INTRODUCTION

1 ENVIRONMENTAL POLLUTION.

General

~~The~~ Pollution has become a common word recently in our country Today many people active in politics, academics or in the industrial management talk often about air and water pollution. It would be very interesting to know that as far back as in 1869, in the U.S.A., the Massachusetts Board of Health passed the following resolution:

"We believe all citizens have ~~our~~ an inherent right to the enjoyment of pure and uncontaminated air, water and soil, that this right should be regarded as belonging to the whole community, and that no one should be allowed to trespass upon it by his carelessness or his avarice or even his ignorance" [1].

The word pollution has its origin in Greek word 'polutus' means to soil or 'to defile'. 'Pollution is something which upsets the equillibrium of a system". Thus any impurity when it interferes with intended use of the water, air or land is called pollutant.

There are number of factors which contribute towards ~~the~~ pollution. The population explosion in the world, rapid industrialization, large scale utili~~ty~~ization of petrochemicals and products based on them, urbanisation, increase in per capita consumption of goods, all these result in two aspects - consume resources and create waste - responsible for intense pollution. The consumption spiral seems to have no end except when we finally run out of resources. Today we are advocating to 'save' every thing or to conserve many resources. One of the oldest religions of India (Jainism) advocates to observe 'Parigrah' i.e. to have minimum needs of life, to consume the least.

There are about 15 factors of the environment, and they are radiant energy, temperature, light, radiation, atmospheric moisture, soil moisture, soil, gravity; substratum, fire, pressure, atmosphere, wind, sound and water. Some of the important factors from above list such as water, atmosphere, soil and temperature are disturbed - getting polluted because of increase in pollution [2].

Our chemical environment has become extremely complex. About 4 million chemicals have been isolated from natural products or been synthesized and about 60,000 of them are in frequent use. Some 1,500 active ingredients are used in pesticides formulations and 4000 in drugs, as well as about 2,000 substances used as excipients. More than 5,000 compounds are used as additives in the food industry. The wastes from power production, transport and industrial technology finish up as pollutants in air, water, soil and food. Homes are flooded with a variety of consumer chemicals in the form of cleaning agents, pesticides, cosmetics and drugs [3].

Almost all these chemicals, if they are present in sufficient quantity or in sufficient concentration can have adverse effects on human health and environmental quality. Exposure to chemicals such as organometallic mercury and particularly alkyl-mercury and organochlorine compounds has caused intoxications affecting large segments of the general population in the area concerned. Animal experiments and human epidemiological studies have shown that certain chemicals in the environment may act directly as causes of chronic diseases, as in the case of chemical carcinogens or mutagens or teratogens or indirectly by modifying the effects of other pathogens; e.g. by changing the body's sensitivity to infectious agents.

Exposure to chemicals can also alter the course and outcome of a disease, as may happen when persons with chronic respiratory or circulatory disease are exposed to heavily polluted air [3].

For a long time no importance was placed on the preservation of the environment and improvement of the environmental conditions in India because industrial development was given absolute priority. The wide scale industrialization, population explosion, urbanization and exploitation of natural resources resulted in high environmental pollution - water and air coupled with detrimental effects on the health of the population, damage to the ecology of water in particular and negligible impact on the ground, the plants and the animals. All hygienically questionable environmental conditions have arisen due to the lack or inadequacy of facilities for the treatment or purification of waste waters and the disposal of refuse. In the face of the recognised problems in the environmental sector, the Indian Government took the steps by enacting a law for the protection of water in 1974. The air-pollution problem also finally created such a situation that the Government enacted a law for the protection of air in 1981 [4].

Water and air are fundamental media in which life exists and as such provide the basis for the division of world in to two major environment, aquatic and terrestrial. Water, not only covers 70% of the earth's surface but also provides media for the existence of life throughout its depths. Water is a universal solvent, has low chemical activity, high surface tension, high ionization, high freezing point, high latent heat of fusion, high latent heat of evaporation and high specific heat. The distribution of water through the atmosphere and over the terrestrial environment is controlled by the hydrological cycle. Fresh water environments are standing water, water-lakes, ponds, swamps, bogs and running water springs, streams and rivers.

Of all the fresh water on earth, estimated at 37.3 million cubic kilometres, less than a quarter or about 8.6 million cubic kilometres can be considered available to human consumption. The remainder of the fresh water is tied up in polar ice and glaciers [5]. It is noteworthy that if we leave out salt water present in oceans, which accounts for about 94% of all water on earth, the remaining 6% of water which is fresh water is contained by and large (95% of it) as ground water and glaciers. Details are presented in Table - 1.

TABLE-1

Water present on earth [6]

Source	Volume 10^6 km^3	Percentage	Residence time years
Oceans	1,370,323	93.93	3,000
Ground waters of which active	60,000 (4000)	4.12 (0.27)	5,000 (330)
Glaciers	24,000	1.65	12,000
Lakes	230	0.016	10
Soil moisture	73	0.005	0.9
Atmospheric vapours	14	0.001	0.027
Rivers	1.2	0.0001	0.033

As things stand today and as much as we can foresee the future, ground water is and will remain our most important repository of fresh water. For ~~Due to~~ this reason we have to be very ~~much~~ careful about the waste water directly put on the ground or in the streams as it will spoil the ground water in the long run. Therefore, subsurface pollution should be prevented ~~carefully~~ since remedial measures are time consuming and expensive.

Water resources of a country constitute one of its most important economic assets. The pattern of water resource development for various beneficial uses, however, differs from country to country depending upon its climate, physiographic conditions and socioeconomic development.

There is no way for society to avoid paying for pollution. If we do not pay for prevention, we pay in other ways; in lost recreational uses of rivers, and beaches, aquatic life, animals, in higher treatment cost for drinking water, in damage to crops, forests and building, materials and most importantly through higher medical bills, time lost because of illness, human suffering and premature deaths.

It is feared that the Toxic Substance Control Act (EPA) will slow down the pace of research and development of new raw materials to replace high emission substances.

Industrial growth is necessary for economic growth and prosperity, but the result~~ed~~ant pollution is affecting the quality of life. The technological and economic constraints render complete elimination of pollution impossible.

Types of Pollution

The pollution can be divided mainly in the following categories:

(1) Water pollution
(2) Air pollution
(3) Noise pollution
(4) Radiation hazards

2. WATER POLLUTION

Water pollution is ~~to be~~ thought not only in terms of health but also in terms of conservation, aesthetics and the preservation of natural beauty and resources.

Raw sewage and industrial effluents find their way into water bodies. Every year thousands of new chemicals are manufactured to fight against diseases, to control the paste for better agriculture products and to eliminate disease carrying insects. Fertilizers for more productivity, new synthetic fibres, textiles, dyes, detergents, rubbers, plastics, papers, leather products, fine chemicals, petrochemicals, metallic compounds etc. varieties are developed for better living standard of man. These chemicals are finding their way into water bodies for which even formulas are not known and much less ~~about their acute~~, chronic or genetic toxicity.

Another industrial waste is heat. Temperature of effluent can drastically alter the ecology of a stream or lake. This alteration is sometimes favourable because of fishing or an ice-free docking area. Temperature rises can deplete dissolved oxygen and increase metabolic activity which may result into more demand for oxygen. Therefore, ~~in~~ which summer ~~some time~~ fish kills occur~~s~~, due to oxygen depletion. It affects evaporation rate. Enzymes generally do not tolerate temperature increase more than few degrees above their optimum. If enough heat is added, sufficient evaporation could occur to endanger shallow ecosystems and also influence weather conditions. Heat will result in killing certain organisms while accelerating the growth of more heat tolerant ones and a general shift in populations will occur.

The concern~~ed~~ with pollution from oil-petroleum compounds is important and new. It is estimated that there are no fewer than 10,000 serious oil spills in the U.S.A. every year.

Oil spills at seas spread rapidly ~~in~~ as a thin film. Wave action breaks up the film and emulsification of oil into droplets results. Oil films prevents exchange of gas, heat, transfer of light between water and atmosphere. Some of the plant and animal life is susceptible to such oil and ~~get~~ are demaged. Floating oil scum form an unsightly unaesthetic layer, and photooxidation of oil films result in oxidation of hydrocarbons to form acids, carbonyl compounds, alcohols, peroxides, and sulphoxides which may be soluble in water. Its presence also causes taste or odours of oil-hydrocarbons in the water body [7,8].

In addition to industrial and municipal wastes, water pollution emanates from many other sources. Natural runoff is classified as nonpoint source runoff, and following six major activities are of great concern. Acidic or alkaline nature of runoff water changes the quality and quantity of pollutants [9].

(1) Agriculture : Runoff water carries soil particles, pesticides, insecticides, herbicides, fungicides, fertilizers, grass and animal wastes.

(2) Silviculture : Runoff water carries seeds, leaves, fire control spray, insects, uprooted small plants etc.

(3) Construction : Runoff water carriers soil, sand, cement particles etc.

(4) Mining : Runoff water carries acids, sediments, and toxic substances.

(5) On site sewage disposal : Runoff water carreis organics and inorganics, pathogenic bacteria, viruses, parasites.

(6) Urban storm runoff : Runoff water carries street litter; transport residues, particles from deteriorating roads, etc.

Thus nonpoint sources contribute major pollutants loading to the water ways throughout the nation.

Sediments consist mostly of inorganics. The detrimental effect of sediments include interference with the spawning of fish by covering gravel beds, interfere with light penetration thus making food more difficult to find and direct damage to gill structure. It also reduces the depth of water body.

Unsafe disposal of solid wastes (may be organic or inorganic in nature) are also responsible for odour pollution, ground water pollution, soil pollution and surface water pollution.

Usually, solid wastes ultimately end up into water body because of geographical conditions and many other environmental factors [9].

Colour can be associated with natural as well as artificial substances. Colour can reduce photosynthetic activity and aesthetic value of water. Taste, odour and turbidity also cause aesthetic pollution. Phenol even at very low concentration (0.001 mg/l), give objectionable taste and odour.

Several inorganics such as cyanides, and ions of heavy metals are highly poisonous to aquatic and terrestrial life. Presence of ammonia is considered as an indicator of recent pollution. Alkaline chemicals are responsible for scale formation. High dose of fluorine causes fluorosis. Nitrates have been linked to methemoglobinemia and death in infants. Selenium causes bad teeth, gastrointestinal problems and skin discoloration. The toxicity of some chemicals may be affected by the presence of other chemicals. The combined effect may be additive (no interaction between agents), antagonistic (one agent reduces the effect of the other) or synergistic (the effect of both agents are increased). Several organic and inorganic pollutants build up their concentration in the normal food chain [7,8].

Presence of coliforms, ~~&~~ pathogenic organisms, are responsible for water-borne diseases like typhoid, cholera, diarrhoea etc. Even one or two organisms in water might be sufficient to cause an infection. Organisms can also form coatings on ~~the~~ pipelines and also causes tastes and odours in water. Presence of viruses are also responsible for a number of diseases [7,8].

The effect of chemicals on ~~the~~ organisms depend on their physical and chemical properties, their quantity or dose, the type of exposure (inhalation, ingestion, skin contact) and its frequency, duration, level and distribution in time, the metabolism of the chemical in organism including its adsorption, distribution, biotransformation and excretion and the capacity of the organism to resist chemical insults.

Acid rain's corrosive effect on building and water systems costs untold millions of dollars annually. There are observations of some researchers which suggests that acid rain may cause leukemia. The reliable studies show that average precipitation today is 100 times as acidic as 180 years - old ice cores in Greenland. Canadian environmental officials have already estimated that 2000-4000 lakes in Ontario have become so acidic that they can no longer support trout and bass (fishes). In Sweden 4000 lakes are fishless, although some have been treated with massive doses of lime to neutralize acidification temporarily. Acid rains emerge from the acidic gases which have been wafted in to the atmosphere, SO_2 and NO_2 are emitted from power plants, industrial boilers, processes, and smelters. NO also comes from motor vehicles and fertilizer plants. In 1980 ~~only~~ alone, the USA ejected more than 26 million tons of SO_2 and 22 million tons of NO_x in to the environment [10].

Acid rain has impact on soil, water. vegetation, forests, structures, aquatic and human health, wild life and man-made materials. Aluminium and other metal salts leached by acid rain have created damages in aquatic and other environments.

Water pollution problems can be best understood by first describing them in the context of an ecosystem and then studying one specific aspect of that ecosystem : biodegradation of organics.

3. ELEMENTS OF ECOLOGY [11].

Plants and animals in their physical environment make up an ecosystem. It is difficult to draw a boundry line for any ecosystem because every thing is connected with every thing else. Within an ecosystem there are three main categories of actors. The producers take energy from sun, nutrients from soil-water and through the process of photosynthesis produce high energy chemicals. These organisms are called as "Autotrophs".

The Second group of organisms are consumers who use some of this energy by ingesting the high energy molecules.

The third group of organisms, the Decomposers or Decay organisms, use energy in animal wastes and dead plants and animals, and in so doing convert the organic molecules to stable inorganic molecules. These residual inorganics then become the building blocks for

in this really true
for end of the fragile Amazon.

new life through "Autotrophs". The important ecological principle, the stability of an ecosystem is proportional to the number of organisms capable of filling various niches. A jungle is very stable ecosystem whereas the tundra in Alaska and deep oceans are extremely fragile. Inland water courses tend to be fairly stable ecosystems but certainly not totally resistant to destruction by outside forces, like heavy metals, refractory organics, depletion of dissolved oxygen which is more concerned with biodegradation activity.

4. BIODEGRADATION

Plant growth or photosynthesis can be represented by the equation :

what in the H₂CO is balanced?

$$CO_2 + H_2O \xrightarrow[\text{and nutrients}]{\text{Sunlight}} HCOH + O_2$$

OK

Here, of course, formaldehyde is not the end product of photosynthesis but it is an organic molecule. ~~Thus resulted~~ High energy molecules ~~is~~ are eaten by animals (consumers) and during their digestion process some of the energy is released and used by the animals. Release of this energy is quite rapid and end products of digestion (excrement) consist of partially stable compounds which are food for other organisms and are thus degraded further but at a slower rate to form more stable inorganic compounds which are again used by plants. Thus many of the organics responsible for water pollution enter water courses at high energy levels. It is the biodegradation or the gradual use of their energy by a chain of organisms which causes many of the water pollution problems.

There are two types of biodegradation processes - where microbial agency is utilized under controlled conditions to convert complex organics into simpler and stable compounds. Natural cycles of aerobic, anaerobic and carbon cycles are schematically presented in Fig. 1,2 & 3 respectively [1,12].

Aerobic process (in presence of oxygen).

Basic reaction :

Synthesis
Organic matter + O_2 + Microorganisms → more microorganisms
→ CO_2 + H_2O
Energy

Complex organics + O_2 $\longrightarrow$ CO_2 + H_2O + Stable products

Thus H_2O and CO_2 are the most stable end products, low in energy and used up by plants for photosynthesis. Sulfur compounds are converted into the stable end product SO_4''. Similarly phosophorous ends up as PO_4''' orthophosphate, Nitrogen bearing compounds goe~~s~~ through a series of reactions ending up as NO_3'. Organic Nitrogen $\longrightarrow$ NH_3 $\longrightarrow$ NO_2' $\longrightarrow$ NO_3'

Anaerobic process (in absence of free O_2)

Basic reaction : Degradation and then fermentation.

Synthesis
Organic matters + Microorganisms → more microorganisms
→ organic acids
Energy

Synthesis
Organic acids + Microorganisms → more microorganisms
→ CO_2, CH_4, NH_3, H_2S, etc.
Energy

This anaerobic degradation is performed by a completely different set of microorganisms to which O_2 is in fact toxic.

Complex organics ⟶ CO_2 + CH_4 + Other partly stable componds. Methane ~~Here~~ CH_4 is a high energy-gas called as marsh gas, physically stable but still able to decompose biologically. Nitro compounds stabilize only to $NH_3$and sulfur compound ends up as evil-smelling H_2S.

In aerobic decomposition O_2 serves as hydrogen acceptor to form water, while in anaerobic decomposition free O_2 is not available hence next preferred hydrogen acceptor is N producing NH_3. If N is not available the next preferred hydrogen acceptor is sulfur thus forming H_2S.

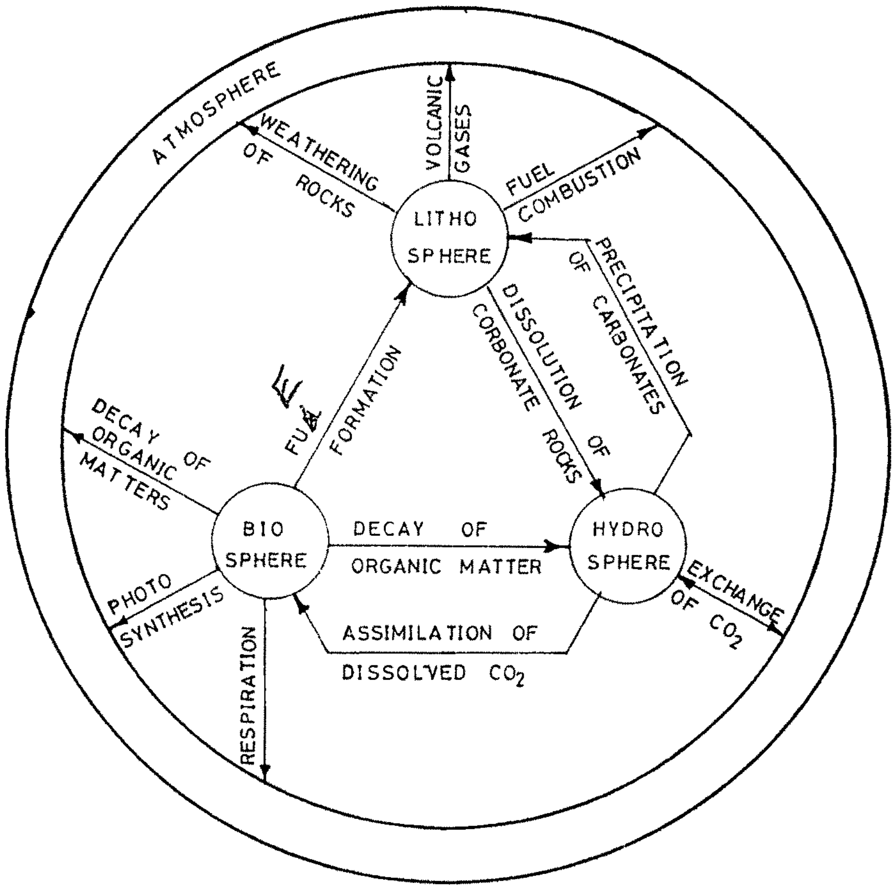


FIGURE-3 CARBON CYCLE BIOGEOCHEMICAL CYCLE

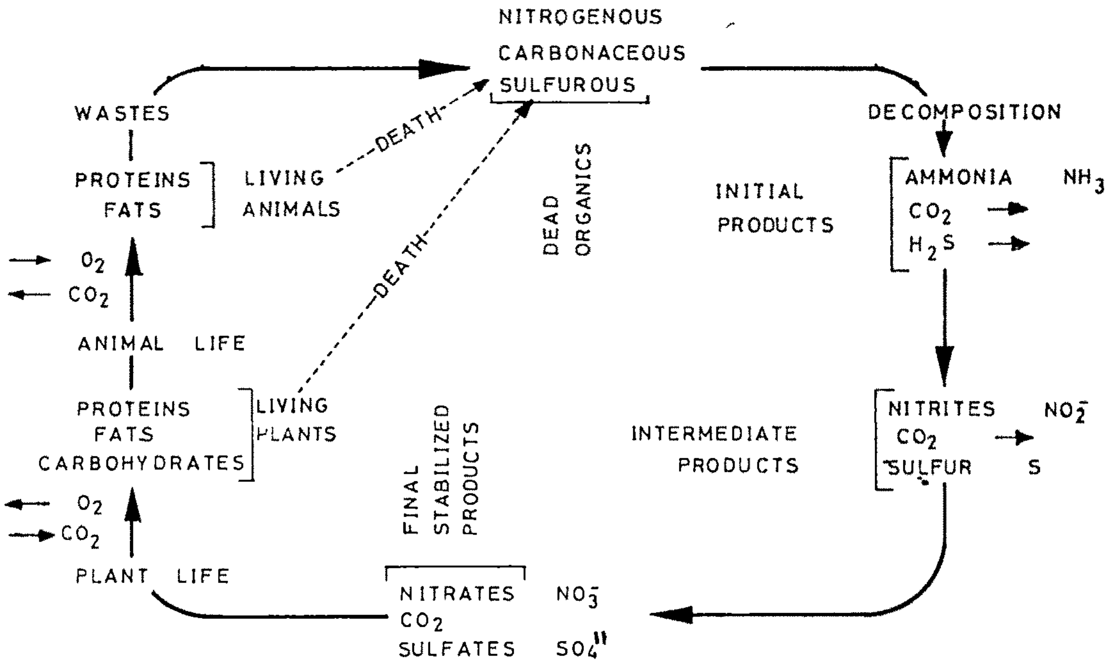


FIGURE - 1 AEROBIC NITROGEN, CARBON AND SULFUR CYCLES

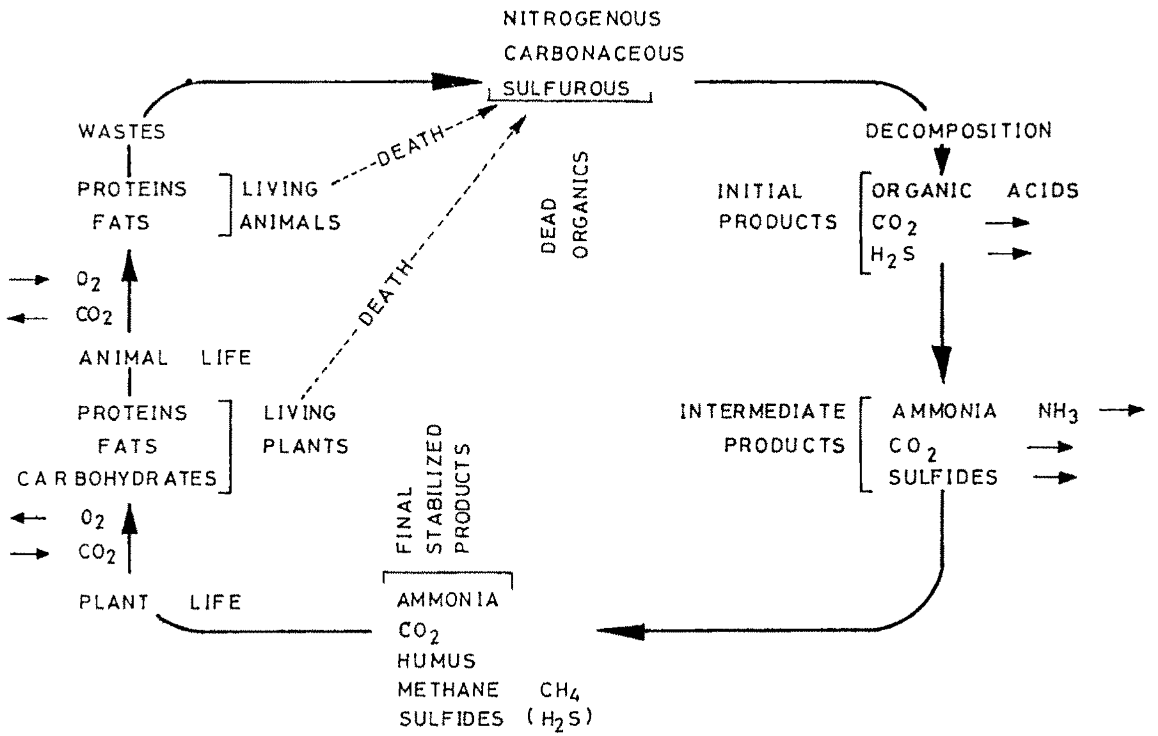


FIGURE - 2 ANAEROBIC NITROGEN CARBON AND SULFUR CYCLES

5. EFFECT OF POLLUTION ON STREAMS

When high energy organic material is discharged to a stream, a number of changes occur down stream from point of discharge. As the organics are decomposed, oxygen is used at a greater rate than before the pollution occurred and dissolved oxygen level drops. The rate of natural reaeration also increases but this is often not great enough to prevent a total depletion of O_2 in the stream and hence stream becomes anaerobic.

6. EFFECT OF POLLUTION ON LAKES.

The effect of pollution on lakes differs in several respects from the effect of stream. Light and temperature have significant influence on lake. Due to the extreme changes of temperatures of water bod~~y~~ies in different weathers, the turn over of water takes place at the intervals, which affect the biotta and planktons of the lake.

Biochemical reaction (ecology) in natural lake can be represented schematically, by Figure - 4 [1,11].

The phenomenon of eutrophication takes place in the lakes. It is geological aging of the water body. They pass through oligo-, meso- and eutrophication stage. A clear water body slowly turns into marshy land in thousand years and ultimately plants and trees grow on the filled lake. This geological aging takes place due to the increase in the concentration of neutrients in the lake. These neutrients are P, N and

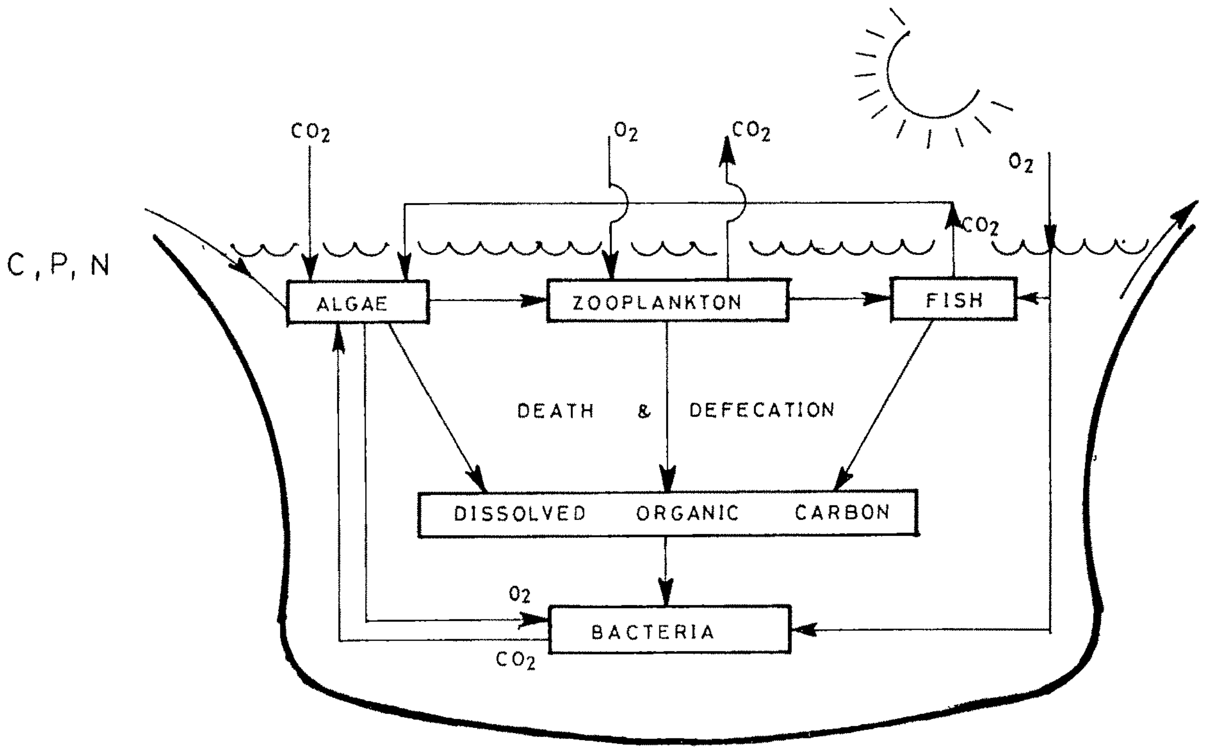


FIGURE-4 SCHEMATIC REPRESENTATION OF LAKE ECOLOGY carbon. The modern civilization rapidly adds to these neutrients, hence the phenomenon of eutrophication is accelerated and in a lifetime one might see a lake becoming marshy land instead of thousand years.

The use of phosphates as ~~builder~~ fertilizers and other organic pollutants have increased the neutrient value of lakes. The best way is to control the constituents (P,N,C) of water which flows in the lake and to reduce the existing ratio by dredging the lakes. Eutrophication creates unstable oxygen conditions, production of organic matters, taste-odour forming substances and toxins.

7. EFFECT OF POLLUTION ON OCEANS

Not many years ago, the oceans were considered infinite sinks, but we now recognize seas and oceans as fragile environments and are able to measure the detrimental effect of our actions. The water in oceans is most complicated chemical solution and there is evidence that it has changed very little over millions of years. Because of this constancy, however marine organisms have become highly specialized and intolerant-sensitive to environmental changes. Oceans are thus fragile ecosystems quite susceptible to pollution.

There are two types of important areas for oceans, the continental shelf and the deep oceans. The continental shelf and major estuaries are most productive in terms of food supply. All over the world many big cities and industrial complex discharge untreated or partly treated effluent into oceans, which has resulted into fish kills and heavy losses in terms of revenue and food [11].

8. ANALYTICAL ASPECTS OF WATER POLLUTION [13].

Most of the pollutants are measured in mg/l i.e. wt./vol. Earlier they were measured in ppm i.e. wt./wt.

There are different methods of sampling and pre~~servation~~paration of the samples and its analysis. They are described in detail in the "Standard methods for the Examination of water and waste water". APHA; AWWA; WPCF; 14th and 15th edition. The analytical techniques for different pollutants are standardized and new techniques or use of sophisticated equipments are added from time to time. The routine analysis of water for the pollution measurement and monitoring is of the following factors:

(a) Physical Properties

pH

Colour

Hardness

Suspended solids - dissolved solids.

Temperature

(c) Inorganic-Nonmetallics

Acidity

Alkalinity

Chloride

Cyanide

Fluoride

Nitrogen (Ammonia, nitrite, nitrate)

Dissolved oxygen

Phosphorus.

Sulfide

Sulfate

(b) Metals

Antimony

Arsenic

Boron

Cadmium

Chromium

Copper

Lead

Mercury

Nickel

Sodium

Zinc

(d) Organics

Biochemical Oxygen Demand
(BOD) (5 days, 20°C)

Chemical Oxygen Demand (COD)

Oil and Grease

Phenolics

Methylene Blue Active substances

Pesticides - insecticides

Petroleum Hydrocarbons

(e) Bactoriological Examination

Pathogens

Fecal coliforms

(f) Measuring radiation

Alpha, Beta and Gamma radiation.

9. WASTE - WATER TREATMENT.

9.1 General methods of waste water treatment

Waste waters are mainly of two types (i) Domestic and (ii) Industrial. For the health and hygiene of the population both types of waste waters need certain treatment before they are disposed to other water bodies or on the ground.

Domestic waters of towns and cities are being treated by statutory public governing bodies like 'Municipality' or 'Corporation' under the sewage treatment schemes. A Number of approaches are adopted for the sewage treatment and the processes are discussed in detail in number of books and monograms [8,14-21].

In the present study the main approach is on the treatment of Industrial waste waters, hence it will be discussed in greater detail.

The object of waste water treatment is to reduce the concentration of specific pollutants to the level, where discharge of the effluent will not adversely affect the environment. The Philosophy of pollution control can be upheld by the industries by switching from one type of process, which emits more pollutants, to another type of process which emits less pollutants or pollutants which can be more easily and economically removed.

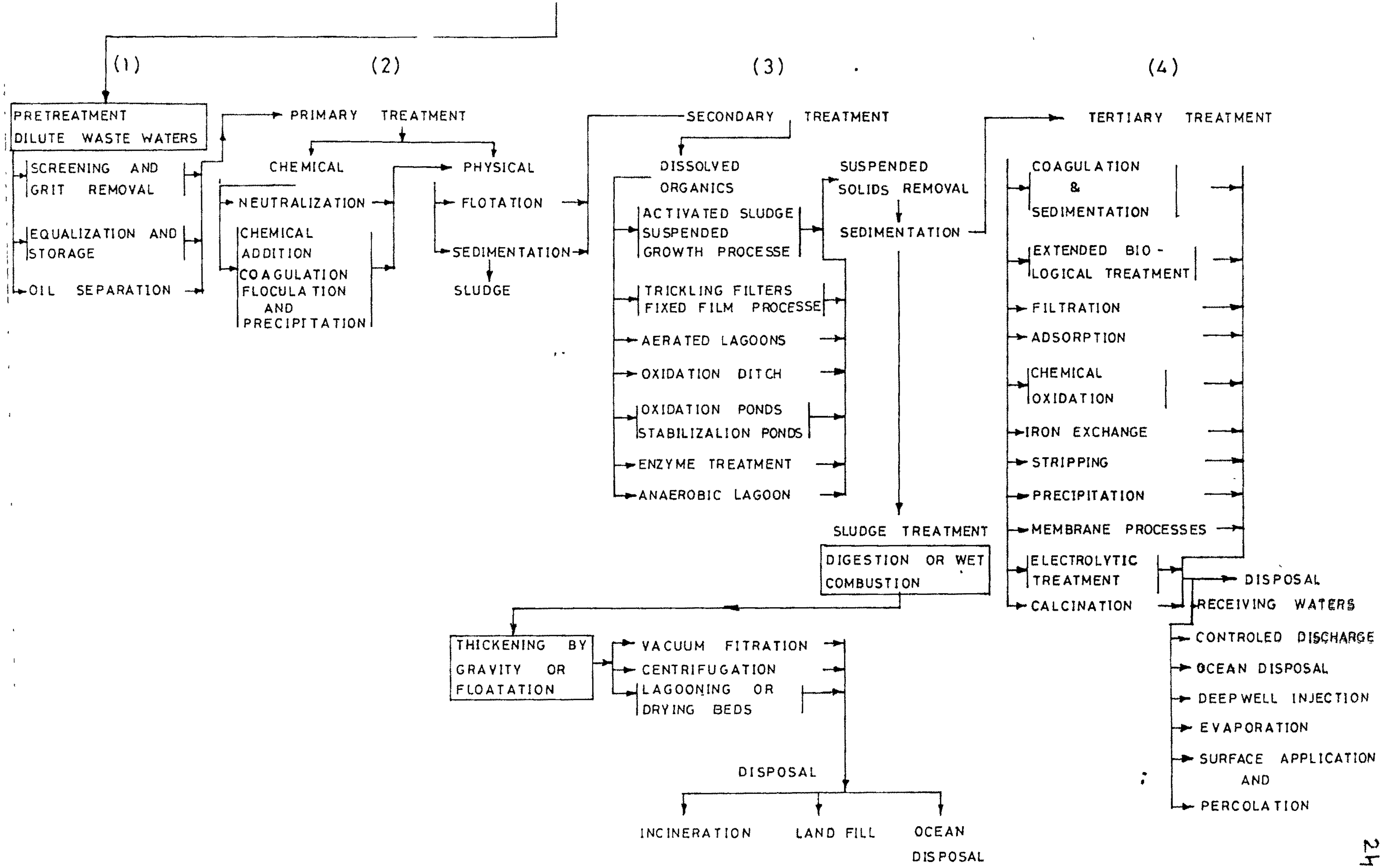
Generally industrial waste water has widely varying characteristics like high concentration of COD, BOD and TDS, toxic or refractory chemicals and heavy metals. Therefore, the type of waste water treatment depends on the nature and concentration of pollutants, intended use of the receiving waters or any other receiving systems, not only this but standards prescribed by the respective Governments.

If, by-products can be recovered from the industrial waste waters, the recovery of such products may change the future of such industries. In some industries the recovery of materials from Industrial waste water has become an attractive proposition. The list of the industries and the by-products recovered is given in Table-2.

TABLE - 2

	Type of Industry	Recovery
01.	Pulp and Paper Mills	Chemicals from black liquor (lignosulfonate)
02.	Steel Mill	Ferrous sulfate from pickling waste.
03.	Coke oven plant	Ammonia, Phenols, etc.
04.	Electroplating shops	Metals such as Cr, Cu, Ni, Ag, Zn etc.
05.	Textile Mills	Alkali from Kiering and mercerizing process.
06.	Distillary	K - salts.
07.	Soap industry	Fatty oil.
08.	Rayon industry	Zn, Na_2SO_4 etc.
09.	Stack gases of metallurgical plants.	Sulfur.
10.	Flue gas	To neutralize alkali
11.	Chlor-alkali industry	Mercury.

WASTE WATER TREATMENT FIGURE NO - 5



Reuse of certain waste waters in the process after removal of pollutants can reduce water consumption. Segregation of certain waste water stream can render the major part of waste water treatable, can reduce the concentration of pollutants in the main stream of the waste water, can make the overall waste water management economical.

The flow-sheets (Fig.5) provides the treatment methodology for the waste-waters. Pre-treatment and primary treatment are relatively simple and can be operated with lesser investment. Secondary and tertiary treatments are complex, require~~s~~ larger investments and involve~~s~~ large ~~good~~ recurring expenses also. Though they are expensive, where the organic pollutants are in higher concentrations, one can not avoid them. The western world has large industrial complexes, and they have to pay heavy price ~~revenues~~ for the fresh water and penalt~~y~~ie for the pollution due to strict regulation of law enforcement body, hence they can afford large investments in the treatment methodology. In our country where mixed sectors, public and private are promoting industries and help to small scale industries are the goal of the government, there will be a number of limitations. The small scale industries, in the beginning, hardly will be able to invest heavily on the waste water treatment.

9.2 Pretreatment

This includes physical processes for the removal of insoluble pollutants - may be inorganic or organic in nature.

(1) Screening : These screens are typically parallel steel or iron bars. These can be hand-cleared or mechanically cleaned to avoid clogging-flooding. Screens remove~~s~~ large floating matter~~s~~ from the waste water

which might damage equipment or hinder further treatment.

Grit chamber : It is simply a wide place in the channel where the flow is slowed down sufficiently to allow the heavy grit (e.g. sand, gravels etc.) to settle out. Grit is removed to protect the mechanical equipment and avoid deposition in pipelines.

(2) Equalization (Storage) : This is nothing but a storage tank to receive waste water for a definite time, to allow the self neutralization to some extent. This will save acid or alkali. This storage will produce uniform quality of waste water which is a must for further treatment.

(3) Oil-grease seperation : Removal of oil-grease is necessary to increase treatability. Various patterns are available for the removal of oil-grease. Skimming devices are most often provided in the settling tank. Removal of oil-grease is partly removal of organic load from the waste water to be treated.

9.3 Primary Treatment.

This treatment includes physical, chemical and physico-chemical treatment to remove soluble organics and inorganics.

(1) Neutralization : Presence of acids or alkalies in waste water alter the pH of the receiving body. Hence to prevent corrosion, scaling and for easy survival of organisms in treatment process, neutralization of waste water is necessary. Acidic waste is neutralized with lime stone, lime slurry, soda ash or sodium hydroxide, while alkaline waste is treated with HCl, H_2SO_4 or boiler flue gas/CO_2.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$H_2CO_3 + 2NaOH \longrightarrow Na_2CO_3 + 2H_2O$$

(2) Coagulation and Floculation - Precipitation : No distinction can be made between coagulation and floculation. This is the process by which small, colloidal and unsettleable suspended particles in a liquid medium are made to aglomarate into larger, more settleable particles. Then sedimentation takes place.

The most common coagulants are alum, ferrous sulfate with lime, ferric chloride, ferric sulfate, and synthetic polylectrolytes. Coagulants can be added in powdered form or in the form of solution and used between optimum pH range to achieve maximum efficiency. At the time of addition, violent agitation is required and then gentler action when floc is forming. This is most practical, effective and relatively low-cost process, and is carried out in either the baffle type basin or the mechanically agitated type basin.

In case of precipitation some or all of the substance in solution is transformed into a solid phase and thereby removed from solution. The most common precipitation reaction involves removal of inorganic ionic species from waste waters e.g.

$$ZnCl_2 + Na_2S \longrightarrow ZnS + 2NaCl$$

Phosphate, magnesium, chromium, cadmium salts are precipitated out by the use of lime. In the rayon industry, zinc is precipitated out from waste water using lime solution. The $Zn(OH)_2$ is recovered as solid and treated with H_2SO_4 and this sulfate solution can be recycled in the rayon plant. Starch xanthate has been used to remove metal ions from the waste water forming precipitates.

(3) Flotation : It is physico-chemical method of separating solid particles suspended in a liquid. Air bubbles carry the selected materials to the surface to form a stabilized froth, which is then skimmed off, while the waste material remains. Flotation has been applied to mineral processing, waste paper separation and oil separation.

(4) Sedimentation : It is purely physical process whereby, solid particles in liquid are made to settle by means of gravitational and inertial forces action on both the particles in the liquid and the liquid itself. Sedimentation can be carried out in conventional settling basins, either in batch or continuous process.

The rate of setting will depend on particle size, shape, density, particle concentration, temperature of liquid, velocity of flow, detention time, type of flow (horizontal-radial-up flow) and design of the system. Tube-settlers is latest in design.

We will review secondary and tertiary treatment processes in greater detail.

9.4 Secondary Treatment

These proesses are commonly biological in nature, thus it is a reproduction of the degradation processes which occur in nature. The major purpose is to remove the soluble BOD as well as the suspended solids which are not removed in the primary treatment. They are used for the domestic as well as industrial waste waters.

The degradation of complex organic molecules may involve many steps and may require several types of enzymes from different microorganisms. Enzymes begin digestion of solids before the material passes through the membrane ~~skin~~ of the microorganisms.

There are two types of microorganisms.

(i) Aerobic : may die in absence of oxygen.

(ii) Anaerobic : may die in presence of oxygen.

Microorganisms can also be grouped on the basis of their source of carbon.

(1) Heterotropic microorganisms : use carbon from the organic matters.

(2) Autotrophic microorganisms : use CO_2 as their carbon source.

Thus autotrophic microorganisms may become a carbon source for heterotrophic microorganisms. For effective results waste water treatment system should contain both ~~the~~ types of microorganisms.

Biological processes are complex in nature. Many factors affect the efficiency of these processes.

Biological treatment processes involve~~s~~ placing of waste water in contact with a mixture of microorganisms, the process optimises the microbial environment so that natural degradation is enhanced. Optimization of the process depends on the factors like pH, temperature, dissolved oxygen, nutrients like nitrogen, phosphorous, sulfur, calcium, magnesium etc., micronutrients like Iron, Boron, Copper, Manganese, Zinc, Chromium, Cobalt, etc. concentration of microbs, and available food etc. In aerobic biological treatment processes, both simple and complex organics can be decomposed to carbon dioxide and water. In anaerobic biological treatment processes only simple organics such as carbohydrates, protein, alcohols, and acids can be decomposed.

Biological treatment does not alter or destroy inorganics, ~~however~~, their concentration should be kept low so that enzymatic activity is not inhibited.

Adequate equalization, preliminary treatment and acclimatized microbial population, ensure a uniform hydraulic flow and organic concentration for better efficiency of the system.

Different biological treatment processes are listed below [22,23].

(1) Enzyme treatment
(2) Activated sludge
(3) Aerated lagoons
(4) Oxidation ditch
(5) Oxidation pond
(6) Trickling filters
(7) Anaerobic lagoon

All the above processes, except enzyme treatment depend on the natural functions of living microorganisms. Enzyme treatment is included here because enzymes are normally formulated from living cells.

Aerobic synthesis proceeds faster than anaerobic synthesis and has a higher growth yield of cells resulting in more biomass sludge residual.

Chemicals required for biological processes are limited, chemicals may be needed for pH adjustment, metal precipitation, and/or nutrient addition.

Environmental impacts associated with biological treatment processes are limited. No exotic compounds are formed in aerobic system. In anaerobic system methane bacteria may transfer methyl group to Hg or Arsenate receptors. The gas emissions in aerobic systems are CO_2 and N_2

and in anaerobic systems methane, H_2S, NH_3 etc. Solid emissions are biomass sludges consisting of spent microorganisms with some accumulation of non-biodegradable inorganics and refractory organics. The liquid effluents of biological treatment contains some dissolved inorganics and those soluble organics which have not been decomposed by microbial activity.

In general biological treatment processes are probably the most cost-effective techniques for treating organic containing waste water. Among all biological treatment processes, the activated sludge treatment system is best for industrial organics.

Anaerobic biological treatment has been proved to be an effective means of pretreatment for many organic wastes. Anaerobic system can be acclimated to accept wastes which can not be handled in aerobic system and convert them to an acceptable feed for activated sludge or aerated lagoon systems. Biological processes are not much useful for the compounds classified as toxic substances e.g. cyclic chlorinated organics, metallic cyanide complexes and certain dyes.

9.5 **Biological Treatment Processes** [1,7,8,14,22].

(1) Enzyme Treatment : Due to high cost and specificity of enzymes, this may be useful for specialized industrial application and is not feasible for the general industrial waste water treatment.

(2) Activated sludge process.

It is a well developed technology for the decomposition of variety of organics present in the waste waters having less than 1% suspended solids content. Pretreatment with lime of incoming waste stream is almost always necessary to remove heavy metals as they have adverse effect on microbial metabolism. i.e. they inhibit enzyme catalysis.

Certain refractory organics also produce an inhibitory effect on activated sludge similar to metal inhibition.

Activated sludge applied to treat waste waters from municipalities, pharmaceutical manufacturing, cannories, pulp and paper mills, refineries, petrochemical plants etc. conventional activated sludge treatment shows 90-95% BOD removal.

Activated sludge process is continuous system in which aerobic biological growths (suspended growth) are mixed with influent waste water to allow development of an acclimated microbial population and then physically separated by gravity clarification (or by air floatation). The part of the concentrated sludge is recycled to the reactor to mix with incoming waste waters. Oxygen is provided in a variety of ways, by diffused aeration, surface aeration, static mixers and may be introduced either as air, oxygen, or oxygen enriched air. The waste product from the process is excess sludge, which is a mixture of dead and living organisms, floculated by their slimy coating and containing non-biodegradable inorganics and refractory organics by their adsorption capacity. This must be ultimately disposed off. As the concentration of organics in the waste waters decreases, the rate of biological removal also decreases since the remaining organics are progressively more difficult to remove. Thus BOD removal may be excellent but the removal of COD may be low.

There are certain limitations of activated sludge process. The influent is to be continuously monitored and adjusted for its COD/BOD values or heavy doses of COD will kill the biomass and one has to develop then and begin again. Certain organics which are biostatic can not be treated by this method. Treatment of dyes and dyes intermediate effluents by this method is not effective. It does not help in complete removal of colour.

Continuous power supply and high cost of electricity compared to western world is the limitation of this process for our country. Activated sludge treatment cannot function where COD value is very high. In such cases heavy dilutions are to be carried out. The disposal of the sludge is an additional problem. Its filteration, drying etc. also adds to the cost.

Number of other modifications are suggested to overcome some of the limitations of activated sludge treatment. These modifications are [22,23,24]:

(a) Contact stabilization
(b) Step aeration.
(c) Extended aeration
(d) Completely mixed
(e) Pure oxygen
(f) Combined biological-carbon system.

(3) Other biological processes are variation in techniques, essence being the same that microbes in presence of air degrade organic compounds, oxidation ditch, aerated lagoons, oxidation pond etc.

(4) Trickling filters : This differs in the technique that additional supply of the air is not required. It is a fixed-film biological process. In the trickling filter process waste waters are sprayed through the air to absorb oxygen and are allowed to trickle through a packed bed or rock or synthetic media coated, with biological slime. Oxygen and organic matter diffuse into the slime film where oxidation and

synthesis occur. BOD efficiencies are relatively low.

The sludge is similar to the biomass residue and is to be disposed off.

Trickling filters need cleaning and replacement of packed bed after certain intervals. Rotating biological contactor (RBC) and Biological fluidized bed are also working on the same principles.

(5) Anaerobic lagoons : Aerobic systems cannot take high doses of COD value. It gives shocks and biomass get killed. Anaerobic lagoons can be used to treat waste waters with high COD values. Air is not supplied and retention time is considerably higher (25-35 days) [7,25].

For the anaerobic lagoons longer retention time is the only disadvantage compared to aerobic processes. Anaerobic lagoons are advantageous as they do not consume power. Biogas plants are recommended in rural areas to obtain cheap energy from disposable organic matter. Some scientists have pointed out that microbes of anaerobic lagoons can create havoc by converting nutrients to methane in the animals (cattles etc.)

Comparison of anaerobic and aerobic biotechnology per metric ton COD destroyed is given below [25] :

Factor	Anaerobic	Aerobic
Electricity	-	1100 KWh
Methane	1.1×10^7 Btu	-
Net cell production	20-150 kg.	400-600 kg.

Typical petrochemicals, cheese making, corn wet-milling and pharmaceutical plants have the potential of producing in excess of $ 500000/y of methane alone from anaerobic treatment of their industrial waste waters [26].

Three stages of methane fermentation is visualized in the following manner [27].

$$\text{Complex organics} \xrightarrow[\text{fermentation}]{\text{Hydrolysis and}} \text{Higher organic acids, alcohols} \xrightarrow[\text{and dehydrogenation}]{\text{Acetogenesis}}$$

$$H_2 + \text{Acetic acid} \xrightarrow{\text{Methanogenesis}} CH_4$$

For industrial waste waters containing high concentration of sulphates, sulfites or thiosulfates pose special problem due to elevated concentration of H_2S. It could be possible to operate the anaerobic process for such effluents to produce hydrogen sulphide rather than methane as end product of waste stabilization. The BOD value and the pH of the waste water are crucial factors because they control the gas stripping of H_2S.

Anaerobic digestion is applicable only to simple organic wastes like carbohydrates, lipids, proteins, alcohols and organic acids. Essentially no degradation of long chain or cyclic hydrocarbon occurs. The appearance of oil, fat and grease in the system is troublesome, causing scum formation and microbial inhibition. The methane forming bacteria are highly sensitive to pH levels, operating best in a narrow range of pH of 6.8 to 7.5 [28].

The gas produced from domestic sewage averages about 1 lit/gram of volatile solids destroyed [29]. The gas is typically 30-35% CO_2 and 65-70% CH_4. The sludge obtained in anaerobic lagoons or digester has to be disposed, either for the land fill or can be used as fertiliser.

9.6 Tertiary Treatment (Advanced Treatment)

Effluent coming out from primary and secondary treatment facilities, still contain certain organics, undesirable inorganics, toxic-heavy metals and dyes and dyes intermediate colouring matter (organic in nature). Due to these reasons present primary and secondary conventional methods are not always sufficient to render the waste water to an acceptable level for the receiving body. To remove these undesirable pollutants, tertiary treatment is necessary. These processes can be physical, biological or chemical. Industries use these more advanced methods either in conjuction with the conventional primary and/or secondary treatment methods or to replace the conventional methods. Tertiary methods even can render water suitable for in-plant purpose.

Types of tertiary treatments in practice are listed below.

01. Coagulation and sedimentation
02. Extended biological treatment
03. Filteration
04. Precipitation
05. Electrolytic treatment
06. Calcination-Incineration
07. Stripping
08. Extraction
09. Ion-exchange
10. Membrane processes
11. Adsorption
12. Chemical oxidation

Coagulation and sedimentation, filtration, precipitation etc. are normally incorporated in pre-treatment or primary treatment. Common coagulating agents are used (lime, alumn, $FeSO_4$ etc.). The precipitation is mainly used for certain metal ions or phosphate and sulphides. The incorporation of these unit processes in tertiary treatment have definite role to play to remove a typical pollutant or secondary products of tertiary treatment. Extended biological treatments are mentioned along with the secondary treatments.

10. ELECTROLYTIC TREATMENT [30].

Electrolysis of waste waters, containing metals in ppm level or a few per cent, by ordinary cell can not be economical, it also may not remove metals below the permitted levels. The cells used for the waste water treatment are highly modified versions of the ordinary cells. The literature survey reveals that the recovery of ferrous ion is carried out from acid mine drainage water by anodic oxidation in electrolytic reactor in a packed bed [31]. Copper is recovered by fluid bed electrolysis from the waste water [32]. Heavy metals can be recovered by extended surface electrolysis [33].

11. CALCINATION - INCINERATION [22]

Calcination is the conversion by thermal decomposition at elevated temperature of aqueous liquids and sludges into solid materials, without any interactions with the gàseous phase (such as air oxidation which occurs during incineration).

Incineration is a controlled process that uses combustion to convert a waste to a less bulky, less toxic or less noxious material. The principle products of incineration are particulates and gaseous air pollutants, which needs control devices to prevent air pollution. Typical incinerator operates at 1000-2400°F temperature [1].

Incineration is a well developed technology, broadly applicable to most organic wastes, applicable to handle large volumes of liquid waste. It does not require large expensive land areas. The good combustion depends upon time, temperature and turbulance of the system. Liquid wastes may be classified into two types from a combustion stand point : Combustible liquids and partially combustible liquids. Combustible liquids include all material having sufficient calorific value to support combustion in a conventional combustor or burner. Noncombustible liquid cannot be treated or disposed off by incineration and include materials that would not support combustion without the addition of auxiliary fuel and would have a high percentage of noncombustible constituent such as water.

The waste should be pumpable at ambient temperature or capable of being pumped after heating to some reasonable temperature level. Since liquids vaporize and react more rapidly when finely divided in the form of a spray, atomizing nozzles are usually employed to inject waste liquids into incineration equipment. If waste cannot be pumped or atomized it cannot be burned as a liquid but must be handled as a sludge or solid. For adequate combustion, adequate supply of air/oxygen to burn organics is also important. The heat from the auxiliary fuel must be sufficient to raise the temperature of the waste and the combustion air to a point above the ignition temperature of the organic material in the waste.

Fluidized bed incinerators, rotary kiln incinerators and multiple hearth incinerators are used in the field.

Incineration is costly alternative for pollution control. It is not always a means of ultimate disposal, in that normally an ash remains which may or may not be toxic but which in any case must be disposed of safely. It also needs air pollution control devices to prevent air pollution. In an ideal sense, incineration always adds to air pollution as it will have the effect of changing the constitution of air and will have thermal pollution effect.

12. STRIPPING [22]

Air stripping of ammonia from biologically treated domestic waste water is being developed as a means of reducing nitorgen content before discharge. It is suitable only for dilute solutions since the emission level of ammonia from a concentrated solution would be too high. Steam stripping would permit recovery of the ammonia from more concentration solutions.

The energy required to heat the water in steam stripping is a significant economic factor and the formation of azeotropes may limit the degree of concentration of the recovered pollutants. Several examples are given in this reference [30]. Removal of acidic contaminants such as H_2S, HCN, CO_2 etc. is promoted at low values of pH which can be attained with the addition of an acid. On the other hand, stripping of basic components such as ammonia is hampered by low values of pH due to fixation of the contaminants in the waste water. This fact is used to selectively strip the acidic and the basic contaminants by adjusting the pH properly.

The contaminated foul condensate in kraft mill accounts for 25% of the BOD of the total effluent from a kraft mill. Steam stripping of condensates allows recovery of turpene and other volatiles in addition to removal of odour, toxicity and BOD. Steam stripping is used to recover solvent which are used in extraction of pollutants e.g. n-butyl acetate and diisopropyl ether used in extraction of phenol. Vacuum stripping can be used to strip volatile, sparingly soluble organic compounds from waste water.

13. SOLVENT EXTRACTION [22,30,34]

Liquid-liquid solvent extraction, referred to just as solvent extraction, is the seperation of the constituents of a liquid solution by contact with another immiscible liquid. If the substances comprising the original solution distribute themselves differently between the two liquid phase, a certain degree of seperation will result and this may be enhanced by use of multiple contacts.

The process deals only with the extraction of relatively unionized species where the primary forces of attraction between the solute and the solvent are not ions. The separation of ionized substances is covered in the "liquid ion exchange" system.

Solvent extraction should be considered as a viable waste treatment process for selected, concentrated and segregated waste streams primarily where material recovery is possible and desirable.

Fig.6 is a schematic diagram of solvent extraction of waste water [34].

Normally the solvent extraction process involves three major unit operations i.e. (i) extraction (ii) solvent removal and (iii) solvent recovery. However, the solvent extraction system seldom produces raffinate

TYPICAL FLOW SHEET

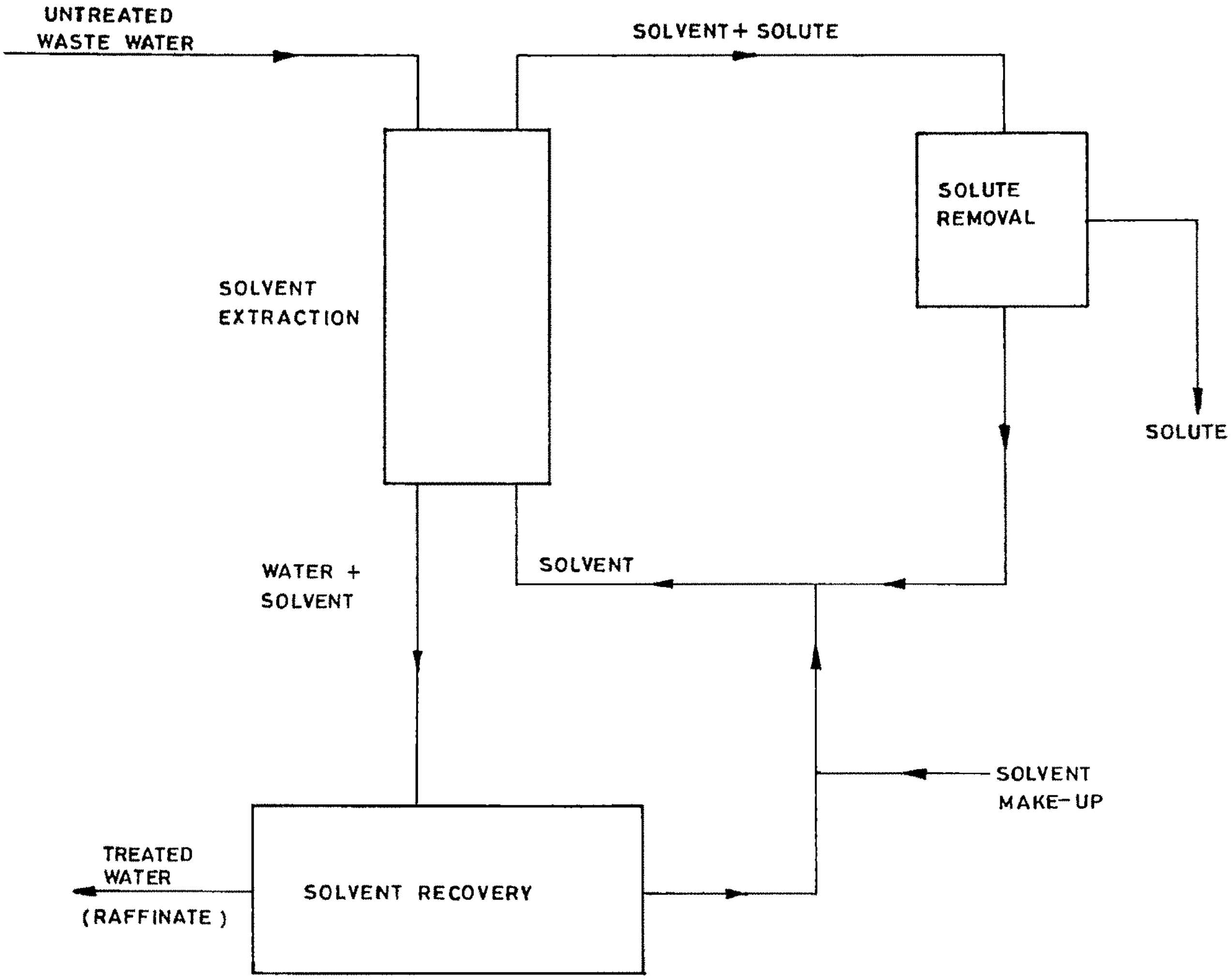


FIGURE - 6 SCHEMATIC DIAGRAM OF SOLVENT EXTRACTION OF WASTEWATER.

that is suitable for direct discharge to surface waters, it needs polishing treatment.

Following two parameters are considered important in assessing the potential for solvent extraction :
(i) the choice of solvent and (ii) optimum solvent to solution ratio (and associated flow rate). Number of factors play their role for selecting a solvent for the extraction process. In conventional extraction process the principal operating cost are for energy requirements and make-up solvent [23].

Recent developments in the application of solvent extraction processes for the removal of organic chemicals from waste-waters have occurred in two areas (i) new applications for conventional extraction system and (ii) new extraction systems.

Solvent extraction cannot be compatible with biological treatment and thus extraction should be considered only for refractory chemicals (i.e. non-biodegradable chemicals) or in situation where biological treatment is ruled out for other reasons. Number of processes are discussed for the extraction of different organic materials from the waste waters in the literature [22,30].

Extraction with Reaction [30,35-38]

Low molecular fatty acids, cyanides, and mercury chloride are removed from the waste waters by using this method.

Trioctyl phosphine oxide, high molecular weight amines (e.g. tri-n-octyl amine) are normally used which form association complexes, highly soluble in organic solvents. Immiscible solvent is separated and the waste organic material is recovered and/or removed from the solvent.

14. EXTRACTION BY LIQUIFIED SOLVENTS [30]

It is well established fact that a solvent in its supercritical state can dissolve substantial quantities of solutes (compounds) which would be sparingly soluble in the same solvent in its ordinary liquid or gaseous state. Moreover, this enhanced solubility effect is selective to some extent. Extracted solutes can be recovered from the solvent by lowering the density of the super critical fluid. This can be achieved either by reducing the pressure (at constant temperature) or by increasing the temperature (at constant pressure).

CO_2, hydrocarbons such as butane, isobutanes and other solvents such as freons are used as liquified solvents.

15. LIQUID ION EXCHANGERS [22].

Liquid ion exchange (LIE) process is often termed as solvent extraction process in which the ion exchanger is a water insoluble liquid, resembling to a liquid-liquid extraction process rather than conventional ion exchange process. Normally water-immiscible solvent containing a liquid ion-exchanger is used to extract the impurities, from waste water, which is capable of formation of complexation, salt etc. Complexed species are more soluble in organic solvent, hence they are transferred to organic layer, which is separated and solvent and liquid ion-exchanger are seperated and recycled. The process requires large quantity of solvent.

LIE process is competitive with conventional ion exchange process and can be used to treat much higher concentrations than the latter. Liquid ion exchange process is mainly used for the removal of metal ions (cations), anions, mercury ions etc. [39-42].

Long chain fatty amines are preferred as liquid ion-exchanger. Secondary and tertiary amines are more suitable as the ion-exchanger. Other compounds like trialkyl phosphates, are also used.

The extractants are classified in different subclasses as acidic, chelating, ionic and inert.

16. ION EXCHANGE PROCESS [22,30].

Ion exchnage phenomena has been used in the industries for softening of water, removal of cations and anions from the solutions. Water soluble and ionic organic matters are also removed by this method. Number of types of ion-exchange resins are commercially available for different applications. Ion exchange method is used in many waste-water treatment plants. Mercury is removed from the effluents of chloralkali industries in India by the use of ion-exchange resin.

17. MEMEBRANE PROCESSES [23,30]

Phenomenon of osmosis was known since last century but its application in terms of reverse osmosis could be envisaged only recently and after the development of strong synthetic polymeric membranes which can stand very high pressures. Reverse osmosis phenomenon finds many applications in modern industrial world.

The three membrane processes that are finding increased interest in pollution-control applications and for inplant recovery systems are ultrafiltration (UF), reverse osmosis (RO), and electrodialysis (ED).

Ion exchange and RO are used and applied in the lower concentration ranges while ED has greater application in the intermediate range and distillation is most effective in the upper range. Membrane processes are considered as a seperation technique for the mixtures which are difficult or costly to separate by other conventional methods such as distillation, adsorption, absorption, extraction or crystallization etc.

There is no sharp distinction between UF and RO, and both are dependent on the use of selective porous membranes for accomplishing molecular separation. The separation is entirely effected in liquid phase.

The membranes, commercially available for RO equipment are the anisotropic cellulose acetate membrane in sheet, tube or hollow fiber form and the anisotropic aromatic polyamide hollow fibers. For ultrafiltration, tubular rod/tube bundle module, capillary module, plate module, spiral-wound module, and hollow fiber module are prominent.

Some of the advantages of RO and UF include low capital cost, low energy and labour cost, simple operation and low space requirement while the limitations include a limited pH range, requirement of pretreatment to avoid precipitation and/or membrane fouling and/or chemical degradation of membrane. These factors decline membrane performance. RO has a few additional limitations, such as inability to concentrate solution to very high concentration because increase of concentration causes a corresponding increase of osmotic pressure which in turn reduces the flux and permeate quality, incomplete rejection of small non-ionized molecules. Most of the membrane currently available can operate over pH range 2.5 - 11; however membrane hydrolysis could be controlled at pH range 5-9 for both cellulose acetate and polyamide membranes.

Inorganic UF membranes, are claimed to operate upto 200°F or more and over a pH range of 1 to 14.

In many cases, the products and byproducts recovery using the RO and UF processes make pollution abatement a profitable enterprise.

Several applications of UF and RO in waste water treatment are reported in the literature [30]. e.g. Removal and/or recovery of pollutants from brackish water, fermentation effluent, meat wastes, dyes, detergent, cooling water, soyabean and paper industry.

18. DIALYSIS AND ELECTRODIALYSIS (ED) [30]

In contrast to the membrane processes of reverse osmosis and ultrafiltration, dialysis employs the removal of solute (with some small amount of accompanying water) from solution rather than the removal of the solvent. The other major distinction is that only ionic species are removed. Dialysis can be applied for desalination of high molecular weight solutions and recovery of specific metals from waste waters.

Operating costs for dialysis and electrodialysis tend to be lower than those in the case of RO and UF becuase less energy is required to transport the component of the solution to be seperated and concentrated (as compared to water) since this component is present to a much smaller extent. Removal of ionic species allow for the simultaneous seperation of these substances from any neutral or non-ionized organic matter that may be present.

Factors affecting performance and stability of membrane are same as RO and UF. Most membranes permit operation up to 50°C. The polorization effects can be minimized by maintaining high flow rates, by recycling the dilution stream in part, by increasing turbulance and by keeping the spacing between the membranes narrow.

Most of the stable membranes used are based on copolymers of divinylbenzene-styrene with ion exchange groups.

Potential application of ED in waste water treatment are -

- reduction in salt content of whey solutions from 6000 ppm to 300 ppm so as to allow the use of lactose solutions in food application.

- Recovery of inorganics and organic salts, metals, acids and lignosulfonate from pulp liquors.

19. ADSORPTION [30]

Adsorption processes, in particular those, using activated carbon are finding increased use in waste water treatment for removal of refractory organics, toxic substances and colour. Thus it has been considered as techno-economical method for treatment of various waste waters. In these processes dissolved substances in the waste water are attracted to adhere to a solid adsorbent surface, as result of hydrophobic nature of the solutes in the solvent (waste water) and the affinity of the solute for the solid.

Solubility of the solutes (dissolved organics) is directly related to hydrophobic behaviour - organics of low solubility are more easily adsorbed. The adsorption is greater for the higher molecular weight compounds in a homologous series due to decrease in water solubility of the organic substances with an increase in the size. Polar solutes as well as ions are poorly adsorbed. Since adsorption is a surface phenomenon, the effect of the solute on the surface tension of the solvent has an influence on the process of adsorption. Thus decrease in surface tension upon addition of solute will result in migration of solute towards a solid surface.

Solute (sorbate) affinity for the solid (sorbent) is due to a combination of (a) electrostatic attraction (activated carbon has negatively charged sites) (b) physical adsorption and (c) chemical adsorption. Low temperature favours physical adsorption whereas high temperature favours chemical adsorption. An effective adsorbent must have high surface area per unit weight. Adsorption capacity of an adsorbent increase with increase in the liquid phase concentration. The adsorption of organic molecules is affected by factors such as functional groups, molecular weight and side chain branching. Adsorption capacity will decrease with increasing temperature (since adsorption is an exothermic process). The important adsorbent properties are surface chemistry, treatment, pore size, pore distribution and particle size. Temperature, pH and contact time are also important conditions affecting adsorption. Larger pore sizes will give a greater adsorption capacity for large molecules.

Water pollutants like phenols, cresols, chlorophenols, nitrophenols, benzene, benzaldehyde, dodecylbenzene sulfonic acid, benzoic acid, acetic acid, cyanides, heavy metals and colour etc., can be recovered/removed from the waste waters by adsorption. The concentration of adsorbates in the influents should be less than 1% when recovery is not involved, concentration upto 5% is acceptable when recovery is involved.

Activated carabon adsorption

Waste water can be treated with activated carbon in a treatment column or by direct addition of carbon to an active sludge system. Activated carbon is available in both granular and powder form. The choice of use depends on the treatment type, granular size, surface area and pore size, carbon density and regeneration capacities. Granular carbon is made from either lignite or bituminous coal. Lignite carbon is favoured due to its lower density and higher impurity loading capacity. The use of granular carbon is favoured as more efficiently it can be used for the total adsorption capapcity, operation can be continuous and regeneration is easier. The use of powdered carbon is favoured due to its lower cost, greater treatment flexibility, and for uniform operation. The powdered activated carbon has certain inherent disadvantages as regeneration process bring high losses, it is also difficult to handle, higher amount of carbon is required compared to granulated carbon [43,44].

The major advantage of the activated carbon treatment include higher organic removal. The major limitations are relatively high capital and operating costs, loss of activated carbon if not regenerated and also if generated, low tolerance of suspended solids and inability to remove low molecular weight and/or highly soluble organic chemicals [44].

Aromatics are more adsorbed than aliphatics among the organics. Macromolecules would be too large to reach a significant fraction of the internal pores of carbon and therefore difficult to remove from waste waters.

There are three types of carbon adsorption systems used industrially. These are the fixed bed, the pulsed-bed and the moving bed systems. These can be used singly in series, in parallel or as a series - parallel combination. Most of the systems on-stream, at present, are either fixed bed or pulsed bed systems. All these systems, their merits, demerits, and operating modes are discussed in detail in number of monograms [22].

Polymeric Adsorption [22,30,45]

The use of polymeric adsorbents, a relatively new waste treatment technique, offers a more desirable alternative to ion exchange. Since polymeric adsorbents act as true adsorbent having no exchange sites, organics can be readily removed by regeneration. Thus synthetic polymers can remove organics from an aqueous medium by physical-chemical adsorption. The solute generally gets bound to the solid surface. The binding energies of these polymers are lower than those of activated carbon for the same organic molecules. These lower binding energies permit easy regeneration.

Resin adsorption should be given consideration

For the treatment of highly coloured organic waste.

When material recovery is practical.

When selective adsorption is desired.

Where carbon regeneration is not practical.

Where the waste stream contains high level of dissolved inorganics.

Their utility rests in their high capacity, selectivity, regeneration efficiency and outstanding chemical and physical stability which provides long service life, relatively compact system thus requires little space.

Feed stream should have less than 50 ppm suspended solids. These adsorbents can be used in wide pH range 1 to 12, temperature as high as 80°C. Feed stream should not contain very strong oxidants.

Polymeric adsorbents can be regenerated either by changing pH or by using solvent, the principles remains the same as the ones in the case of activated carbon.

Caustic soda or formaldehyde are used as regenerant in the case of phenol removal, sulfuric acid or hydrochloric acid is used as regenerant in the case of heavy metals removal, by synthetic adsorbents. To regenerate an adsorbent resin loaded with a solute, a solvent system is chosen such that the solvating forces of the solvent for the sorbate will overcome the adsorbent resin attractive forces, the sorbate will then migrate to the solvent phase.

Cross linked polymethyl acrylate resin, cross-linked polystyrene type resin (Amberlite XAD-4) are used for the adsorption of phenol. Heavy metal like Hg, Ag, As, Cr, Cd, Zn, can be reduced to ppb level in the waste water by synthetic resins. Phenolics like para-nitro phenol, chlorinated phenols can be adsorbed on synthetic resins.

Colour reduced from 75000 to 500 APHA units and COD is reduced from 5280000 to 2600 ppm from the dyestuff production waste water, using synthetic adsorbent [46]. The resin adsorption system removes 92-96% of colour (initially 30-40,000 Pt-Co units), 80-90% of the COD and

40-60% of the BOD from the effluent of the caustic extraction stage in the bleach plant [47]. Some resins are used, to remove colour in water supply system, to decolorize sugar, wines, pharmaceutical products etc.

20. CHEMICAL OXIDATION [22,23]

Chemical oxidation processes are differentiated from thermal, electrolytic and biological oxidation. There are several oxidizing agents, such as ozone, chlorine gas, chlorine dioxide, potassium permanganate, hydrogen peroxide, nitrous acid. Ozone, chlorine and hydrogen peroxide are preferred over others. They are used for destroying organic pollutants, that are resistant to biological or other treatment processes, and also used for toxic compounds.

Destruction of cyanide by alkaline chlorination is of well known industrial application. The stepwise chlorine oxidation of mixture of compounds present in industrial waste such as glycols, chloro-alcohols, organic acids, and ketones is described in a patent by controlling the pH in alkaline range initially to oxidize those most favourably destroyed by hypochlorite ion, then allowing the pH to drop to the acidic range to destroy those oxidized more rapidly at low pH. The oxidation of carboxylic acids in brines by chlorination in the presence of UV light catalysis is described in an US patent.

Cyanide destruction

$2\ NaCN + 5\ Cl_2 + 12\ NaOH \longrightarrow N_2 + 2Na_2CO_3 + 10\ NaCl + 6H_2O$

gas

$2\ NaCN + 5\ NaOCl + H_2O \longrightarrow N_2 + 2NaHCO_3 + 5\ NaCl$

Sod. hypochlorite

Hydrogen peroxide is used to destroy phenol, cyanide, and sulfur compounds.

Ozone Treatment

Ozone(O_3) is powerful oxidizing reactive gas that reacts rapidly with many compounds present in the waste waters. It has relatively low solubility in water and is unstable having a half-life of several minutes. Ozone generation therefore, must be done at the plant site. It can break carbon-carbon bonds and even to cleave aromatic ring system (e.g. conversion of phenol to 3 molecules of oxalic acid). Complete oxidation of organic species to CO_2, H_2O etc. is not improbable if O_3 dosage is sufficiently high.

Ozone is found to be effective in many applications for colour removal, disinfection, taste and odour removal, Fe and Mn removal and in the oxidation of many complex organics, including indane, aldrin, surfactants, cyanides, phenols, and organo-metal complexes. With the latter the metal ion is released and can be removed by precipitation.

In Japan a combination of ozonation and activated carbon adsorption has been used to remove colour, BOD and COD from 3300 m^3/day of waste dyeing water. Ozone reduces phenol from 300 ppb to 10 ppb, increases the capacity of activated carbon.

It has been observed that in a number of studies ozonation converts COD to BOD. Thus non-biodegradable, toxic-organics could be safely treated biologically. Among organics, low molecular weight saturated acids (e.g. acetic), saturated hydrocarbons, pyridine and chloroform appear to be resistant to ozonation. One of the advantage of ozonation is that the process leaves no inherent harmful residue.

21. AIR POLLUTION

It is difficult to define clean air. It is appropriate to define air pollutants as those substances which exist in such concentrations as to cause an unwanted effect. These pollutants can be natural or man made and can be in the form of gases or particulates. Components of normal, clean dry air are given in Table - 3 [1].

Air pollution is not of recent occurence. Primitive man too introduced foreign substances in the atmosphere with his fire activities. The difference is, modern man has accelerated this process of pollution till it has reached alarming proportions.

It is true that nature has her own ways of maintaining an environmental balance. Air pollutants are dispersed by wind, washed away by rain or snow, diluted and often broken into non-toxic components by the action of sun light and bacteria. But natural processes are limited in scope and extent. Some times natural processes may even convert non-toxic substances into deadlier ones.

The study of air pollution involves scientists of various disciplines like physics, chemistry, mechanical engineering, meteorology and economics. The atmospheric conditions determine the behaviour of air pollutants often they leave the source or sources until they reach receptors such as people, animal, plants, water body or land. Therefore, knowledge of meteorological and topographical characteristics of a study area is of utmost importance.

Air pollutants occur in the form of gases, vapours, solid particles and liquid droplets. These forms can exist either separately or in combinations. They are classified in two major groups.

(i) Gaseous and vapour pollutant.

(ii) Particulate pollutants.

Particulate matters present in the atmosphere may be orgnic or inorganic in composition and in liquid or solid physical state.

Earth's atmosphere is an envelope of gases extending to a height of about 200 kms. However, the quality of air upto 5 to 10 kms. is more important as the air contained in this area is more than half of total atmospheric air and it contains the air we breathe and air in which all weather processes occur.

TABLE -3

Components of Air :

Component	Concentration (ppm)
Nitrogen	780,900
Oxygen	209,400
Argon	9,300
Carbon dioxide	315
Neon	18
Helium	5.2
Methane	1.0 - 1.2
Krypton	1.0
Nitrous oxide	0.5
Hydrogen	0.5
Xenon	0.008
Nitrogen dioxide	0.02
Ozone	0.01-0.04

In India, Bhopal gas (methyl Isocynate-MIC) tragedy occurred on 3rd December, 1984, and claimed more than 2000 lives, upto 40000 people have serious lungs damages, and thousands of people still suffer from medical disabilities, like breathlessness, quick-fatigue, deterioration of vision and neurotic depression.

Another episode of historical significance is one involving the accidental release of hydrogen sulfide gas from a refinery at Poza Rica, Maxico, in Nov. 1950.

If we estimate amount of the air consumed in burning major fuels, we would find that a ton of petrol needs 9900 cubic metres of air, oil needs 10300 cu.m., coal needs 11600 and gas needs 15500 cu.m. [48]. Various air pollution sources and pollutants emitted from such sources are given in Table-4 [1,48].

TABLE - 4

Classification of Air Pollution sources and Emissions

	Type	Category	Examples	Important pollutants
A.	NATURAL SOURCES			
	Natural Processes	Particulates	Natural products forest fires volcanic eruptions	Yeasts, algae,bacteria Pollen grains,fungus spores, salt spray, smoke, dust etc.
		Gaseous	Degradation of hemoglobin, terpenes,cysteine, sulfur containing amino acids.	Carbon monoxide, hydrogen sulfide, nitrogen oxides, methane etc.
		Radioactivity	Radioactive minerals, cosmic rays from outer space.	Radon and Thoron

B. MANMADE SOURCES

Combustion	Fuel burning	Domestic burning, thermal power plants.	Sulfur, nitrogen oxides, acid rain having pH as low as 2 or even below. Organic acids, aldehydes, carbon monoxide, ammonia etc.
	Transportation	Cars, trucks, aeroplanes and railways.	Carbon monoxide, nitrogen oxides, lead, smoke, organic vapours, odours etc.
	Refuse burning	Open burning	Fly ash and particulate.
Manufacturing Processes	Chemical Plants	Petroleum refineries, fertilizers, cement, paper mills, ceramic glass manufacture clay products. Petrochemicals, dyes, rayon.	Hydrogen sulphide, sulfur oxide, flourides, odours, organic vapours, dusts.
	Metallurgical plants.	Aluminium refineries, Steel plants Mines.	Metal fumes (Pb&Zn) fluorides and particulates.
	Waste Recovery	Scrap metal yards, rendering plants.	Smoke, odours, metal fumes,organic vapours.
Agricultural activities	Crop spraying	Pest and weed control.	Organic phosphates, chlorinated hydrocarbons, Pb,As,Hg.
	Field Burning	Burning of refuse firewood and dry cattle dung.	Soot,fly ash,smoke, sulfur oxides, organic vapours, particulates.
Solvent usage	Spray painting, solvent extraction, inks, solvent cleaning	Furniture and appliances,finishing,dyeing,printing,and chemical seperations, dry cleaning, degreasing.	Hydrocarbons, and other organic vapours.

Nuclear energy programmes	Fuel fabrication	Gaseous diffusion	Fluorides
	Ore Operation	Crushing,Grinding and Screening.	Uranium, beryllium, dust and other particulates, argon-41, iodine-131.
	Nuclear device testing	Bomb explosions	Radioactive fallout, Sr-90, C-14, Cs-137 etc.

21.1 **Types of Air Pollutants** [1].

(1) Gaseous Pollutants.

Gaseous pollutants include substances that are gases at normal temperature and pressure as well as vapours of substances that are liquid or solid at normal temperature and pressure. Most of the gaseous air pollutants, their properties and significance as air pollutant is listed in Table - 5. Pollutant concentrations are commonly expressed as microgram per cubic meter ($\mu g/m^3$).

TABLE - 5

Air pollutants - properties - effects.

Name	**Formula**	**Properties of importance**	**Significance as Air Pollutant**
Sulfur dioxide	SO_2	Colourless gas,intense choking odour, highly soluble in water to form sulfurous acid H_2SO_3.	Damage to vegetation, property and health

Name	Formula	Properties of importance	Significance as Air Pollutant
Sulfur trioxide	SO_3	Soluble in water to form sulfuric acid H_2SO_4.	Highly corrosive.
Hydrogen sulfide	H_2S	Rotten egg odour at low concentrations, odour less at high concentration, heavy gas.	Highly poisonous
Nitrous oxide	N_2O	Colourless gas, used as carrier gas in aerosol bottles.	Relatively inert. Not produced in combustion.
Nitric oxide	NO	Colourless gas	produced during high temperature, high pressure combustion. Oxidizes to NO_2.
Nitrogen dioxide	NO_2	Brown to orange gas	Major component in the formation of photochemical smog
Carbon Monoxide	CO	Colourless, Odourless	Product of incomplete combustion, poisonous.
Carbon dioxide	CO_2	Colourless, Odourless	Formed during complete combustion. Possible effects in producing changes in global climate.
Ozone	O_3	Highly reactive	Damage to vegetation,and property. Produced mainly during the formation of photochemical smog.
Hydrocarbons	C_xH_y or HC	Many	Some hydrocarbons are emitted from automobiles and industries, others are formed in the atmosphere. Harmful to health.

(2) Odours

Odours are offensive. They cause nausea and disturb sleep. They are caused by the presence of minute particles in ambient air. Sources of odours are animal, sewage systmes, chemical plants, combustion processes and solid wastes etc.

(3) Particulate Pollutants

Particulate pollutants include finely divided solids and liquids, and are classified as follows.

(i) Dust : Solid particles which are

(a) entrained by process gases directly from the material being handled or processed e.g. coal, ash and cement.

(b) direct offspring of a parent material undergoing a mechanical operation e.g. saw dust from wood working.

(c) entrained materials used in a mechanical operations e.g. sand from sand blasting. Dusts from grain elevator and coal - cleaning plants.

Dust particles size ranges from 1 μ to 100 μ in diameter.

(ii) Fume : A solid particle, frequently a metallic oxide, formed by the condensation of vapours by sublimation, distillation, calcination or chemical reaction processes e.g. Zn and Pb oxide resulting from the condensation and oxidation of metal volatilized in a high temperature process. The particles in fumes are quite small, with diameters from 0.03 to 0.3 μ.

(iii) Mist : A liquid particle formed by the condensation of a vopour and perhaps by chemical reaction e.g. formation of sulfuric acid mist.

$$SO_3 \text{ (gas) } 22°C \longrightarrow SO_3 \text{ (liquid)}$$

$$SO_3 \text{ (liquid) } + H_2O \longrightarrow H_2SO_4$$

Sulfur trioxide gas becomes a liquid since its dew point is 22°C and SO_3 particles are hygroscopic. Mists typically range from 0.5 to 3.0 µ in diameter.

(iv) Smoke : Solid particles formed as a result of incomplete combustion of carbonaceous materials. Although hydrocarbons, organic acids, sulfur oxides and nitrogen oxides are also produced in combustion processes, only the solid particles resulting from the incomplete combustion of carbonaceous materials are smoke. Smoke particles have diameters from 0.05 to 1.0 µ.

(v) Spray : A liquid particle formed by the atomization of a parent liquid.

(vi) Smog : This is a special phenomenon occuring in special conditions. This is a synchronym of two words-smoke and fog. Smog can be of two types - photochemical or coal induced. It reduces visibility, causes eye irritation, vegetation damage and cracking of rubber. Prolonged or serious exposure to this smog may result in high mortality rates. Smog formation takes place as a result of complex reactions such as oxidation, decomposition, reduction, condensation and polymerisation of several active air pollutants.

21.2 **Primary and Secondary Pollutants** [1].

An important approach to classification of pollutant is that of primary and secondary. A primary pollutant is defined as one that is emitted as such to the atmosphere, as a result of some process and found in the form in which it was emitted e.g. SO_2, NO_x whereas a secondary pollutant is one formed in the atmosphere as a result of some reaction, hydrolysis, oxidation etc.

Key reactions in the formation of photochemical smog is as under.

$$\underset{\text{Nitrogen dioxide}}{NO_2} + \text{light} \longrightarrow \underset{\text{Nitric oxide}}{NO} + \underset{\text{Atomic oxygen}}{O}$$

$$O + \underset{\text{molecular}}{O_2} \longrightarrow \underset{\text{ozone}}{O_3}$$

$$O_3 + NO \longrightarrow NO_2 + O_2$$

$$O + \underset{\text{Hydrocarbon}}{HC} \longrightarrow \underset{\text{Radical}}{HCO^{\bullet}}$$

$$HCO^{\bullet} + O_2 \longrightarrow \underset{\text{Radical}}{HCO_3^{\bullet}}$$

$$HCO_3^{\bullet} + HC \longrightarrow \text{Aldehydes, ketones etc.}$$

$$HCO_3^{\bullet} + NO \longrightarrow \underset{\text{Radical}}{HCO_2^{\bullet}} + NO_2$$

$$HCO_3^{\bullet} + O_2 \longrightarrow O_3 + HCO_2^{\bullet}$$

$$\underset{\text{Radical}}{HCO_x^{\bullet}} + NO_2 \longrightarrow \text{Peroxyacetyl nitrates}$$

21.3 **Effects of air pollution** [1,14,48].

Effects of air pollution can be classified under five sections.

(1) Health Effects

(2) Effects on vegetation.

(3) Effects on domestic animals.

(4) Effects on materials.

(5) Effects on atmosphere.

(1) Health Effects

Four of the most difficult problems in relating to air pollution to health are unanswered questions concerning :

(a) the existence of thresholds (b) the total body burden of pollutants (c) the time versus dosage problems and (d) synergistic effects of various combinations of pollutants.

The major target of air pollutants is the respiratory system. Pollutants are either absorbed into the blood stream or moved out of the lungs by tiny hair cells called cilia which are continually sweeping mucus up into the throat. The site and the extent of the dposition of particulates in the respiratory tract is a function of particle size. Alveolar deposition is especially important since that region of the lungs is not provided with cilia to remove particulates and hence particles deposited would remain for a greater time. Particles greater than 1 μ will generally be caught before they reach the alveoli. Other factors that determine the amount of particulate deposition are respiratory frequency and the volume of air moved in and out of the lungs with each breath. Soluble particles will be transferred to the blood.

Certain particulates or gaseous pollutants can slow down or even stop the action of cilia which by its sweep in movement, they propel the mucus, germs and dirts cought in it, out of respiratory tract. The irritants can cause the production of increased or thickned mucus. They can induce swelling or excessive growth of the cells that form the lining of the airways. Because of such reactions breathing may become difficult and foreign matters including bacteria may not be efficiently removed. Thus respiratory infection takes place.

Air pollution is mainly occupational hazards for the people working in the industries producing air pollutants. e.g. Insecticides, asbestose, textiles, cement and many other chemical industries.

Approximately 7600 litres of air we inhale daily, the particulates may end up deposited in the lungs, causing a buildup on the lung lining. This buildup on lungs reduce the ability of the luns to transfer O_2 into the blood. The normally elastic and spongy lung tissues harden, reducing the lung's breathing efficiency.

The SO_2 in the air, often with particulates acting as a catalyst (reaction site) can be converted to SO_3, which can further react with water vapour to produce H_2SO_4. This acid can easily damage lungs tissues, cause irritation of mucus membranes and bronchial constriction. H_2SO_4 will produce from four to twenty times the physiological effect of SO_2. Sulfur dioxide effect is more acute than chronic.

Nitrogen dioxide (NO_2) is a pulmonary irritant. Ozone (O_3) is a highly irritating oxidizing gas. The symptoms of exposure are initially a dry throat, followed by headache, disorientation and altered breathing patterns. O_3 aggravates asthma, emphysema and chronic bronchitis. Carbon monoxide (CO) combines readily with hemoglobin (Hb) to form carboxyhemoglobin (COHb). Human hemoglobin has a CO affinity 210 times greater than its affinity for O_2, thus preventing O_2 transfer. Inhalation of CO impair vision, produce headache and exert a strain on the heart.

Among the organic gases formaldehyde (HCHO) causes irritation of mucous membranes and bronchial constriction. Among the chronic diseases thought to be casually related to air pollution are lung cancer, emphysema and asthma.

Effect on Vegetation

Vegetation is injured by air pollutants in three ways.

(1) necrosis (collapse of the leaf tissue)

(2) chlorosis (bleaching or other colour changes)

(3) alteration in growth.

Sulfur dioxide produces, marginal or intervenial blotches which are white to straw in colour broad-leafed plats, on grasses it shows a streaking (light tan to white). SO_2 can have either chronic or acute effects on plants life. Fluoride produces an injury at the periphery of the leaf or tip burn in grasses.

At sufficient concentrations of O_3 produces tissue collapse and marking of the upper surface of the leaf.

Effect on animals

The health effects of the various pollutants on animals are much the same as their effects on humans. Certain chemicals, in the form of air pollutants enter into food chain which causes adverse effect on health. Perhaps the best known of the pollutants affecting livestock is fluoride. Farm animals like cattle, sheep and swine are susceptible to fluorine poisoning.

Effects on Materials

One of the most serious problems affecting materials is due to the SO_2 and H_2SO_4 in the air - the acid rain. It reacts with marble, mortar, concrete, metals, rubber, plastics and some type of fabrics. NO_2 can bleach fabrics. Particulates are responsible for soiling of building surface, clothing and other articles. Ozone, a principal ingredient of smog causes cracking of rubber. Hydrogen sulfide in presence of moisture reacts with lead dioxide in paint to form lead sulfide producing a black surface.

Effect on Atmosphere

The decrease in visibility is caused by a variety of pollutants. Visibility has a psychological impact on man. On a clear day in a pollution free environment one can see approximately 163 miles. As the air becomes more polluted the visibility becomes poorer and poorer.

The presence of the particulate catalyzes the initial moisture condensation, (using a particulate as necleus), and droplet formation of sufficient size to form rain. Air pollution can also have the opposite influence on precipitation. Too many particulates can encourage the formation of too many small nuclear particles compared to the available moisture. Each particle cannot attract enough water vapour to itself so it can not grow enough to form rain droplets. The net effect is a decrease in precipitation.

The global climatic effects relate to the earth's heat balance. There are two proposed but opposing theories to predict the net effect of air pollution on the temperature.

Although CO_2 is usually not considered a pollutant but CO_2 concentration in the atmosphere have been increasing in recent years attributable to increased combustion of fossil fuels. Atmospheric CO_2 is transparent to visible radiation but is a strong absorber and back radiator of infrared (heat) radiation. The visible light is degraded on the earth's surface and the heat formed cannot radiate back outward. The CO_2 concentration will increase from the 1968 level of 0.032% to about 0.038% by the year 2000. This would theortically result in an increase of 0.5°C and is often referred to as the "green house effect".

In contrast to the CO_2 effect, is the observation that the temperature near the earth's surface has declined in recent years. Some investigators attribute this decline to an increase in the earth's albedo (reflectivity) as a result of an increased atmospheric aerosol from pollution (i.e. decrease in sunlight penetrating, the air pollution layer).

It is estimated that a rise of 3.6°C in earth's temperature would bring major flooding due to melting of the polar icecaps. The sea level will go up by about 100 metres. Temperature drop of about 4°C, as a result of cooling brought about by increasing dust particles will create another iceage. Between these two limits some point out the two opposing forces could be made to maintain the heat balance.

The presence of the O_3 layer is very important to life on our planet, it helps shield us from potentially damaging UV radiation. NO reacts with O_3 to produce NO_2, in stratosphere. However, the new suppersonic transport planes emit nitrogen oxides directly into the stratosphere, right at the O_3 layer, so it is possible that the effect could be serious.

21.4 Meteorology, Pollution measurements, and control devices [1,14].

Air pollution cycle can be considered to have three stages consisting of (1) the release of air pollutant from the source (2) the transport and diffusion in the atmosphere and (3) the reception of the pollutants.

Stage (1) and (2) have already been discussed in earlier chapters. Meteorological factors play an important role for the transport and diffusion of the pollutants to the atmosphere. Specially micrometeorology tells us the atmospheric conditions confined to an area of a few square kilometers and upto an elevation of 500 to 1000 meters in the atmosphere which governs the transmission and diffusion of air pollutants. Dispersion (may be horizontal or vertical) is the process of spreading out emission over a large area and thus reducing the concentration of the specific pollutants. Following are the main meteorological factors:

- Wind velocity and direction
- Temperature
- Humidity
- Berometric pressure
- Qualitative description of weather conditions (cloudy, foggy, rainy, solar radiation etc)

Sensitive, precise instruments are available for the measurement of all above mentioned parameters. Without meteorological study, air pollution survey and its interpretation would remain incomplete.

Standard methods have been prescribed for the measurement of emissions from the stationary and mobile sources, as well as ambient air quality. Measurement of particulates and gases is carried out by high-volume sampler. There are series of processes in nature, for cleansing the air. Such as gravity, surface sink (gas adsorbed by the earth's surface) and precipitation (rainout and washout). However, these natural processes are not adequate to purify the environmental air which is polluted by manmade activities and hence several artificial means are necessary to prevent pollution of air.

Most effective and easy approach to control pollution of the source is to never generate the pollutant at all, or at least minimize the amount. This can sometimes be accomplished by changes in raw materials, operating conditions, type of equipment or even the drastic steps to totally changing the process. This type of action may avoid huze investment and installation of control systems. If the pollutant cannot be prevented from forming, equipment which destroys, masks, counteracts or traps the pollutants are required.

The control device for particulate as well as gaseous emissions, are available, in wide variety of designs depending upon various parameters, such as initial cost, operation-maintenance costs, space requirement, material of construction, operation and collection efficiency. The selection of proper device for a particular problem depends on the following factors.

(1) Particulate characteristics : Particle size, shape, density, corrosiveness, stickiness, toxicity, electrical conductivity etc.

(2) Carrier gas characteristics : Temperature, pressure, humidity, due points, density etc.

(3) Process factors : Gas flow rate, particute concentration, collection efficiency requirements, allowable pressure drop etc.

(4) Operational factors : Head room, floor space, corrosion service requirements etc.

Several basic principles, employed in pollution control systems are based on gravity settling, internal forces, filtration, electrostatic attraction, and particle enlarging etc.

Dry systems include Dry mechanical collectors, Gravity settling chambers, Recirculation baffle collectors, Cyclones, Multiple cyclones, Dynamic precipitators, several types of fabric collectors.

Wet systems include various types of scrubbers such as spray chambers, spray towers, packed spray towers, ventury scrubbers, and flooded disc scrubbers. These wet systems use a stream of water or dilute solutions and hence able to remove particulates as well as gaseous pollutants.

The electrostatic (or cottrell) precipitator is a very versatile and efficient type of collector which can operate at over 1000°F and can be used for dry particles , or fumes as well as mists. Electrostatic precipitator is highly efficient often approaching 99.9% efficiency but because of high installation costs it may be preferable to use other collection techniques in actual practice. A novel air pollution abatement technology is microbial filters where culture is immobilized on a fine filter element. The pollutants are adsorbed and degraded. The microbial filters are disposable.

Fume incineration is used to destroy odour, hydrocarbons, photochemically active compounds and toxic substances. Three types of fume incinerators are in actual use namely direct flame incineration, thermal incineration and catalytic incineration.

Tall stacks are sometimes used to diffuse the pollutants, but it cannot reduce the quantity of pollutants. Now a days tall stack is not considered as a solution to the pollution control because it solves problem at one place but creates at the other place.

22. NOISE POLLUTION

Noise is ear pollution. It is often called "unwanted sound". Loud noises can affect one's hearing. Noise of any kind may make one nervous or affect one's sleep. Noise can also affect the speech and work performance, ability to think. The noise has been linked to cases of heart disease, ulcers, mental illness and other sickness. People exposed to high noise levels are inclined to be more aggressive, distrustful and easily irritated.

Noise is perhaps the most overlooked and underestimated form of environmental pollution. This is partly true because noise has long been regarded as an inevitable accompaniment to modern life. The clamor of machinery and tools, construction, social and religious ecstasies of the population, roar of air craft and automobiles, all have been considered to be the sound of progress. We have accepted the noise and adjusted to it, without fully recognizing its adverse effects on human both physiologically as well as psychologically.

Perhaps the most serious concern of noise pollution is that it diminishes the quality of life.

Some 16 million Americans in fact suffer some hearing loss because of noise pollution [49]. Scientists estimated that noise levels in Chicago caused property values in the city to fall $ 460 million in 1971 (cleaning up the Nation's cities, Natural Resources Current focus, Washington).

EPA has initiated a "Quiet Communities Progarm" to demonstrate how cities and town can develop comprehensive approaches to reducing noise.

Sound pressures are expressed in decibles (dB)[1].

22.1 Noise Control

The control of noise is possible at three levels.

(1) Reducing the sound produced.

(2) Interrupting the path of the sound.

(3) Protecting the recipient.

When we consider noise control in industry, in the community or in our home we should keep in mind that all problems have these three possible solutions.

22.1 (a) Industrial Noise Control

Generally involves the replacement of noise producing machinery or equipment with quiet alternatives. (e.g. fan noise is reduced by increasing the number of blades, or decreasing speed)

The second method of decreasing industrial noise is to interrupt the path, e.g. by converting noisy motor with insulating material. Third method is to protect the recipient by providing earmuffs to the employees.

22.1 (b) Community Noise Control

The three major sources of community noise are aircraft, highway traffic and construction.

Construction noise must be controlled by local ordinance. Control involves the muffling of air compressors, hammers, etc.

Aircraft noise is controlled by setting limits on aircraft engine noise and will not allow aircraft exceeding these limits to use the airport. The second effort has been to divert flight paths away from populated area.

The third major source of community noise is from highways. The car-trucks create noise by a number of means;

(1) Exhaust noise

(2) tire noise

(3) engine intake noise

(4) gears and transmission noise

(5) aerodynamic (wind) noise

The total noise generated by vehicles can be correlated directly to the truck volume. A number of alternatives are available for reducing high-way noise. The source can be controlled by making quieter vehicles, highway could be routed away from populated area; lowering speed limits, designing for nonstop operation.

23. RADIATION HAZARDS

In the late eighteenth century French scientists determined that Uranium minerals routinely emitted invisible radiation capable of passing through solid objects. Radiation is a result of an atomic disintegration, as atoms of the minerals somehow exploded spontaneously through time. Three atomic decay chains are found in nature, the Uranium, actinium and thorium, resulting into alpha, beta and gamma emissions.

An atom that is radioactive has an unstable nucleus that moves to a more stable conditions either by emitting a nuclear particles (α & β emissions) or an amount of energy (gamma emissions).

Dangerous Radioactive Products

Product	Type of Radiation	Half - life
Krypton - 85	β & γ	10 years
Strontium - 90	β	20 years
Iodine - 131	β & γ	8 years
Cobalt - 60	β & γ	5 years
Carbon - 14	β	5770 years

Alpha Radiations

They are identical to the nuclei of helium atom. As these charged particles travel along at about 10,000 miles per second; they interact with other atoms. Each interaction transfer a portion of the energy to the electrons of these other atoms, and results in the production of an ion pair i.e. a negative electron with an associated possitive ion.

Beta Radiations

Electrons are also emitted from the nucleus of a radioactive atom at a velocity approaching the speed of light. Exposed organs such as eyes are sensitive to beta rays.

Gamma Radiations

This is identified as invisible, electromagnetic rays emitted from the nucleus of radioactive atoms.

23.1 Measurement of Radiation

Devices have been developed to measure the radiation dose, dose rate, or the quantity of active material that is present. The particle counter, the ionization chamber and photographic film are three methods widely used in the field.

23.2 Sources of Radioactive Waste

The radio active wastes may be gaseous, liquid or solid. It may be soluble or insoluble in water and may emit all types of radiations.

The major source of radiation to mankind is from nuclear power plants and atomic explosions. The number of nuclear power plants are increasing. The radioactive waste of these power plants has to be stored and dumped so that it cannot find its way out to environment. The operation of power plants exposes workers to radiation. The hazards of power plants are horryfying. The last example is Chernobyl accident in April 1986 (U.S.S.R.).

The plight of Nagashaki and Hiroshima shows the danger of radiation to which mankind is exposed if a neclear war breaks as there are thousands of nuclear weapons readyto go off. The accidental hazards have come up in lime light lately due to the major break downs of nuclear power plants in different countries.

Low level residue found in many mineral processing technologies and medical, industrial, scientific applications.

Long lived waste are particularly bothersome because they represent continued risks to public health and the environment far into the future. Transuranic (TRU-produced from U^{238}) contaminated wastes isotopes with atomic numbers greater than 92 like Np, Pu and Am are especially critical because of their long half-lives.

The increasingly wide spread use of radio isotopes in research, medicine and industry has created a lengthy list of potential source of other radioactive wastes. Wastes resulted from phosphate and copper mining and coal combustion, tend to contain low level of the naturally occuring radioisotopes of Uranium, thorium and radium.

23.3 Health Effects

When alpha, beta and gamma radiation pass through living cells or any other matter, they transfer their energy through a series of collisions with atoms or nuclei of receiving material.

Many molecules are damaged in the process as chemical bonds are broken and electrons are lost (ionization). This may cause a disordering in the chemical or biological structure of the tissue and subsequent dysfunction of the cells.

Alpha particles have a high linear energy transfer (LET) and potentially cause significant damage. However, because of their LET is high they lose their energy quickly, they cannot penetrate and are characteristically stopped by 1 in. of air or the outer layer of human skin. Beta and gamma radiation on the other hand lose energy slowly and penetrate deeper into living organisms.

Biological effects can be grouped as somatic and genetic. High doses could come from a nuclear bomb or an accident at nuclear power plant. For man, it is estimated that a gamma radiation dose of 400-500 rads to a major portion of body in short time will result in death within few months. Lower doses but above 100 rads will lead to vomiting, diarrhoea and nausea in humans; hair loss is observed within few weeks, genetic disturbances and cancer.

In short health effects of a given dose of radiation depends on a large number of factors.

(1) magnitude of the absorbed dose
(2) type of radiation
(3) penetrating power of the radiation
(4) sensitivity of receiving cells and organs
(5) rate at which the dose is delivered
(6) proportion of the cell/organ/human body exposed.

23.4 Radioactive waste Management

The objective of radioactive waste management is to prevent radiation from being introduced into the biosphere over the life line of the radioactive waste.

Many options have been suggested for the long term storage of radioactive waste.

(1) Land Disposal
  - liquid injection into geological formations
  - burial in deep caverans.
  - burial in deep holes

(2) Ocean Disposal
  - direct ocean dumping
  - disposal in trenches
  - sea bed disposal

(3) Polar ice Disposal

(4) Spaceship technology

OBJECTIVES

People at large are concerned with increasing air and water pollution. We are progressing with a faster rate in the growth of chemical industries which contributes substantially towards pollution if proper measures are not taken. Our economic policy is the mixed one - Private and Public Sector. Small scale industries are also encouraged more. Due to these factors our pollution problems are unique. Highly expensive and sofisticated methods for the pollution control developed in other industriallised countries may not be a total fit.

It was proposed to address the problem of organic pollutants in waste water as they are the most dreaded one.

The present work was devided mainly in two parts.

The first part was to study the problem of waste liquor of caprolactam industry from the zero pollution point of view and to evolve the strategy for the treatment so that the organic materials can be removed, recovered and utilized for beneficial purposes.

The second part is subdivided in to different sections. The common factor is the use of fatty amines as flocculants for waste water treatment.

Dyes and Dyes intermediate waste waters are highly coloured. Gujarat state faces acute problem of drinking water and colour effluents spoil ground water resources.

This problem was to be tackled by using above new flocculating agents and compare the efficiency of these materials with other methods in the removal of colour and organic matters.

It was proposed to test universality of fatty amines as flocculating agent for other couple of waste waters like chlor-alkali industries for the removal of Hg and detergent industry for the removal and recovery of surfactants.