figure: 3.3 Discharge of untreated industrial wastewater to a river

The metals cadmium, lead & mercury are much more toxic and dangerous to the living entities rather than the chromium. These types of metals disrupt the enzyme function by forming bonds with sulpher groups in enzymes as they have a tremendous affinity for sulphur. The other chemically bounded heavy metals are Protein carboxylic acid ($-CO_2H$) & amino ($-NH_2$) groups. Some metals like lead, mercury, copper & the cadmium makes a hindrance in transportation processes through the cell wall as theses ions bind to the cell membranes. The heavy metals catalyze their decomposition and may also precipitate phosphate bio-compounds.

The cadmium pollutes water as discharge of steel waste from the industry, as it is widely used in metal plating. The metals cadmium & zinc are chemically very similar & these two metals are very frequent go for the geochemical processes together and the oxidation state of both the

metals in water is found +2. There is a very serious effects of poisoning by the acute cadmium in humans and this causes a high blood pressure, kidney damage, destruction of testicular tissue, and destruction of red blood cells. Zinc may be replaced by the cadmium, in some enzymes and then changes the stereo-structure of the enzyme and impair its catalytic activity. The harbors surrounded by the industrial facilities are mostly polluted by the sediment pollutants and water of cadmium & zinc.

The inorganic leads present in water from a number of steel industrial sources are in +2 oxidation state. The lead from the leaded gasoline which enters the natural water systems is the major source of atmospheric and terrestrial lead. The severe kidney dysfunction, failure of reproductive systems, liver and the brain & nervous system are because of acute lead poisoning in humans.

Amongst the numerous minerals, the mercury is found as a trace component with continental rocks which contain an average of around 85 parts per billion (ppb) or slightly less of this constituent. The chief commercial mercury ores are cinnabar and the red mercuric sulphide. In the laboratory vacuum apparatus and even in so many other different applications, the metallic mercury is used as an electrode in the electrolytic generation of chlorine gas. The widely used compounds applied as pesticides & fungicides are the organic mercury compounds. Through a large number of miscellaneous sources related to human use of the element like useless and broken thermometers, chemicals from laboratories & batteries, fungicides used in lawns and pharmaceutical products & the tooth fillings amalgam, the mercury enters into the environment. The level of mercury in sewage effluent generally contains up to 10 to12 times the level of mercury found in the typical natural waters. During 1953-1960, the toxicity of mercury was unfortunately illustrated in the bay area of Japan and a total of approx 115 cases of mercury poisoning & 45 deaths were reported among people who had consumed the contaminated seafood. The neurological damage, paralysis, blindness, insanity& chromosome breakage are the toxicological effects of mercury.

- **Cyanide:**

Amongst the various different inorganic types in the wastewater, the cyanide ion (CN-) is perhaps the most important species. Cyanide is present in water as weak acid HCN and this is a very poisonous substance and may cause death also. Having a strong affinity of cyanide with many metal ions, it forms toxic Ferrocyanide [$Fe(CN)_6^{4+}$] with iron(II).and the most toxic ion is the volatile HCN. For the metal cleaning & electroplating the cyanide is widely used in industries. Cyanide is one of the main gas and the coke scrubber effluent pollutant from coke ovens and even it is widely used in certain mineral processing operations also.

- **Ammonia:**

The initial product after decomposition of nitrogenous organic wastes is the ammonia and the presence of this often indicated in wastewaters. Generally ammonia is a regular ingredient of a few sources of groundwater and sometimes it is added to the drinking water to remove the taste & odor of the free chlorine. Since the negative log of the acid ionization constant of the ammonium ion ($NH4^+$) is 9.36 , most of the ammonia present in water is as NH_4 instead of NH_3.

- **Other Inorganic Pollutants:**

The anaerobic decomposition of the organic matter contains sulphur and the product obtained is the hydrogen sulphide(H_2S). The inorganic pollutants are also produced by microorganism during the anaerobic reduction of sulphate and are released as a gaseous pollutant from the geothermal water. In the waste water of steel plants some pollutants are present in the water as intermediate oxidation states of nitrogen like H_2S, Nitrite ions as NO^{2-}. To slow down

corrosion nitrite is added to some industrial processes and is hardly ever found in drinking water at a level greater than 0.1 mg/L. In some industrial wastewater the sulphite ion (SO_3^{2-}) is also found in some extent. In boiler feed water the sodium sulphite is commonly added scavenge oxygen:

$$2SO_3^{2-} + O_2 = 2SO_4^{2-}$$

- **Organic Pollutants:**

A wide variety of pollutants including organic pollutants are from the effluents of the industrial sources and some of these pollutants mainly oxygen-demanding substances, oil, grease & solids are removed from the primary and secondary sewage treatment processes; but some other heavy metals & salts and the refractory organics as organ chlorides, nitro compounds etc. are not removed competently. The potential source of organic pollutant is the detergents, soaps & the related chemicals. The surface-active agents, which improves the wetting quality of water doesn't arise the environmental problems attributed by the detergents. The complex form of calcium; an effective builder is added with the polyphosphate is the major environmental pollutants.

The aromatic or chlorinated hydrocarbons like benzene, bornyl alcohol, bromobenzene, chloroform, camphor, styrene, dinitrotoluene, nitrobenzeneetc are the prominent biodegradable substances and are the biorefractory organics, and many of these compounds have also been found in the drinking water. By using physical and chemical methods including air stripping, ozonation, solvent extraction & carbon adsorption the contaminated water with these compounds must be treated.

The pollutant compound polychlorinated biphenyls (PCB) was found in water, sediments & the tissues of birds and fishes throughout the world and was first discovered as environmental pollutants in 1966. By substituting chlorine between 1 to10 atoms onto the biphenyl aromatic structure, the polychlorinated biphenyls are developed and approx 210 various different compounds may be developed by these substitutes. [Rein2005].

The basic standards of drinking water to study the characteristics of water are as follows:

Table: 3.2 Drinking Water Standards of BIS [IS: 10500: 1991]

S.No	Parameters	Desirable limits mg/L	Permissible limits mg/
Necessary Characteristics			
1	COLOR	6	26
2	ODOR	Agreeable	-
3	TASTE	Agreeable	-
4	TURBIDITY (NTU)	6	11
5	pH	6.6 - 8.6	Zero Relaxation
6	TOTAL HARDNESS, $CaCO_3$	310	610
7	IRON(Fe)	0.4	1.2
8	CHLORIDE (Cl)	252	1100
9	FREE RESIDUAL CHLORINE	0.3	-
10	FLUORIDE (F)	1.2	1.6
Desirable Characteristics			
11	Dissolved Solid	500	2000
12	Calcium [Ca]	75	200
13	Magnesium [Mg]	30	100
14	Copper [Cu]	0.05	1.5
15	Manganese [Mn]	0.1	0.3
16	Sulphate [SO_4]	200	400
17	Nitrate [NO_3]	45	100
18	Phenolic Compounds	0.001	0.002
19	Mercury [Hg]	0.001	Zero Relaxation
20	Cadmium [Cd]	0.01	Zero Relaxation
21	Selenium [Se]	0.01	Zero Relaxation
22	Arsenic [As]	0.05	Zero Relaxation
23	Cyanide [N]	0.05	Zero Relaxation
24	Lead [Pb]	0.05	Zero Relaxation
25	Zinc [Zn]	5.0	15
26	Hexavalant Chromium	0.05	Zero Relaxation
27	Alkalinity	200	600
28	Aluminum [Al]	0.03	0.3
29	Boron [B]	1.0	5.2
30	Pesticides	Absent	0.002

NTU = Nephelo-metric Turbidity Unit