INDUSTRIAL WASTEWATER TREATMENT

UNIT I

Sources of Industrial Waste

Industrial wastewater means used up water from industries. The characteristics of waters depend on the nature of industry.

Generally pollution properties are:

Physical pollution	- Temperature ,Colour ,Odour ,Taste ,Solids
Chemical pollution	- pH, Acidity, Dissolved salts
Organic pollution	- Organic Matter
Biological pollution	- Biological Activities

The industrial wastes either join the streams or other natural water bodies directly, or are emptied into the municipal sewers. These wastes affect the normal life of stream or the normal functioning of sewerage and sewage treatment plant. Streams can assimilate certain amount of wastes before they are "polluted".

Three alternatives for the disposal of the industrial wastes.

1. The direct disposal of the waste into the streams without any treatment.
2. Discharge of the wastes into the municipal sewers for combined treatment.
3. Separate treatment of the industrial wastes before discharging the same into the water bodies.

The selection of particular process depends on various factors:

1. Self Purification Capacity of the Streams.
2. Permissible limits of the Pollutants in the water bodies.
3. Technical advantages if any in mixing the industrial wastes with domestic sewage.

Characteristics of the Industrial Wastes:

The following materials can cause pollution:

Inorganic salts: Inorganic salts, which are present in most industrial wastes as well as in nature itself, cause water to be "hard" and make a stream undesirable for industrial, municipal and agricultural usage. Salt laden waters deposit scale on municipal water- distribution pipelines, increasing resistance to flow and lowering the overall capacity of the lines. Another disadvantage is that, under proper environmental conditions, inorganic salts especially nitrogen and phosphorous induce the growth of microscopic plant life (algae)in surface waters

Acids and /or Alkalis : Acids and Alkalis discharged by chemical and other industrial plants make a stream undesirable not only recreational uses such as swimming and boating, but also for propagation of fish and other aquatic life. High concentrations of sulfuric acid, sufficient to lower the pH below 7.0 when free chlorine is present, have been reported to cause eye irritation to swimmers. A low ph may cause corrosion in air conditioning equipment and a ph greater than 9.5 enhances laundering.

Organic matter : Organic Matter exhausts the oxygen resources of rivers and creates unpleasant tastes, odours and general septic conditions. It is generally conceded that the critical range for fish survival is 3to 4 mg/l of D.O certain organic chemicals such as phenols, affect the taste of domestic water supplies.

Suspended solids : Suspended solids settle to the bottom or wash up on the banks and decompose, cause sing odours and depleting oxygen in the river water. Fish often die because of a sudden lowering of the oxygen content of a stream. Visible sludge creates unsightly conditions and destroys the use of a river for recreational purposes. These solids also increase the turbidity of the watercourse.

Floating Solids and liquids: These includes oils, greases, and other materials which float on the surface, they not only make the river unsightly but also obstruct passage of light through the water, retarding the growth of vital plant food.

Some specific objections to oil in streams are that it

i) interferes with natural reaeration

ii) is toxic to certain species of fish and aquatic life

iii) causes trouble in conventional water treatment processes by imparting tastes and odours to water and coating sand filters with a tenacious film.

Heated Water: An increase in water temperature, brought about by discharging wastes such as condenser waters in to streams, has various adverse effects. Streams waters which vary in temperature from one hour to the next are difficult to process efficiently in Municipal and industrial water treatment plants, and heated stream water are of decreased value for industrial cooling, indeed are industry may so increase the temperature of a stream that a neighboring industry downstream cannot use the water since there may be less D.O in warm water than in cold, aquatic life suffers and less D.O is available for natural biological degradation of any organic pollution discharged into these warm surface waters. Also bacterial action increases in higher temperatures, resulting in accelerated repletion of the streams oxygen resources.

Colour : Colour is contributed by textile and paper mills, tanneries, slaughterhouses and other industries, is an indicator of pollution. Colour interferes with the transmission of sunlight into the stream and therefore lessens photosynthetic action. Furthermore, municipal and industrial water plants have great difficulty, and scant success in removing colour from raw water.

Toxic chemicals : Both inorganic and organic chemicals, even in extremely low concentrations, may be poisonous to fresh water fish and other smaller aquatic microorganisms. Many of these compounds are not removed by municipal treatment plants and have a cumulative effect on biological systems

Microorganisms : A few industries, such as tanneries and slaughterhouses, some times discharge wastes containing bacteria. These bacteria are of two significant types:

i) bacteria which assist in the degradation of the organic matter as the waste moves down stream. This process may aid in "seeding" a stream and in accelerating the occurrence of oxygen sag in water.

ii) bacteria which are pathogenic, not only to other bacteria but also to humans.

Radio Active Materials : Cumulative damaging effects on living cells.

Foam Producing Matter : Foam producing matter such as is discharged by textile mills, paper and pulp mills and chemical plants, gives an undesirable appearance to the receiving streams. It is an indicator of contamination and is often more objectionable in a stream than lack of oxygen.

Effects On Sewage Treatment Plants :

The Pollution Characteristics of Wastes having readily definable effects on Sewers and Treatment Plants can be Classified as follows:

Bio Chemical Oxygen Demand : It is usually exerted by Dissolved and Colloidal Organic Matter and imposes a load on the Biological units of the Treatment Plant. Oxygen must be provided so that Bacteria can grow and oxidise the organic matter. An Added B.O.D load, caused by an increase in Organic Waste, requires more Bacterial Activity, more oxygen, and ~~greater~~ Biological Unit capacity for its Treatment, which (~~makes~~) increases the capital cost and operating cost.

Suspended Solids: Suspended Solids are found in considerable quantity in many Industrial Wastes, such as Paper& Pulp Effluents. Solids removed by settling and separated from the flowing Sewage are called Sludge, which may then undergo an Anaerobic Decomposition known as Digestion and pumped to drying beds or vacuum filters for extraction of additional water. Suspended Solids in Industrial Waste may settle more rapidly or slowly than Sewage Suspended Matter. If Industrial Solids settle faster than those of Municipal Sewage, Sludge should be removed at shorter intervals to prevent excessive build up: a Slow Settling one will require a longer detention period and larger basins and increases the likelihood of sludge Decomposition with accompanying nuisances, during Sewage-Flow Periods. Any Increased demands on the System usually require larger Sludge handling devices and may ultimately necessitates an increase in the Plants capacity, with resulting Higher Capital and Operating Expenses.

Floating and Coloured Materials: Floating Materials and Coloured Matter such as Oil, Grease and Dyes From Textile-Finishing Mills, are disagreeable and visible nuisances. A Modern Treatment Plant will remove normal Grease loads in Primary Settling Tanks, but abnormally high loads of predominantly emulsified Greases from Laundries, Slaughterhouses etc Passing through the Primary Units into the Biological Units will clog Flow Distributing Devices and Air Nozzles.

Volume: A Sewage Plant can handle any Volume of Flow if its units are sufficiently large. The Hydraulic Capacity of all Units must be analysed, Sewer Lines must be examined for Carrying Capacity, and all other Treatment Units are to be Designed for excessive loading

Harmful Constituents: Toxic Metals, Acids, or Alkalis, Pieces of Fat, Flammable Substances, Detergents and Phenols etc. cause nuisance in Treatment Plants.

Unit II

Waste Reduction Alternatives

Volume Reduction

Introduction

In general, the first step in minimizing the effects of Industrial Wastes on receiving Streams and Treatment Plants is to reduce the Volume of such Wastes.

This may be accomplished by:

1.Classification of wastes

2.Conservation of waste water

3.Changing production to decrease wastes

4.Re-using both industrial and municipal effluents as raw water supplies

5.Elimination of batch or slug discharges of process wastes.

Classification of Wastes:

If wastes are classified, so that manufacturing-process waters are separated from cooling waters, the volume of water requiring intensive treatment may be reduced considerably.

Sometimes it is possible to classify and separate the process waters themselves, so that only the most polluted ones are treated and the relatively uncontaminated are discharged without Treatment.

The Three main classes of waste are:

1. Wastes from manufacturing processes
2. Waters used as cooling agents in industrial processes
3. Wastes from sanitary uses.

Conservation Of wastewater:

Water conserved is waste saved. Conservation begins when an industry changes from open to a closed system. Introduction of conservation practices requires a complete engineering survey of existing water use and an inventory of all plant operations using water and producing wastes, so as to develop an accurate balance for peak and average operating conditions. For example steel mills reuse cooling waters to coal processors reuse water to remove dirt and other non-combustible materials from coal.

Changing Production to Decrease Wastes:

This is an effective method of controlling the volume of wastes but is difficult to put into the practice. It is hard to persuade production men to change their operations just to eliminate wastes. Normally, the operational phase of engineering is planned by the chemical, mechanical or industrial engineer, whose primary objective is cost savings, several measures that can be used to reduce wastes, improved process control, improved equipment design, use of different or better quality raw materials, good house keeping and preventive maintenance.

Re-Using Both Industrial and Municipal Effluents for Raw Water supplies:

Practiced mainly in areas where water is scarce and/or expensive, this is proving a popular and economical method of conservation: of all the sources of water available to Industry, Sewage plant effluent is the most reliable at all seasons of the year and the only one that is actually increasing in quantity and improving in quality.

Many industries and cities hesitate to reuse effluents for raw water supply. Certain technical problems such as hardness, colour and an esthetic reluctance to accept effluents as a potential source of water for any purpose. Also treatment plants are subject to shutdown and sudden discharges, both of which may make the supply undependable or of variable quality. However, as the cost of importing a raw water supply increase, it would seem logical to re-use Waste-treatment plant effluents to increase the present water supply by replenishing the ground water. The ever-available treatment plant effluent can produce a low cost steady water source through ground water recharge. Re-use of sewage effluent will reduce the quantity of pollution discharged by the municipality.

Elimination of Batch or Slug Discharge Of Process Wastes

If the waste is discharged in a short period of time, it is usually referred to as a slug discharge. This type of waste, because of its concentrated contaminants and/or surge in volume, can be troublesome to both treatment plants and receiving streams.
There are atleast two methods of reducing the effects of these discharges:

1. The-manufacturing firm alters its practice so as to increase the frequency and lessen the magnitude of Batch discharges.
2. Slug Wastes are retained in holding basins from which they are allowed to Flow continuously and uniformly over an extended (usually 24-hour) period.

Strength Reduction:

Introduction

Waste Strength reduction is the second major objective for an industrial plant concerned with waste treatment. The strength of wastes may be reduced by:

1.Process Changes
2.Equipment Modifications
3.Segregation of Wastes
4.Equilization of Wastes
5.By-Product Recovery
6.Proportioning of Wastes and
7.Monitoring Waste Streams

Process Changes:

In reducing the strength of wastes through process changes, the sanitary engineer is concerned with wastes that are most troublesome from a pollution standpoint.

Equipment Modification:

Changes in equipment can effect a reduction in the strength of the waste, usually by reducing the amounts of contaminants entering the waste stream. An outstanding example of waste strength reduction occurred in the dairy industry. The new cans were constructed with smooth necks so that they could be drained faster and more completely. This prevented a large amount of milk waste from entering streams and sewage plants.

Segregation of Wastes:

Segregation of Wastes reduces the strength and/or the difficulty of treating the final waste from an industrial plant. It usually results in two wastes: one strong and small in volume and the other weaker with almost the same volume as the original unsegregated waste. The small- volume strong waste can then be handled with methods specific to the problem it presents. In terms of volume reduction alone, segregation of cooling waters and storm waters from process waste will mean a saving in the size of the final treatment plant.

Equalization of Wastes:

Plants, which have many products, from a diversity of processes, prefer to equalize their wastes. This requires holding wastes for a certain period of time, depending on the time taken for the repetitive process in the plant. For example, if a manufactured item requires a series of operations that take eight hours, the plant needs an equalization basin designed to hold the wastes for that eight hours period. The effluent from an equalization basin is much more consistent in its characteristics than each separate influent to that same basin.

Stabilization of pH and B.O.D and settling of Solids and Heavy Metals are among the objectives of equalization. Stable effluents are treated more easily and efficiently, than unstable ones by industrial and municipal treatment plants.

By-Product Recovery:

All wastes contain by products, the exhausted materials used in the process. Since some wastes are very difficult to treat at low cost, it is advisable for the Industrial Management concerned to consider the possibility of building a recovery plant which will produce a Marketable By-Product and at the same time solve a trouble some Wastes problem.

Proportioning Wastes:

By Proportioning its discharge of concentrated wastes into the main sewer a plant can often reduce the strength of its total waste to the point where it will need a minimum of final treatment or will cause the least damage to the stream or treatment plant.

It may prove less costly to proportion one small but concentrated waste into the main flow. According to the rate of the main flow, than to equalize the entire waste of the plant in order to reduce the strength.

Monitoring Waste Streams:

Accidental spills are often the sole cause of stream pollution or malfunctioning of treatment plants and these can be controlled, and often eliminated completely, if all significant sources of wastes are monitored.

Neutralization

Introduction

Excessively acidic or alkaline wastes should not be discharged without treatment into a receiving stream. A stream is adversely affected by low or high pH values. This adverse condition is even more critical when sudden sludge of acids or alkalis are imposed upon the stream.

Acceptable Methods of Neutralization:

1. Mixing wastes so that the net effect is a neutral pH.
2. Passing acid wastes through beds of limestone.
3. Mixing acid wastes with lime slurries.
4. Adding the proper proportions of concentrated solutions of caustic soda(NaOH) or soda ash (Na_2CO_3)to acid wastes.
5. Adding compressed CO_2 to alkaline wastes.
6. Adding sulfuric acid to alkaline wastes.

The material and method used should be selected on the basis of the overall cost, since material costs vary widely and equipment for utilizing various agents will differ with the method selected. The volume, kind and quality of acid or alkali to be neutralized are also factors in deciding which neutralizing agent to use. .

Equalization:

Equalization is a method of retaining wastes in a basin so that the effluent discharged is fairly uniform in its characteristics (pH, colour ,turbidity ,alkalinity , B.O.D etc). A secondary but significant effect is that of lowering the concentration of effluent contaminants. A retention pond serves to level out the effects of peak loadings on the plant while substantially lowering the B.O.D and suspended solids load to the aeration unit.

Air is sometimes injected into these basins to provide:

1. Better mixing
2. Chemical oxidation of reduced compounds
3. Some degree of biological oxidation
4. Agitation to prevent suspended solids from settling.

The size and shape of the basins vary with the quantity of waste and the pattern of its discharge from the industry. The capacity should be adequate to hold and render homogeneous, all the wastes from the plant. Almost all industrial plants operate on a cycle basis; thus if the cycle of operations is repeated for every two hours, an equalization tank which can hold a two -hour flow will usually be sufficient.

The mer holding of waste, however is not sufficient to equalizing it. Each unit volume of waste discharged must be adequately mixed with other unit volumes of waste discharged many hours previously.

This mixing may be brought about in the following ways:

1. Proper distribution and baffling
2. Mechanical agitation
3. Aeration and
4. Combination of all three.

Proportioning

Proportioning means the discharge of industrial wastes in proportion to the flow of municipal sewage in the sewers or to the stream flow in the receiving river. In most case sit is possible to combine equalization and proportion in the same basin. The effluent from the equalization basin is metered into the sewer or stream according to a predetermined schedule. The objective of proportioning in sewers is to keep constant the percentage of industrial wastes to domestic sewage flow entering the municipal sewage plant.

This procedure has several purposes:

1. To protect municipal sewage treatment using chemicals from being impaired by a sudden overdose of chemicals contained in the industrial waste.
2. To protect biological treatment devices from strong loads of industrial wastes, which may inactivate the bacteria.
3. To minimize fluctuations of sanitary standards in the treated effluent.

The rate of flow of industrial waste varies from instant to instant, as does the flow of domestic sewage system. Therefore the industrial waste must be equalized and retained, then proportioned to the sewer or stream according to the volume of domestic sewage or stream flow.

Treatment and Disposal of Sludge Solids

Introduction

Of prime importance in the treatment of all liquid wastes is the removal of solids both suspended and dissolved. Once these solids are removed from the liquids, however their disposal becomes a major problem.

The following list contains most of the methods commonly used to deal with sludge solids.

1. Anaerobic and Aerobic digestion
2. Vacuum filtration
3. Drying beds
4. Sludge lagooning
5. Drying and incineration
6. Centrifuging
7. Landfill

Anaerobic and Aerobic digestion:

Anaerobic digestion is a common method of readying sludge solids for final disposal. All solids settled out in primary, secondary or other basins are pumped to an enclosed air tight digester, where they decompose in an anaerobic environment. The rate of their decomposition depends primarily on proper seeding, ph, character of the solids, temperature etc. digestion serves the dual purpose of rendering the sludge solids readily drainable and converting a portion of the organic matter to gaseous end products. It may reduce the volume of sludge by as much as 50% organic

Chapter 2

FLOW MEASUREMENT, CHARACTERIZATION AND TREATABILITY STUDIES OF INDUSTRIAL WASTE WATERS

The design of a waste water treatment plant begins with collecting information about the volume of waste water to be treated, its characteristics, and the degree of treatment required in order to meet specified discharge standards. Knowledge about the mode of manufacture, viz. continuous or batch is also useful. A batch process produces an effluent in the form of a slug which lasts for a short time, while a continuous process generates a waste water stream which flows continuously, although at varying rates. Based on this information, one can decide if a grab sample of the waste water would be representative of its quality, or a composite sample would be necessary. Information about the raw materials, chemicals and other ingredients used in the manufacturing process helps one to decide the physical and chemical tests to be conducted on the representative samples for characterizing the effluent. Correct interpretation of the results of the analysis of the waste water samples enables one to choose a proper treatment process.

2.1 MEASUREMENT OF FLOW

The measurement of waste water flow can be done either on the outfall channel or pipe carrying the entire waste water flow from the industry, or on the individual waste streams within the industry. The first method is useful in knowing the total flow, but cannot distinguish between the contributions of individual streams. It is useful in the case of industries that discharge a more or less uniform quality of waste water and are not likely to contain toxic pollutants, or valuable ingredients, which can be profitably recovered. Measurement of flow from individual streams helps in deciding whether some streams can be segregated, either for giving pretreatment, for recovery of by-products, or for recycling with or without treatment. Such streams, after pretreatment or recovery of by-products, can be mixed with the other effluent streams for further treatment. Measurement of flow rates should be invariably accompanied by collection of waste water samples, either as grab samples or as composite samples.

Flow measurement can be done either by measuring the cross-sectional area of the raw waste water channel and multiplying it by the velocity of flow, or by measuring the time required to fill a tank or drum of known volumetric capacity. Readings taken on a calibrated v-notch, a rectangular notch or weir built in the conveying channel can give a fairly accurate estimate of the flow rate.

2.2 COLLECTION, PRESERVATION AND CHARACTERIZATION OF SAMPLES

2.2.1 Collection of Samples

Sampling can be done as a grab sample, i.e. a sample which represents the instantaneous quality of the waste stream. Where it is known that the waste water flow rate is continuous but of varying quality, composite sampling is done. This consists of either collecting a fixed volume of sample at equal time intervals, or varying the volume of sample in proportion to the flow rate at the time of collection. In either case, the individual samples are mixed together to give one representative sample. The method of flow-proportionate sampling gives a more realistic sample than the 'fixed volume-fixed time interval' sample. The volume of sample collected should be enough to permit all physical and chemical tests to be carried out on it. The sampling period may range from 8 hours to 24 hours or even longer. Items of information, which should accompany the samples, include location of sampling point, time, day and date of sample collection, nature of sample (grab or composite), duration of sample collection (if a composite sample) and any other relevant information, which will help in the analysis.

2.2.2 Preservation of Samples

Samples collected in the field should be conveyed to the laboratory in the shortest possible time, to avoid deterioration in their quality. It is common practice to collect samples in a container surrounded by ice, so that low temperature (about 4°C) is maintained and the samples retain their original quality. Tests such as pH, temperature, colour, odour, etc. are best performed at site immediately after the samples are collected and the observations noted down. If immediate analysis of the samples is not possible, suitable preservatives should be added to them. *Chemical preservatives are to be added only when they are shown not to interfere with the examinations being made. When used, they should be added to the sample bottles initially, so that all portions of the sample are preserved as soon as they are collected* [1].

A list of preservatives, which may be used to maintain the quality of samples is given in Table 2.1.

Table 2.1 Preservatives for Waste Water Samples [2]

Parameter	Preservative	Maximum holding period
Acidity-Alkalinity	Preserve at 4°C	24 hours
Biochemical Oxygen Demand (BOD)	Preserve at 4°C	6 hours
Calcium	None required	
Chemical Oxygen Demand (COD)	2 ml/l H_2SO_4	7 days
Chloride	None required	
Colour	Preserve at 4°C	24 hours
Cyanide	NaOH to pH 10.0	24 hours
Dissolved oxygen	Determine at site	Non-holding
Fluoride	None required	
Hardness	None required	
Metals, total	5 ml/l HNO_3	6 months
Metals, dissolved	Filtrate, 3 ml/l 1:1 HNO_3	6 months
Ammonia nitrogen	40 mg/l $HgCl_2$, preserve at 4°C	7 days
Kjeldahl nitrogen	40 mg/l $HgCl_2$, preserve at 4°C	Unstable
Nitrate-nitrite nitrogen	40 mg/l $HgCl_2$, preserve at 4°C	7 days
Oil and grease	2 ml/l H_2SO_4, preserve at 4°C	24 hours
Organic carbon	2 ml/l H_2SO_4 (pH 2.0)	7 days
pH	None available	
Phenolics	1.0 g $CuSO_4$ + H_3PO_4 to pH 4.0, preserve at 4°C	24 hours
Phosphorus	40 mg/l $HgCl_2$, preserve at 4°C	7 days
Solids	None available	
Specific conductance	None required	
Sulphate	Preserve at 4°C	7 days
Sulphide	2 ml/l Na acetate	7 days
Threshold odour	Preserve at 4°C	24 hours
Turbidity	None available	

Although the table suggests a number of preservatives, the most effective preservative is maintenance of low temperature (4°C or lower).

Further, the samples should be analysed as soon as possible after collection.

2.2.3 Characterization of Samples

Characterization of the samples is the next step. The samples are analysed using physical and chemical methods. **Physical methods** include determination of temperature, colour, odour, total solids, suspended solids, settleable solids, dissolved solids, volatile solids, oil and grease. **Chemical methods** include determination of pH; acidity; alkalinity; biochemical oxygen demand (BOD); chemical oxygen demand (COD); total organic carbon (TOC); cations such as aluminium, arsenic, boron, cadmium, chlorine, chromium, copper, iron, lead, manganese, nickel, zinc; anions such as chlorides, ammoniacal nitrogen, nitrite nitrogen, nitrate nitrogen, phosphates, sulphates, sulphides, etc. In addition to these tests, the samples may have to be tested for cyanides, phenols, detergents, cellulose, hemicellulose, tannin, lignin, etc.—tests that are specific to certain industrial waste waters.

Procedures to be followed in conducting the analyses of samples should be those specified in the Standard Methods for Analysis of Water and Waste Water. It may be necessary at times to modify the analytical procedure for a certain constituent for which a standard method is not available. In such a case, the results of analysis should be presented with special mention of these modifications. The modified procedure should be subjected to a 'recovery' test, consisting of adding a known amount of the specific pollutant to the waste water sample, determining its concentration by the modified procedure and comparing the results of analysis with the original sample.

Results of analysis of the physical and chemical tests are then interpreted so that a preliminary idea of the treatment to be given to the waste water can be had. At the same time, the quality requirements of the treated effluent, as laid down by the pollution control authorities, are studied to enable the designer to narrow down the choice of unit operations and unit processes, and to decide the degree of treatment in order to meet the effluent quality standards.

Based on the results of analysis of the raw waste water samples and the quality requirements of the treated effluent, laboratory-scale experiments are then conducted. The samples are subjected to various unit operations and unit processes to find out the suitability of each for treating the waste water. Parameters such as detention time, food to microorganism ratio, surface loading, volume of sludge to be expected, its settleability, types of chemicals required and their quantities are determined, but laboratory-scale studies do not establish achieveable effluent quality or the suitability of mechanical equipment to be used in the full-scale plant.

In addition to the laboratory-scale studies, it may be necessary to run pilot plant studies, in which the actual conditions in the full-scale plant can be simulated. Pilot plants are designed to offer a certain degree of flexibility and enable collection of data which will be used in finalizing the design, the degree of automation, if any is required, the material of construction and, hence, the capital and running costs of the full-scale plant.

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Chapter **3**

UNIT OPERATIONS AND UNIT PROCESSES

3.1 INTRODUCTION

The various methods used in treating industrial waste water are identical to those used in treating domestic sewage. However, the differences between the two modes of treatment arise because of (a) a very high degree of variability in the quality of industrial wastes compared to domestic sewage, (b) large variations in the flow rates of industrial wastes, and (c) the presence of hazardous and/or toxic pollutants in some industrial wastes. In terms of population equivalent, industrial waste water is usually a few times stronger than an equal volume of domestic sewage. In view of the possible presence of hazardous and/or toxic pollutants, it becomes necessary to provide adequate preliminary treatment to an industrial waste water before subjecting it to further treatment. This is achieved by employing various unit operations and unit processes.

- **Unit operations** are those in which physical forces are employed to purify waste water. Some of the important unit operations are screening, sedimentation, flotation, filtration, mixing, equalization, flow proportioning, drying, incineration, freezing, foaming, dialysis, osmosis, adsorption, gas transfer, elutriation, etc.
- **Unit processes** are those in which chemical and/or biological forces are used to purify waste water, e.g. pH correction, coagulation, oxidation, reduction, disinfection, aerobic and anaerobic biological treatment.

It is rarely adequate to apply only unit operations or only unit processes to an industrial waste water to obtain an effluent fit for discharge to the environment. Therefore, based on laboratory-scale studies and/or pilot plant studies, a proper choice of unit operations and unit processes is made, and this is arranged in a logical sequence to give an acceptable treatment scheme.

A brief description of the various unit operations and processes, and their application in industrial waste treatment is given below.

3.2 UNIT OPERATIONS

3.2.1 Screening

Screening is done to remove large suspended and floating solids from waste water in order to protect pumps, pipes and valves from clogging and damage, e.g. rags and pieces of cloth from cotton textile wastes, fine fibres from woollen mills, spent tan bark from vegetable tanning process, leather trimmings from the leather processing houses, bark from the debarking machines in the pulp and paper mills, fruit peelings and fruit rinds from fruit canning and packing industry, and, generally, in industries where good housekeeping practices are not followed. Microscreening may also be used for complete removal of suspended impurities so as to eliminate primary sedimentation.

Screens may be coarse, medium or fine, depending on the clear space between bars. Fine screens may be rotary drum type, tangential type, or vibratory type. Screens are manually or mechanically cleaned. In any case, adequate arrangement must be made to treat and dispose of the screened material.

3.2.2 Sedimentation and Flotation

Removal of finely suspended and settleable solids is done by plain sedimentation, while chemically aided sedimentation is required for removal of colloidal solids. Flotation, which may be termed 'negative sedimentation', is done to remove impurities, which are lighter than water and do not settle in a reasonable length of time. Like coagulants in sedimentation, flotation may be done with or without, the aid of flotation agents. Industries employing sedimentation include almost all those producing high suspended organic and inorganic solids, while flotation is particularly useful in woollen mills, slaughter houses, pulp and paper mills, oil refineries and dairies. Both sedimentation and flotation help reduce the solids load on the following treatment units. However, flotation is also used for the recovery of useful material from the waste water streams.

3.2.3 Filtration

Filtration of industrial waste water is more often practised downstream of other pretreatment processes than as a stand-alone pretreatment method. It is used during neutralization/precipitation of heavy metals and biological treatment to reduce BOD loads. It may also be used to remove lime precipitates of phosphates and as a pretreatment for waste water before it is discharged to an activated carbon column or to a dialysis or reverse osmosis unit. In reuse applications, filtration is used if the treated waste water is to be spread on land for irrigation, groundwater injection, lawn sprinkling and body-contact recreational uses [1, 2].

3.2.4 Mixing

Mixing is an important unit operation in waste water treatment. It is used for mixing of one substance with another, e.g. chlorine or sodium hypochlorite with treated waste water, liquid suspensions such as in the aeration tank of activated sludge process or sludge undergoing aerobic or anaerobic digestion; for flocculation of finely divided suspended solids with coagulants; for heat transfer as in heated digesters; and for mixing neutralizing chemicals with acidic or alkaline waste streams. Continuous, rapid mixing is achieved by providing baffles or hydraulic jumps in open channels, by fixing static mixers or venturi flumes in pipelines. Continuous mixing is achieved by pumping the tank contents and recycling a part of the pumped liquid, by using mechanical mixers, or with the help of compressed air bubbled into the liquid. Compressed air and mechanical mixers also serve the purpose of maintaining the tank contents in a fresh condition. If the waste water contains oily and greasy matter, compressed air helps float a part of this matter, which can be skimmed off. Mixing helps in giving partial treatment to waste water streams of opposite nature, e.g. mutual neutralization of acidic and alkaline effluents or partial cooling of hot streams when mixed with cold streams. Waste water streams, which are highly fluctuating in their quality and flow rates, are best handled by mixing them in equalization tanks.

3.2.5 Equalization

Equalization is used to overcome the operational problems caused by variations in quality and flow rates, to improve the performance of downstream processes, and to reduce the size and cost of downstream units of treatment. Equalization helps dilute toxic pollutants. It is also an attractive proposition for upgrading the performance of an overloaded treatment plant [2].

Equalization can be done 'in-line' or 'off-line'. The former is done when equalization of plant loading is desired, while the latter is used when the downstream treatment units, especially biological units, are to be protected against shock loads due to slugs of toxic and/or organic pollutants.

The required volume of an equalization basin is determined by constructing mass flow diagram to represent the inflow and superimposing on it the rate of outflow (which would be by pumping). Two parallel lines, representing the rate of outflow, are drawn tangent to the high and low points of the mass diagram. The vertical distance between the two tangent lines represents the required volume of the equalization basin [1].

An essential requirement of an equalization basin is adequate mixing of the basin contents. This ensures a more or less uniform quality of the outflow, minimizes chances of deposition of solids in the basin and helps keep the waste water fresh.

3.2.6 Flow Proportioning

Flow proportioning is not, strictly speaking, a unit operation, but can be used in conjunction with equalization. It consists of storing a waste water stream in a tank of suitable size and discharging it into the other streams (either domestic sewage or industrial wastes), in proportion to the flow in the receiving waste water stream, so that the mixture does not exert an unduly high organic, hydraulic, toxic load on the receiving body of water or the waste water treatment plant. This method is useful in dealing with toxic wastes, or wastes having a high oxygen demand.

3.2.7 Drying and Incineration

Drying and incineration are almost exclusively used for handling waste water sludges generated during the various treatment processes. Drying is done to get rid of a large fraction of the moisture entrained with the sludge solids and to reduce its volume. This is done by spreading the sludge in a layer ranging in thickness from 20 cm to 30 cm on sand drying beds. A part of the moisture evaporates and the rest percolates through the sand and gravel layers of the drying beds. This filtrate is recycled to the plant inlet. Sludge so dried can be removed from the beds when its moisture contents are reduced to between 50% and 55%. If the space for constructing the beds is inadequate, mechanical means such as vacuum filtration, centrifugation, plate and frame presses, or belt filters are employed.

Incineration of the dried sludge is practised when the sludge contains toxic matter in concentrations which would have an adverse effect on the receiving medium such as soil. It reduces biological sludge into harmless end products such as water vapour and carbon dioxide. Incineration is preceded by heat drying so that the sludge can be burned effectively and economically. Heat drying is necessary when the sludge is to be converted into soil conditioner. Drying permits grinding of the sludge, reduction in its weight and prevention of continued biological activity. The moisture is reduced to 10% or less. Heat drying is achieved by using flash dryers, spray dryers, rotary dryers, multiple hearth dryers, or multiple effect evaporators [2]. Care must be taken to ensure that incineration does not give rise to problems of air pollution.

3.2.8 Freezing

When impure water (such as an industrial effluent) is frozen, the ice crystals formed are essentially pure water. Three steps are involved in the freezing process. First, heat is removed from the water to cool it to its freezing point. Additional heat is then removed by the vaporization of a refrigerant such as butane in direct contact with the cooled water. This causes fine crystals of ice to freeze out of the solution. When roughly half the water is frozen to ice, the ice-water slurry is transferred to another tank where the unfrozen liquid is drained off and the crystals are washed with pure water. The washed ice is transferred to another tank, where it is melted to form a pure end product [3].

3.2.9 Foaming

Foam separation is particularly useful for waste water containing foaming agents such as detergents and other surface-active pollutants. The process takes advantage of the tendency of surface-active pollutants to collect at a gas-liquid interface. A large interface is created by passing air (or gas) bubbles through the liquid. The foam becomes enriched in the pollutant and the liquid is depleted of the pollutant. The foam is subsequently collected and collapsed to produce a solute-rich liquid product [3].

3.2.10 Dialysis and Osmosis

When an electric potential is impressed across a cell containing mineralized water, cations migrate to the negative electrode and anions migrate to the positive electrode. If cation- and anion-permeable membranes are placed alternately between the electrodes, ions will concentrate in alternate compartments and become dilute in the intervening compartments. If the apparatus is arranged so that the concentrated and dilute streams flow continuously, large-scale demineralization of water can be done. Only partial demineralization is possible by this method. As the phenomenon is specific to ions, application of the process is limited to the removal of soluble ionized contaminants [3].

When solutions of two different concentrations are separated by a semi-permeable membrane, water tends to pass through the membrane from the more dilute side to the more concentrated side and produces concentration equilibrium on both the sides of the membrane. The driving force that impels this flow is related to the osmotic pressure of the system. If the pressure on the more concentrated side is deliberately increased, the flow of water through the membrane reverses, i.e. water moves from the more concentrated compartment to the less concentrated compartment. This is reverse osmosis [3]. This process can be used for the recovery of caustic soda from the spent caustic resulting from mercerizing of cloth in the cotton textile industry.

3.2.11 Adsorption

Organic contaminants in waste water, which are resistant to biodegradation and are present in dissolved state, are suitably removed by the process of adsorption. This is a surface phenomenon. It involves collection of the contaminants on a suitable interface, which can be a liquid and a gas, a solid, or another liquid. This process is used as a polishing step for improving the quality of an effluent, which has already received treatment for removal of a bulk of the contaminants. Adsorption occurs in the activated sludge process, when the dissolved and colloidal organic matter, which acts as a substrate for microorganisms, concentrates at the biomass-water interface. In the treatment of dye-bearing textile wastes, powdered activated carbon is used to adsorb the difficult-to-degrade dye molecules on the carbon along with the microorganisms. The return sludge, which contains both the carbon and the adsorbed contaminants, is aerated in a separate tank. The microorganisms in the sludge consume the dye molecules, get desorbed in the process and are returned to the aeration tank [4].

3.2.12 Gas Transfer

Gas transfer is a process by which gas is transferred from one phase to another, usually from gaseous to liquid phase. The functioning of aerobic processes such as the activated sludge process, trickling filtration, aerobic digestion of sludge depends on the availability of sufficient oxygen. Chlorine, used as a disinfectant, must be transferred from gaseous phase to liquid phase. Postaeration of treated effluents depends on gas transfer. One process for nitrogen removal consists of converting the nitrogen to ammonia and transferring the ammonia gas from water to air [2]. Industrial wastes containing volatile solvents can be conveniently treated by aeration to strip off a large fraction of the solvents, which may be recovered, thereby helping to reduce the COD of the waste water to some extent and permitting the reuse of the solvents.

3.2.13 Elutriation

Elutriation is a unit operation in which a solid, or a solid-liquid mixture is intimately mixed with a liquid for the purpose of transferring certain components to the liquid, e.g. chemical conditioning of anaerobically digested sludge before mechanical dewatering can be done by washing the digested sludge with water containing low alkalinity. Such a sludge contains a high concentration of alkalinity, which consumes a lot of conditioning chemicals. Elutriation transfers the alkalinity from the digested sludge to the wash water. The wash water is returned to the waste treatment plant. Elutriation can be done as a single stage, multi-stage, or countercurrent process. It is seldom used today because the finely divided solids washed out of the sludge may not be fully captured in the main waste water treatment facility [2, 5].

3.3 UNIT PROCESSES

3.3.1 pH Correction

pH correction is an almost universally used unit process required to render a waste water stream fit for further treatment in which pH value plays a vital role, e.g. ammonia removal, biological treatment, nitrification and denitrification, disinfection with chlorine, phosphorus removal and coagulation. Chemicals commonly used are sulphuric acid, hydrochloric acid, nitric acid, phosphoric acid, lime, sodium hydroxide, sodium carbonate, sodium bicarbonate, ammonium hydroxide, etc. This step in treatment requires adequate mixing between the waste stream and neutralizing chemical. As an equalization tank is provided with mixing arrangement, pH correction can be conveniently combined with equalization. Care should be taken to check whether pH correction results in increasing the suspended solids in the waste water, because some solids, which are in solution at low pH may precipitate out due to increase in pH. It is advisable to conduct laboratory-scale studies in order to choose the right type of neutralizing chemical and its optimum dose, as this has a direct bearing on the operating cost of treatment.

3.3.2 Coagulation

Coagulation is used to aid the removal of suspended solids from waste water by sedimentation. Chemicals commonly used for this purpose include alum, ferric chloride, ferrous sulphate, ferric sulphate, lime, etc. Sedimentation following coagulation results in an increase in the volume of sludge to be handled. Organic polymers are sometimes used as coagulant aids. Sludge resulting from chemical coagulation may be difficult to dewater, or difficult to biodegrade. Therefore, laboratory-scale trials should be made to select the appropriate coagulant and to provide for handling, treatment and disposal of the sludge generated by coagulation.

3.3.3 Oxidation and Reduction

Oxidation-reduction is occasionally used to remove pollutants from industrial wastes, e.g. reduction of hexavalent chromium to its trivalent form before its removal by precipitation, ozone oxidation to remove dissolved organics and cyanide during pretreatment. Alkaline chlorination is preferred to ozone treatment for destruction of cyanides [1]. Oxidation with chlorine is used for BOD reduction, odour control, as an aid to grease removal, reduction of sludge bulking in the activated sludge process, eliminating ponding and fly nuisance in trickling filtration and wet scrubbing of gas from anaerobic digestion. Chlorine is also useful in minimizing biological aftergrowths in pipelines and conduits conveying treated effluents over long distances. If a biologically treated sewage or industrial waste is to be subjected to tertiary treatment with a view to recycle it, chlorine plays a vital role in keeping down biological growths in the tertiary treatment units as well as in the recycle system.

Chlorine has been successfully used in the treatment of cyanide-bearing wastes, textile wastes, phenol-bearing wastes, oil refinery wastes, paper mill wastes, food processing wastes and tannery wastes. In these applications, chlorine acts in one or more of the following ways: (i) as an oxidizing agent, (ii) as a bleaching agent, or (iii) as a disinfectant, depending on the nature of the pollutants present in the waste water [6]. As industrial wastes are highly variable in their quality, it is necessary to determine the proper dose of oxidizing agents by conducting laboratory-scale studies.

3.3.4 Aerobic and Anaerobic Processes

Aerobic and anaerobic processes aim at converting non-settleable organic matter into settleable organic matter and to stabilize it. Purification of waste water containing biodegradable organic matter is economically done with the help of microorganisms, which may be inherently present in the waste water, or may be introduced to it in the form of domestic sewage, or in certain cases, as pure cultures of organisms for destruction of specific pollutants. Provision of proper environmental conditions to the microorganisms, such as adequate balanced food, availability of dissolved oxygen (for aerobic systems), total absence of molecular oxygen (for anaerobic systems), absence of pollutants toxic to microorganisms, correct pH value, proper temperature of waste water (depending on whether the organisms are mesophilic or thermophilic in nature), sufficient time for microorganisms to grow and complete the biochemical reactions (which result in destroying a large part of the pollutants) and the presence of inorganic cations and anions in concentrations below the toxic limits for the organisms, results in producing a satisfactory effluent.

It is apparent that almost all industrial wastes need some form of pretreatment before they can be subjected to biological treatment. This may take the form of one or more of the above-mentioned unit operations and/or unit processes, which are aimed at creating environmental conditions fit for microorganisms to work in.

Microorganisms require carbon, nitrogen, phosphorus and other elements in proper amounts, so that their metabolic activities are not hindered, e.g. the C:N:P ratio should be in the range 100:5:1–100:20:1 for aerobic treatment. Anaerobic organisms being inherently slow acting, require much less nitrogen and phosphorus compared with aerobic organisms. Inorganic ions required by most organisms, which act as micronutrients, are given in Table 3.1.

Table 3.1 Inorganic Ions Necessary for Most Organisms [2]

Substantial quantities	Trace quantities
Sodium (except for plants)	Iron
Potassium	Copper
Calcium	Manganese
Phosphate	Boron (required by plants and certain protists*)
Chloride	Molybdenum (required by plants, certain protists* and animals)
Bicarbonate	Vanadium (required by certain protists*and animals)
	Cobalt (required by certain plants, animals and protists*)
	Iodine (required by certain animals)
	Selenium (required by certain animals)

*Protists include algae, protozoa and fungi.

Dissolved oxygen is essential for truly aerobic organisms to survive. Its desirable concentration ranges between 1–2 mg/l in the activated sludge process, trickling filter process and aerated lagoons. It is maintained by mechanical or pneumatic aeration in activated sludge process and aerated lagoons. Adequate ventilation and limiting the depth of media to about 2 metres in trickling filters using stone media, along with uniform distribution of the waste water over the media, ensures proper aerobic conditions. The depth of the filter can be considerably increased with the use of plastic media, which have large voids (90% to 95%) compared with stone media (40% to 45%) and permit adequate ventilation in spite of great depths (up to 12 metres, against 2 metres for stone media). Oxygen is supplied in large quantities during daytime by the algal activity in waste stabilization ponds. Some organisms use oxygen available from nitrates in waste waters. These are anoxic organisms and are useful in the process of denitrification. Anaerobic organisms cannot tolerate even a small concentration of oxygen. Great care must, therefore, be taken when they are employed in treatment, to see that molecular oxygen has no access to the anaerobic biomass.

Toxic and inhibitory concentrations of organic and inorganic pollutants are frequently observed in industrial wastes. These can either slow down the biological process of treatment or stop it altogether if present in large concentrations. Microorganisms adapt themselves to the presence of these pollutants to some extent. A list of some of these substances, along with their threshold concentrations, is given in Table 3.2 and in Table 3.3 the list of common inhibitors of anaerobic digestion is given.

Table 3.2 Threshold Values for Aerobic Biological Treatment [7, 8]

Item	Threshold for biological treatment
pH value	6.5–8.5
Sulphides	200 mg/l
Phenols	500 mg/l (after adequate acclimatization)
Chloroform extractables (oil and grease)	50 mg/l
Hexavalent chromium	2 mg/l
Maleic acid	400 mg/l
Oxalic acid	200 mg/l
Acrylonitrile	400 mg/l
Benzoic acid	500 mg/l
Lead as Pb	1 mg/l
Nickel as nickel chloride	15 mg/l
Zinc	10 mg/l
Chlorides	8000–15,000 mg/l
Ammonia	1,600 mg/l
Dissolved salts	16,000 mg/l

Table 3.3 Some Common Inhibitors of Anaerobic Digestion [9]

Substance	Toxic threshold
Anionic detergents	900
Methylene chloride (CH_2Cl_2)	100
Chloroform ($CHCl_3$)	0.5–1.0
Carbon tetrachloride (CCl_4)	2.0–10.0
1,1,1,trichloroethane	2.25
1,1,2-trichloro-1,2,2,trifluoroethane	About 10
Monochlorobenzene	900
Orthodichlorobenzene	900
Paradichlorobenzene	1300[a]
Pentachlorophenol	1 to 2.
Cyanide	3–30[b]
Zinc	590[c]
Nickel	530[c]
Lead	1800[c]
Cadmium	1000[c]
Copper	850[c]

Note: Concentrations in mg/l for a digester fed with raw sludge with 4.5% dry solids.
[a]Concentration in sewage entering works.
[b]Initially very toxic, but bacteria acclimatize with time.
[c]Toxicity can be controlled by precipitation as non-toxic sulphide salts.

It should be noted that in waste water treatment, one rarely comes across situations where only pure cultures of microorganisms can be used to treat the waste water. This is mainly because waste water contains a large variety of organic and inorganic pollutants, which microorganisms can use as substrates. As a result, biological treatment takes place in the presence of a variety of microorganisms, all acting on specific substrates either simultaneously or sequentially. This condition can lead to either stimulation or inhibition of reactions, e.g. Table 3.4 shows the stimulatory and inhibitory concentrations of alkali and alkaline earth cations on anaerobic digestion.

Table 3.4 Stimulatory and Inhibitory Concentrations [10]

Cation	Stimulatory	Moderately inhibitory	Strongly inhibitory
Sodium	100–200	3500–5500	8000
Potassium	200–400	2500–4500	12,000
Calcium	100–200	2500–4500	8000
Magnesium	75–100	1000–1500	3000

Note:

(a) Concentrations in mg/l.
(b) Sodium and potassium—best antagonists, effective when present in stimulatory concentrations.
(c) Calcium and magnesium—Poor antagonists, add to toxicity. They become stimulatory if another antagonist is already present, i.e. 7000 mg/l of sodium and 300 mg/l of potassium decrease retardation by 80%. Add 150 mg/l of calcium and eliminate inhibition. Calcium is ineffective in the absence of potassium.

It may be mentioned here that while designing an industrial waste water treatment plant using biological process, the population of microorganisms being dealt with is a mixed culture. They act on different constituents of the waste water at different rates depending on a number of factors such as environmental conditions, presence of inhibitory or toxic substances, nature of the pollutants and their degradability, stage of growth of the organisms, their doubling time, etc. The slowest rate of degradation determines the overall rate of treatment. Adequate hydraulic retention time must, therefore, be provided in the biological reactor to ensure that 'washout' of organisms does not take place. This precaution is necessary especially at the time of startup and commissioning of the plant. The time given to the microorganisms at this stage also helps them acclimatize to the presence of various constituents of the waste water and produce a satisfactory quality of treated effluent.

REFERENCES

1. Water Environment Federation (1994): Manual of Practice FD-3, *Pretreatment of Industrial Wastes*, Virginia, USA.

Chapter **5**

Pretreatment of Industrial Wastes

Pretreatment involves some unit operations and unit processes, suitably combined and arranged in a logical sequence, in order to produce an effluent fit for further treatment. If the raw waste contains non-biodegradable pollutants, pretreatment is mostly given by using unit operations. If the waste has toxic and biodegradable pollutants in it, pretreatment aims at removing the former and creating conditions favourable for the microorganisms to work effectively on the latter. It is often observed that a combination of unit operations and unit processes is necessary to achieve the desired degree of pretreatment.

Unit operations frequently used are screening, sedimentation and flotation, mixing, equalization, and gas transfer. Unit processes employed include pH correction, coagulation, oxidation and reduction. A combination of the unit operations and processes is required when the above-mentioned unit processes are carried out, because they tend to convert solids in solution or colloidal state into settleable state. A detailed treatability study of the waste water reveals which of the unit operations and/or processes will be useful.

Pretreatment is also required when waste water is to be discharged into a common sewer, leading to the common effluent treatment plant, or to the municipal sewer leading to the sewage treatment plant. In the case of wastes which are very strong, the industry may be required to provide even biological treatment and produce an effluent acceptable for discharge to the common effluent treatment plant or the sewage treatment plant.

The applications of the pretreatment steps as applied to various industrial wastes are briefly described in the following sections.

5.1 UNIT OPERATIONS

Screening: This is used for the removal of floating, large-sized matter such as rags from textile industry, fine fibres of wool in woollen mills, bark and wood chips in pulp and paper industry, rubber bungs, bottles, vials, etc. in pharmaceutical industry, fruit peelings and rinds in the fruit canning industry, spent tan bark, hairs, fleshings, leather trimmings in the tanning industry, dead yeast and other solid agents used in winery and brewery, empty plastic bags, bottles and cartons in dyes and dye intermediate industry, dairies.

Sedimentation: This method is used in plain or following coagulation— in the ceramic industry, mining industry, ore beneficiation, iron and steel mills, vegetable and mineral oil refining, paper making industry, beet sugar manufacture, lubricant manufacture and engineering industry.

Flotation: This method is used in soaps and oil industry, paper industry, detergent manufacture, mining industry, lubricant manufacture.

Mixing: This is used in industries producing effluent streams with different pH values, as in chemical manufacture, regeneration and rinse waters from demineralization units, blowdown from boiler houses and cooling towers.

Equalization (in-line or off-line): This method is used in batch manufacturing processes such as pharmaceuticals, fermentation products, industries producing different effluent streams with wide fluctuations in quality, toxic chemical manufacturers, e.g. herbicides, pesticides, weedicides.

Gas transfer: This method is used in chemical manufacture using volatile solvents, waste water containing large concentrations of ammonia, pharmaceutical industry, waste water containing highly biodegradable pollutants as in the dairy industry. The purpose in this case is to reduce the chances of waste water from becoming stale or septic and creating odour nuisance. Gas transfer, in the above cases, is achieved by using compressed air, which supplies oxygen and helps to keep the waste water solids in suspension. A gas, such as ammonia, can be removed by stripping in a closed tower packed with ceramic rings.

5.2 UNIT PROCESSES

pH correction: This method is used where wastes containing high concentrations of oil and grease, with high or low pH values, high in suspended solids which can be coagulated and settled, with high biodegradable contents in addition to high or low pH, containing heavy metals which can be precipitated by adjustment of pH value.

Coagulation: This is used where all waste streams mentioned under 'pH correction' except those with high biodegradable contents are handled unless the resulting sludge with high organic content can be properly treated and disposed of.

Oxidation and reduction: This is used in wastes with chemically oxidizable pollutants, certain organic molecules which become amenable to biological treatment after oxidation, wastes containing heavy metals which can be precipitated, cyanide bearing wastes, phenol containing wastes, etc. An incidental benefit of oxidation is partial satisfaction of the oxygen demand of the waste.

Aerobic and/or anaerobic treatment: Aerobic or anaerobic treatment follows pretreatment by the above-mentioned unit operations and unit processes. Subjecting them to anaerobic process, followed by aerobic process, economically treats wastes, high in biodegradable matter. In these cases, anaerobic treatment knocks out a sizeable portion of the oxygen demand from the waste and allows aerobic treatment to be done economically, especially in terms of power consumption for mechanical methods of oxygen supply and land requirement for non-mechanical methods. An added advantage of anaerobic treatment is the availability of methane, a useful component of the result of gases formed during anaerobic degradation. The digested solids from anaerobic process can also be used as soil conditioners.

The various methods described above help 'end of the pipe' treatment of the waste water. Further, economy in treatment can be achieved by using one or more of the following measures:

1. Reduction of water consumption in the manufacturing process.
2. Reduction of the strength of waste water.
3. Modifying the manufacturing process.
4. Replacing polluting chemicals by those, which pollute less, or are non-polluting.

Some good housekeeping practices are:

1. Recycling and reusing, either with or without treatment, slightly polluted waste water streams.
2. Recovering by-products from the waste streams, where feasible.

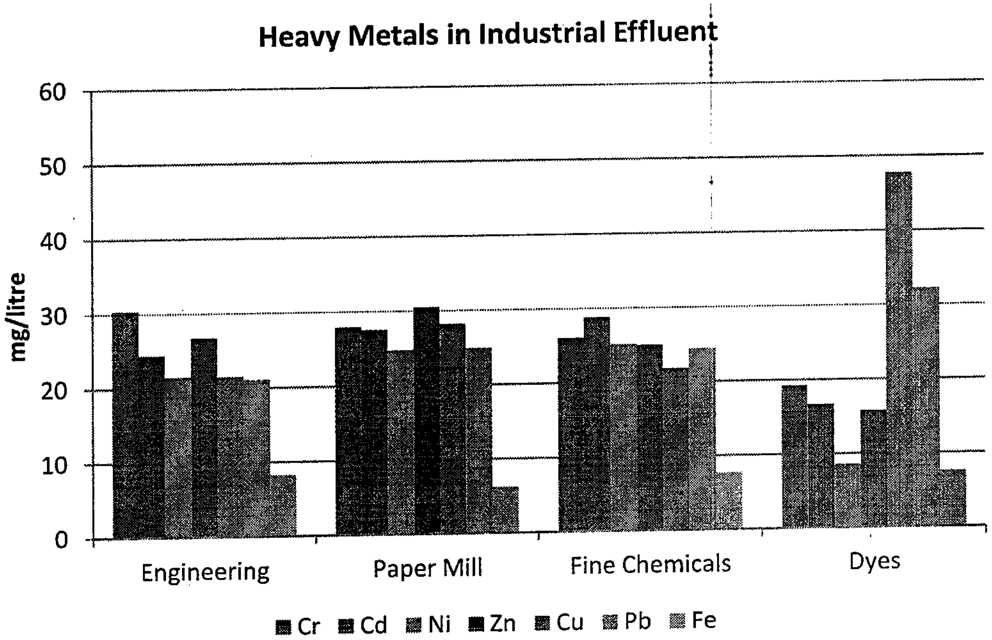
Execution of the above measures must be done only after ensuring that they do not have an adverse effect on the quality of the finished product. It is possible to economically control pollution due to industrial wastes by following these measures.

Industrial Effluents – Heavy Metals

Dangerous Metals in Effluents

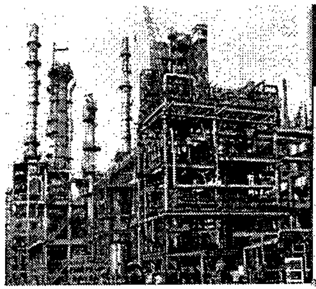
- Study shows that some of the major industries discharge dangerous heavy metals which are considered to be highly toxic – Cr, Ni, Cd, Zn, Pb, Cu
- This leads to contamination of ground as well as surface water that leads to long lasting health problems and threatens the aquatic life of the marshy lands and landfall in to the sea

A study conducted of the industrial belt in Taloja, Navi Mumbai showed dangerous levels of heavy metals being discharged in the effluents from the industries in the area



Source : "Toxicity Study of Heavy Metals Pollutants in Waste Water" by Ram S Lokhande

Major Industrial Effluent Pollutants

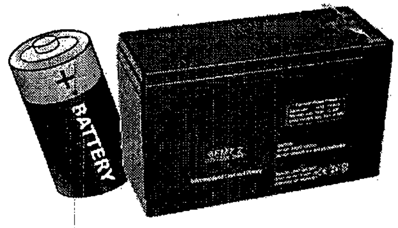


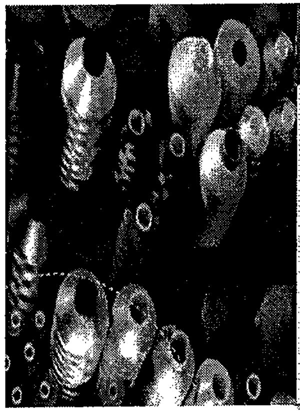
Refineries

- Toxic Hydrocarbons
- Oils and grease with high BOD and COD

Battery Manufacturing

- Lead
- Heavy Metals
- Acids

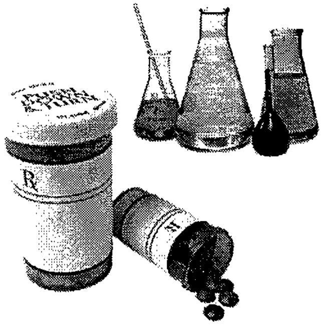




Textiles

- Dye, Color
- Surfactants
- Phenols
- Heavy Metals (e.g. Cr, Co, Zn, Pb, or Ni)
- Halogens
- Amines

Major Industrial Effluent Pollutants

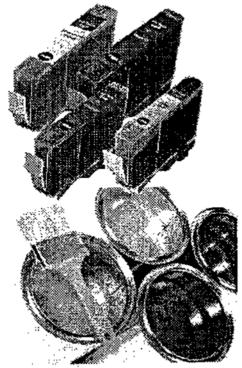


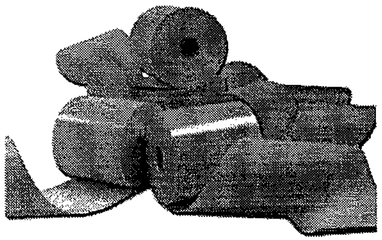
Chemical & Pharma

- Organic Solvents
- Methanol
- Toluene
- Hexane
- Branched chain fatty acids & Ketone

Paints & Inks

- Heavy Metals
- Solvents

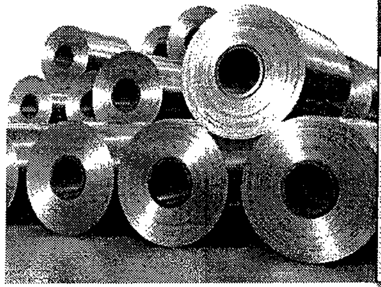




Pulp & Paper

- High BOD & COD
- Heavy Metals
- Inflammable Solvents

Major Industrial Effluent Pollutants

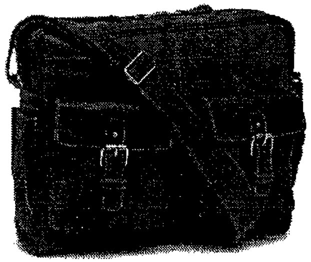


Metals

- Low pH Acid Waste
- Heavy Metals
- Cyanide waste,
- Paint waste

Beverages & Sugar

- Spent Wash containing Methanol
- High BOD & COD



Leather & Tanning

- BOD
- COD
- Sulphate,
- Chromium
- Oil & Grease

INDUSTRIAL WATER REUSE AND RECYCLE

Industrial water reuse and recycling has many drivers and benefits.

What is Industrial Water Reuse and Recycling?

Industrial water reuse and recycling is the process by which wastewater produced from one source is treated so it can be used in an industrial process. Sometimes the source wastewater may be produced by the same industrial facility that treats it and reuses it.

Industrial wastewater can be recycled on or off site depending on space constraints and budgetary considerations. Recycling wastewater is important for the environment as it avoids straining drought-stricken areas and natural habitats such as wetlands.

BENEFITS OF WATER RECYCLING

The benefits of recycling industrial wastewater are many:

- Reducing fresh water costs
- Increasing operational efficiency
- Reducing wastewater flows
- Improving production capacity due to increase availability of clean water
- Providing good "corporate citizenship" in your community, particularly in regions where seasonal droughts can occur
- Reducing the size of your water footprint
- Impacting the image of your company positively. If negative publicity around a company's water use can adversely impact a company's sales/growth then positive attention for water recycling can be beneficial.

COMMON INDUSTRIAL WATER REUSE OPPORTUNITIES

Industrial water may be reused in many different ways. Before determining how to reuse waters, you should consider where potential water reuse opportunities exist.

Some opportunities for water reuse in an industrial plant may include:

Wastewater recycling

Cooling tower blowdown

Boiler blowdown

RO reject recovery and reuse

Once through cooling water

Collected rain waters

THE NEED FOR WATER RECYCLING AND REUSE

Whatever is behind your need to recycle and reuse wastewater, decreasing your plant's water footprint is beneficial to your company and the community. The need for industrial water recycling and reuse has many drivers, including:

Industrial and population growth: A growing population increased the need for power generation, for example, which placed greater demands on water use.

Fresh water costs: The cost of clean, fresh water is continually increasing, and is impacting all regions.

Regulatory requirements: Many industrial sites have wastewater discharge permits that include flow and quality restrictions. Moreover, EPA Industrial Effluent Guidelines are often revised.

Social responsibility: Protecting the world's resources is a global concern: the general public is paying attention. Negative publicity around a company's water use can have an impact on a company's sales/growth.

- **Discharge costs:** Sewer and wastewater costs have increased at a higher rate than fresh water costs.
- **Water scarcity:** Many regions in North America are susceptible to drought. Additionally, some industrial plants have limited access to clean/fresh water.
- **Wastewater processing limitations:** In many industries, plant wastewater treatment capacities have not increased proportionally with plant production. Plants are challenged to meet higher flows and have limited operational resources.
- **Sustainability efforts:** Many companies strive towards sustainability by utilizing economically sound programs that help minimize a plant's negative environmental impact while conserving energy and natural resources.