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THE PROCESS CONTROLLER's GUIDE TO

POLLUTION CONTROL

This is number 1 in the Process Controller Guide series of documents

Number 1 Pollution Control

These notes were prepared for delivery to persons studying for the Diploma in Water Care Technology offered by the then Cape Technicon, in the early 1980's.

Since the time of writing, new Acts of Parliament, Guidelines and Regulations have been implemented. These have NOT been incorporated into this document. Person interested in the latest Acts, Guidelines and Regulations need to look elsewhere for these.

It is intended that this document be a useful reference and training manual guide to all persons involved in the Water and Wastewater Industry.

When originally prepared, the series of documents consisted of:

1. Pollution Control
2. Watercare Technology 1 (both Water and Wastewater)
3. Watercare Technology 2 (both Water and Wastewater).

The series has been arranged so that Pollution Control remains as volume 1, while the Water documents have been combined into one document, as Volume 2. Similarly, the Wastewater documents have been combined into one document as Volume 3.

Where photographs and images are taken from published sources, credit is not explicitly made here. However, the original producers of such material are thanked for their information that will contribute to this document being of use to all in the water and wastewater industry.

These documents are dedicated to the thousands of men and women (both present and past) who are involved in the life critical profession of Water and Wastewater Treatment.

POLLUTION CONTROL

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PART 1

INTRODUCTION TO POLLUTION CONTROL.

1. <u>INTRODUCTION</u>

The status of man's health represents the result of complex interactions between his internal biological system and the total external environmental system. Although this volume is concerned primarily with the external environmental system, it is important to bear in mind the relationship between man and his environment.

The environment is modified by man's work and presence. These changes may tax his adaptive capabilites. Even if he is able to adapt, we do not know what the costs to his biological system maybe. As man engages in the activities associated with living, wastes are produced. These are products which have no apparent useful purpose, or are of such marginal utility that recovery is uneconomical. Such products include human, residential, agricultural, commercial and industrial wastes of all kinds. The continuous removal and safe disposal of these wastes is essential to the continued existence of any community; otherwise the community may be overwhelmed and its citizens endangered. These wastes may be solid, liquid or gaseous.

Man is continuously subjected to a variety of environmental hazards. Some of these are natural, but to an increasing extent environmental hazards result from man's activities and numbers. Sometimes man-made hazards are direct in their impact on other men, but they may be indirect in their influence, acting through other biological systems or overburdening the capacity of natural system for removal, dispersion or assimilation.

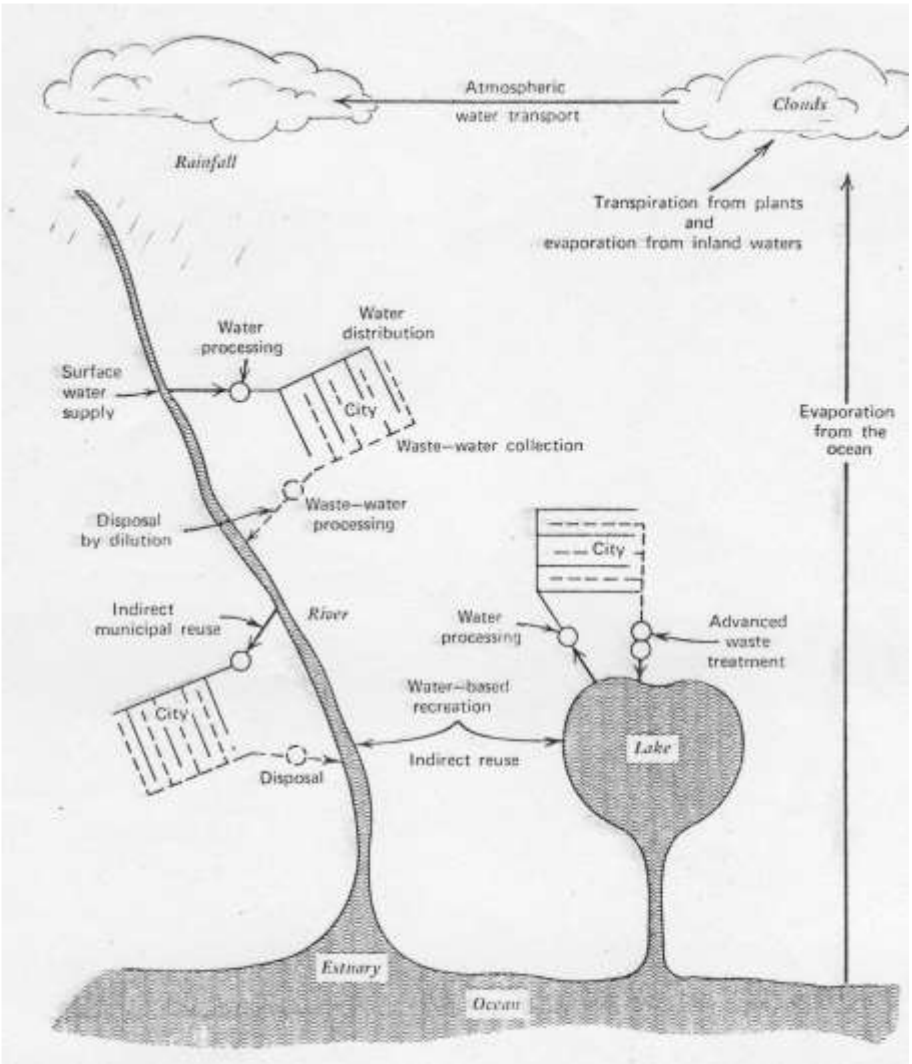

Figure 1 – THE WATER CYCLE

1.1 BIOLOGICAL ASPECTS of POLLUTION CONTROL.

Biological hazards are concerned primarily with the entry of disease - causing agents into the man's body. These agents may be transmitted via the water and food one consumes, via the air one breathes or via direct contact with an infected person or article.

Water treatment will be seen to be needed to prevent the transmission of the disease-causing agents by the water that one drinks. Wastewater treatment will be seen to be necessary to reduce the degree of pollution of the water into which the wastewater is discharged.

1.2 CHEMICAL ASPECTS of POLLUTION CONTROL

Man's reaction to a chemical depends on :

1.2.1 its toxicity;

1.2.2 the individuals susceptibility;

1.2.3 the duration of the exposure;

1.2.4 the concentration of the chemical;

1.2.5 the form of the chemical i.e. solid, liquid or gaseous;

1.2.6 the synergistic effects of other chemicals;

1.2.7 the relative amount of the chemical with respect to one’s body mass.

Chemicals may concentrate in certain tissues of plants, animals, man and fish. As higher forms of life consume lower forms, and the big eat the little, successive concentrations may result in a tenfold increase over the initial concentration. Thus pesticides washing into a stream may not result in a high concentration at that point, but through biological concentration, some food sources may become hazardous to man or to other life.

Although some chemicals may be hazardous, the proper use of some of these same chemicals can enhance the quality of life.

Nitrogen in fertilizer is necessary to the production of crops, but an overbundance, while increasing the crop yield, will also result in a build up of nitrates in the ground or surface water.

1.3 PHYSICAL ASPECTS of POLLUTION CONTROL.

Physical hazards in the environment may cause death, disease, or disability. These may include a wide range of factors such as dusts, humidity, temperature, vibration, noise and radiation.

These dusts are which are not absorbed into the body, but which cause a fibrosis when deposited in the lungs, examples of these are silica and asbestos. Humidity and temperature can be modified indoors by air conditioners. Mechanical vibration and noise can cause hearing loss and produce other psychological and physical disturbances. People living in cities may suffer some hearing loss from community noise. Radiation includes x-rays, ultra-violet, intra-red and microwaves. Prolonged exposure may cause skin burns, a rise in body temperature and even death.

1.4 THE BASICS of POLLUTION CONTROL.

Pollution control maybe practiced by one or more of the following methods :

1.4.1 The complete destruction of the pollutant. For biological hazards this would mean killing the organisms, this may be done by heat, radiation or chemical methods.

1.4.2 The conversion of the harmful substance into a less harmful or harmless substance, this usually involves a chemical or biochemical process.

1.4.3 The removal of the pollutant and disposing of it in a place where it will no longer be harmful.

1.4.4 The inhibition of the pollutant, this will usually mean that the pollutant has been dispersed or diluted to such a point that it is no longer harmful.

In thisseries, the three main states of pollutants viz liquid, gas and solid will be treated separately. It is important to remember that there will always be an interaction between the three states.

PART 2

WATER SOURCES

2. WATER SOURCES

There are 3 main sources of fresh water:

Rainwater, Surface water and Groundwater

In this context, rainwater is taken as water that is collected off roofs or specially designed paved areas, as in Gibralta. As these waters are usually not treated or distributed for communal use, they are not considered further.

Surface water usually forms the major water supply of a town or city. Surface water may be drawn from the following sources :

1. from streams, rivers and lakes by continuous withdrawal at the required rate;

2. from streams and rivers by intermittent seasonal withdrawal and the storage of such water in a suitable reservoir from which water may be drawn as required;

3. from streams and rivers whose dry weather flows are below the required minimum but whose annual flows are sufficient, by the storage of water by constructing a dam across the river valley.

Groundwater supplies are generally smaller than surface water supplies in terms of quantity delivered, but are many times more numerous. Groundwater may be drawn from the following sources :

1. from springs;

2. from wells;

3. from boreholes.

Springs occur when the groundwater table reaches the surface due to the ground surface dropping sharply to below the groundwater table or when a geological obstruction impounds the water behind it and forces the water to the surface.

A well is a hole dug into the ground in order to provide access to the groundwater, they are usually of a relatively large diameter (1 metre or more).

A borehole is usually drilled into the ground and usually contains a sieve to prevent sand etc from entering the shaft. Borehole diameters are usually in the range of 100 to 300 mm. Boreholes differ from wells in that there is no storage volume within the excavated portion.

2.1 Quality Standards for Water Sources.

Although it is theoretically possible to treat almost any water to the potable standard, the cost of treating certain waters can become excessive. Without resorting to very sophisticated types of treatment, a guide can be given to the quality of the raw water that can usually be treated economically to a potable standard.

2.1.1 Physical quality of a water source.

The limiting value for colour is generally set at 300 Hazen Units, on the basis that a value of less than 300 Hazen Units indicates an acceptable quality for treatment and anything over 300 Hazen Units indicates that special treatment may be needed to provide water meeting the standards. No general figures can be given for turbidity, each case must be decided on its merits.

2.1.2 Chemical quality of a water source.

These may be subdivided 4 categories as indicated below in Tables 1 to 4.

(PLEASE NOTE COVERING REMARK ABOUT NEW GUIDELINES AND STANDARDS INTRODUCED SINCE THE 1981 WRITING OF THIS DOCUMENT)

TABLE 1 SUBSTANCES AFFECTING POTABILITY.

PARAMETER	**Maximum Allowable Concentration**
Total Dissolved Solids	1500 mg/L
Iron as Fe	50 mg/L
Manganese as Mn	5 mg/L
Copper as Cu	1.5 mg/L
Zinc as Zn	15 mg/L
Mg + Na + SO_4	1 000 mg/L
Alkyl Benzene Sulponates	1.0 mg/L

TABLE 2 SUBSTANCES AFFECTING HEALTH.

PARAMETER	**Maximum Allowable Concentration**
Fluoride as F	1.5 mg/L
Nitrate as N	10 mg/L

TABLE 3 TOXIC SUBSTANCES.

PARAMETER	**Maximum Allowable Concentration**
Total Phenols as C_6H_6OH	1500 mg/L
Arsenic as As	0.05 mg/L
Cadmium as Cd	0.01 mg/L
Chromium (hexavalent) as Cr	0.05 mg/L
Cyanide as CN	0.2 mg/L
Lead as Pb	0.05 mg/L
Selenium as Se	0.01 mg/L
Barium as Ba	1.0 mg/L
Radioactivity (Gross Beta Activity)	1 000µµC/L

TABLE 4 CHEMICAL INDICATORS OF POLLUTION.

PARAMETER	**Maximum Allowable Concentration**
Chemical Oxygen Demand	10 mg/L
Biochemical Oxygen Demand	6 mg/L
Total Nitrogen, excluding NO_3 , as N	1.0 mg/L
Ammonia Nitrogen as N	0.5 mg/L
Carbon Chloroform Extract	0.5 mg/L
Grease	1.0 mg/L

2.1.3 Bacteriological quality of a water source.

TABLE 5: BACTERIAL INDICATORS OF POLLUTION

CLASSFICATION	Coliform Bacteria MPN/100mL
Bacterial quanlity such that only disinfection required	0 - 50
Bacterial quality requiring conventional methods of treatment (coagulation, filtration, disinfection)	50 – 5 000
Heavy pollution requiring extensive types of treatment	5 000 – 50 000
Very heavy pollution, unacceptable unless special treatment designed for such water ise used - use as last resort	➢ 50 000

Note: When more than 40 % of the number of coliform bacteria are found to be of the faecal coliform group, the water source should be demoted into the next worst grade.

2.1.4 Radioactivity

The World Health Organisation has tentatively established the following as a guide to maximum acceptable limits in treated drinking water.

TABLE 6: RADIO ACTIVE SUBSTANCES LIMITS

PARAMETER	CONCENTRATION µµC/L
Strontium 90	30
Radium 226	10
Gross Beta concentration in the absence of Strontium 90 and α emitters	1 000

The conventional water treatment works will remove 70 - 90 % of radio active materials from surface waters.

2.2 Types and Sources of Water Pollution.

All domestic, industrial and agricultural wastes affect in some way the normal life of a river or lake. When the influence is sufficient to render the water unacceptable for its best usage, it is said to be polluted. The principle sources of water pollution are shown in figure 1.

2.2.1 Industrial Wastes.

Industrial wastes vary in composition with industrial operations. Some are relatively clean rinse waters, others are heavily contaminated with organic or mineral matter or with corrosive, poisonous, flammable or explosive substances. Some are so objectionable that they should not be admitted to the public sewer system. Cooling water is classified as in industrial waste even though the only change it might have undergone is an increase in temperature. Polluted waters may be discharged as a result of mining operations. These can be both from the dewatering of mines or as a result of increased soil erosion due to the removal of the protective vegetation layer.

Some industrial wastes are not amenable to biological treatment and need to be treated using a physico -chemical process before being discharged into the sewer. Certain saline wastes cannot be pretreated economically before being discharged into the sewer, they may have to be evaporated to dryness or discharged into special sacrificial disposal areas.

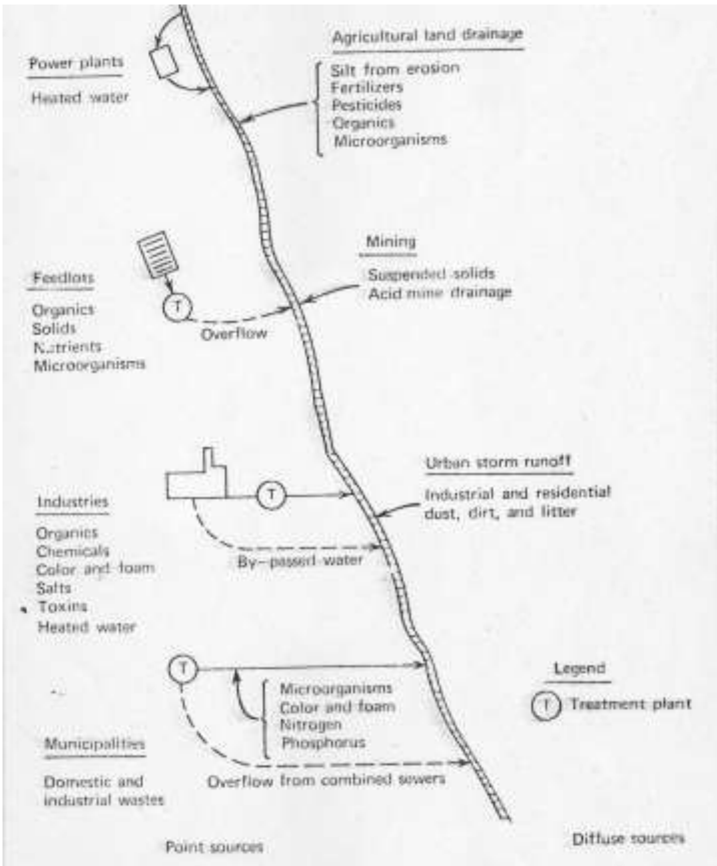

Figure 2 - SOURCES OF POLLUTION

2.2.2 Domestic Wastes.

This refers to the wastewater from the kitchen, bathroom, toilet and laundry from houses and flats and to the wastes from toilets at business and industrial premises. To the mineral and organic matter already present in the water supplied to the community, is added a load of human wastes, paper, soap, dirt, food wastes, sometimes including garbage from garbage grinders. Some of the waste matters remain in suspension, some go into solution and others are, or become, so finely divided that they acquire the properties of colloidal particles.

Although the organic load attributable to each person does not vary widely, the quantity of wastewater discharged per person can vary between 1 litre per day when bucket toilets are used, up to 400 litres per day in high income residential areas when supplies are unmetered. Much of the increase in water consumption will be attributable to the use of automatic washing machines and automatic dishwashers.

2.2.3 Agricultural Wastes.

These will include silt from erosion of ploughed areas, traces of fertilisers and pesticides, contained in the run - off from farmed areas and the run - off from feedlots. Soluble salts and organic substances can pass down into the groundwater. Wastewaters from the processing of dairy and other agricultural products may be considered as agricultural or industrial wastes depending on the situation.

2.2.4 Water Pollution resulting from Air Pollution.

Substances present in the air can fall by gravity into rivers and lakes and can cause a deterioration in the quality of the water. Rainfall will result in the "washing out" of water soluble gases and of fine particulate matter. Certain industrial processes liberate gaseous, liquid or particulate matter into the atmosphere. Wind may carry these pollutants far and wide and can cause a water pollution problem. The use of gas scrubbers or wet cyclones may under certain circumstances turn an air pollution problem into a water pollution problem.

2.3 <u>The Effects of Pollution on the Water Enviroment</u>.

2.3.1 The Oxygen Sag.

When the rate of deoxygenation of a quantity of water exceeds the rate of reaeration, the dissolved oxygen content of the water will decrease. This deoxygenation may be as the result of the addition of reducing agents to the water that have an immediate oxygen demand or as a result of the biological decomposition of waste organic matter.

This is covered in more detail under reasons for wastewater treatment in Part D.

2.4 <u>The classifiation of lakes and other water bodies according to their Eutrophic state</u>.

Eutrophication is the process whereby bodies of water, particularly lakes, become enriched with nutrients that alters the numbers and types of organisms present in the water and results in a deterioration in the quality of the water. Lakes may be categorized in terms of their biological productivity i.e. in terms of the quantity of organic matter formed.

2.4.1 The Oligotrophic Lake.

These lakes have low concentration of nutrients. They are often deep and have a large hypolimnion (lower layer) that remains cold. There is dissolved oxygen at all depths through the year. The water would be transparent due to the low algal population. The plankton population would be low.

2.4.2 The Mesotrophic Lake.

These lakes have an increased concentration of nutrients. The presence of a higher concentration of algae would result in the water taking on a greenish tinge. There would be moderate numbers of game fish. There would be some organic matter on the bottom of the lake. In a stratified lake there would be some reduction of the dissolved oxygen content of the water in the hypolimnion.

2.4.3 The Eutrophic Lake.

These lakes have an even higher concentration of nutrients. The water becomes turbid due to the high algal population. In an extreme case the water takes on the appearance of "pea - soup". A deep stratified eutrophic lake will have little or no dissolved oxygen in the hypolimnion. Algal blooms are common, these are seasonal sudden increases in the concentration of algae. The sequence of events is as follows:

1 algae take up and store nitrogen and phosphorus,

2. the algae die and settle to the lake bottom,

3. the dead algae decompose and liberate the nitrogen and phosphorus,

4. the spring overturn carries the nitrogen and phosphorus up to the surface where they promote the growth of new crops of algae and this causes the algal bloom.

2.4.4 The Dystrophic Lake.

These are usually shallow with abudant organic matter in suspension and on the bottom. In stratified dystrophic lakes, dissolved oxygen is generally absent from the hypolimnion. The concentration of calcium, phosphorus and nitrogen are small, but the concentration of humic materials is large. Algal blooms are rare.

In the course of time natural pollution changes oligotrophic lakes sequentially into mesotrophic, eutrophic and finally dystrophic lakes. Man usually hastens this deterioration.

Phosphorus and nitrogen are usually the nutrients that limit the growth of algae, as most water has enough free or combined carbon dioxide to act as a carbon source. The amounts of inorganic nitrogen and phosphorus needed to produce abudant algae growth are relatively small. The generally accepted upper concentration limits for lakes to remain free of algal nuisances are 0.3 mg/l of inorganic nitrogen (i.e. ammonia, nitrite or nitrate) and 0.02 mg/l of inorganic phosphorus (i.e. ortho - phosphate). Since certain algae can obtain their nitrogen directly from the atmosphere, inorganic phosphorus is usually taken as being the nutrient that limits the growth of algae, but this is not always so.

2.5 The Effect on Organisms.

The effect of pollution on organisms is most easily identified in taking the case of a river into which a stream of wastewater is discharged. By examining the variety and relative numbers of organisms at various points above, at and below the discharge point one can see how the course of self - purification takes place.

A body of water polluted from a substantial point source of organic matter exhibits four fairly well defined zones. These are : the zone of degradation immediately below the point of introduction of the pollutant, the zone of active decomposition, the zone of recovery and the zone of clear water. The relative sizes of the zones depends on many factors such as, the relative quantity of pollutant discharged, the nature of the pollutant, the temperature, the degree of mixing in the water etc.

The microorganisms which exist in any body of water are direct indicators of the condition of that water. The types and numbers of microorganisms are all a direct result of the nutrient concentration. It is impossible to have a high nutrient concentration without a high biological population in nature, unless there is a deficiency of a key element or toxic materials are present.

For the sake of illustration, it is assumed that the water in the river is of high quality above the discharge point.

2.5.1 The upstream zone of clear water.

In this zone, assumed to have a low organic content, the total number of micro-organisms is low since quantity of food is limited. However the number of different species is high. The algae tend to grow better than the bacteria since they can utilize the inorganic elements in the water for their nutrients. The algae which die and decompose form most of the food for the bacteria, while the living algae are the major food source for the protozoa, rotifers and crustaceans.

The dissolved oxygen content of the water will be high, probably nearly saturated and thus aerobic conditions will be present. There may be an anaerobic layer of sediment at the bottom in which anaerobic decomposition may be taking place, but providing the rate of decomposition is low and sludge is not buoyed up by gas generation, this decompostion may proceed without becoming aesthetically objectionable. Since the dissolved oxygen content is high, game fish could probably be present.

2.5.2 The zone of degradation.

At the point at which the waste is discharged into the river, the organic content of the water is suddenly increased. Previously the concentration of bacteria had been limited by the amount of food available, suddenly this limit is removed and the bacteria are able to multiply rapidly. This increased growth results in a proportional decrease in the dissolved oxygen content of the water since the bacteria would have been metabolising the waste aerobically. As the dissolved oxygen concentration decreases, the higher forms of life are affected first.

The game fish are the first to feel the effects of the oxygen depletion, followed by the coarse fish, the crustaceans, rotifers and the higher protozoa. If the organic load is too high, the rate of oxygen utilization may be so high that the dissolved oxygen content is reduced to zero. If this occurs, then anaerobic conditions will exist and a different type of decompostion will occur. Instead of carbon dioxide being the decompostion product of carbonaceous materials, a mixture of carbon dioxide and methane will be formed and instead of sulphate being the decompostion product of sulphur containing materials, sulphides will be formed.

In these anaerobic conditions, bacteria will predominate since most other forms of life are dependent on dissolved oxygen being present. The number of bacteria present can exceed 10 million per millilitre even though the number of species will be small. It is seen that a polluted stream is characterized by a large number of organisms but few species, whereas a clear stream is characterized by a small number of organisms but many species. As the organic waste that was discharged into the river is metabolised by the bacteria, the biochemical oxygen demand of the water is being satisfied and is so reduced. The metabolism of the nitrogenous waste will yield ammonia, and hence the ammonia content will increase through this zone.

If the dissolved oxygen content does not read zero, free swimming ciliates are able to survive and feed on the bacteria.

2.5.3 The zone of active decompostion.

Here the rate of decompostion is higher than in the previous zone due to the higher numbers of micro-organisms present. The dissolved oxygen content in the early stage of this zone can be lower than that in the zone of degradation. However as the stream passes through this zone the minimum dissolved oxygen concentration will be passed and as the end of the zone is reached the rate of reaeration will exceed the rate of deoxygenation and the dissolved oxygen content will start to rise again. The biochemical oxygen demand of the water will continue to increase in the early stages of the zone until the dissolved oxygen content rises high enough to enable the nitrifying bacteria to oxidise the ammonia to nitrate.

The bacterial population will decrease through this zone as the ratio of food to micro - organisms decreases. As the bacterial population starts to decrease, the turbidity of the water will reduce, this will allow better penetration of the water by sunlight. This together with an increase in the dissolved oxygen content will allow the algae population to increase. During the day, the quantity of oxygen released by the alcae as a result of photosynthesis will be in excess of their respiratory needs and this will help to increase the rate of reaeration of the water towards the end of the zone.

As the bacterial population decreases, the population of free swimming ciliates will also decrease, as the former are food for the latter.

2.5.4 The zone of recovery.

Here the rate of reaeration exceeds the rate of deoxygenation by a significant amount and the dissolved oxygen content increases significantly. The bacteria population reduces still further. With a decreasing bacterial population, the free swimming ciliates demand so much energy that they give way to stalked ciliates. Later in the zone even the stalked ciliates cannot obtain enough energy and rotifers and crusteans take their place. The algae content continues to rise but not so rapidly as in the previous zone. The rate of nitrification has increased to such an extent that the ammonia content is reduced to near zero. The biochemical oxygen demand is further reduced.

Later in the zone when the ammonia content is low enough and the dissolved oxygen is high enough coarse fish will appear. Some aquatic weeds will develop and will use the nitrate produced from the oxidation of ammonia as a nutrient, and this will reduce the nitrate concentration.

2.5.5 The zone of clear water.

Provided there are no more discharges of waste materials into the river, the water will soon reach a quality similar to that found above the discharge point. The dissolved solids content of the water may be higher or lower than that found in the upper clear water zone. The dissolved oxygen content will be approaching the saturation value, and the biochemical oxygen demand of the waste will have been almost satisfied. Once the dissolved oxygen content has exceeded the minimum value for game fishes, these should reappear.

2.6 The Prevention and Control of Pollution.

A source of pollution may be described as a point source or as a non-point (or diffuse) source. In a point source of pollution, the source can be traced to a pipe or a number of pipes from which a gas, liquid or solid is discharged either continuously or intermittently. A non -point source of pollution can be defined as any source of water pollution not coming directly from a pipe.

2.6.1 Elimination of Point Sources.

Examples of point sources are the effluent from a wastewater treatment works, overflow from combined sewer systems, cooling water discharges from power stations and industrial effluents being discharged. Point sources of pollution can be sampled and the flow rate determined so that the mass of pollutant discharged per unit time can be calculated. Standards exist to which effluents discharged into rivers etc must conform. Many Local Authorities have regulations prescribing maximum limits for certain pollutants present in industrial effluents discharged into sewer systems.

Point sources can usually be traced by analysing the water where the pollutant or its effect are noticed and then systematically working back upstream. Once the source of the pollution is located, suitable action can be taken. This could include legal action in terms of the Water Act, the Municipal Ordinance or the Divisional Council Ordinance.

If more than one point source of the same pollutant is located, then by determining the relative masses of pollutant discharged per unit time, onecan decide upon which source to concentrate ones effort.

2.6.2 Reduction of Non - point Sources.

Usually the elimination or reduction of point sources of pollution is a relatively easy problem, but this is not so with non - point sources. Due to the lack of a distinct effluent which can be routinely sampled or monitored, non - point sources lack suitability for regulation by the approach of limiting the concentration of certain pollutants. Not even the more realistic mass loading effluent control method can be used.

Non - point sources can conveniently be divided into 2 categories : rural and urban.

2.6.2.1 <u>The reduction of rural non - point sources.</u>

Potential sources of pollution from the rural enviroment include wildlife waste, leached plant residues, fertilisers, pesticides, organic matter eroded with soil, inorganic sediments from the weathering of rocks and soil, excess drainage from rural septic tank systems, and from feed lots. In general, minimizing disturbances to the land surface will minimize erosion and pollutant production. Erosion - control practices will reduce sediment production. The prevention of over - grazing will allow the grass cover to regenerate and prevent erosion.

Since surface water run off is the carrying medium for excess fertilizers, pesticides etc., traditional soil conservation practices that control run off such as contour ploughing, terracing and crop rotation are the most effective means of controlling pollutant discharges. Proper timing and correct amounts are important in reducing chemical losses. Manures and compost should be worked into the ground immediately to prevent run off losses.

Leachates from landfill sites can be an important and serious non - point source. This will be covered later in the section on the control of landfills.

2.6.2.2 <u>The reduction of urban non - point sources.</u>

The urban run off generated during a period of rain can create three types of discharges : combined sewer overflows, storm water discharges in separate systems and overflows from sewers in the separate system due to infiltration of stormwater into the sewer.

Roads and streets are major sources of contaminant material in urban run off. The contaminant materials include oil and grease washed off the underside of vehicles, grit off roads, particles of rubber from tyres, particles of asbestos from brake linings, lead and hydrocarbons from fuel and street litter. The best form of control is regular sweeping of the streets.

Another very important urban non-point source are the pollutants washed out of the air by rain. These pollutants can include lead and hyrdocarbons from fuel, dust, dirt, and combustion products such as sulphur and nitrogen oxides. Sometimes these pollutants can be traced back to specific identfiable and controllable sources of air pollution such as a chimney.

2.7 <u>Natural Pollution.</u>

Pollution is occurring all the time, nature is slowly eutrophying lakes and is slowly eroding away mountains. However life is able to keep in step with the change. Man is, however, in many cases accelerating the rate of pollution and by so doing is upsetting the delicate balance of nature.

Nature is capable of enormous powers of regeneration and self - purification but even these can be over taxed, when toxins are present or when the load becomes excessive.

Other forms of natural pollution are salt spray from the sea being carried inland and heavy rainfall causing floods. Wwith man paving over areas for roads, etc., the rate of run off has been increased and this increases the chance of flooding. Run off from natural grassland will contain nutrients that will pollute rivers but the quantities would be small, but with man using fertilisers the quantity of nutrient contained in the run off will be increased.

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PART 3

THE NEED FOR WATER TREATMENT.

This part deals with the need to treat water. An indication is given as to when more sophisticated treatment is required. The various treatment processes will be dealt in Volume 2 – Water Treatment.

The quality of water is changed during its cycle from abstraction from the source of supply to the ultimate disposal after use into the receiving water. A qualitative illustration is shown in figure 3.

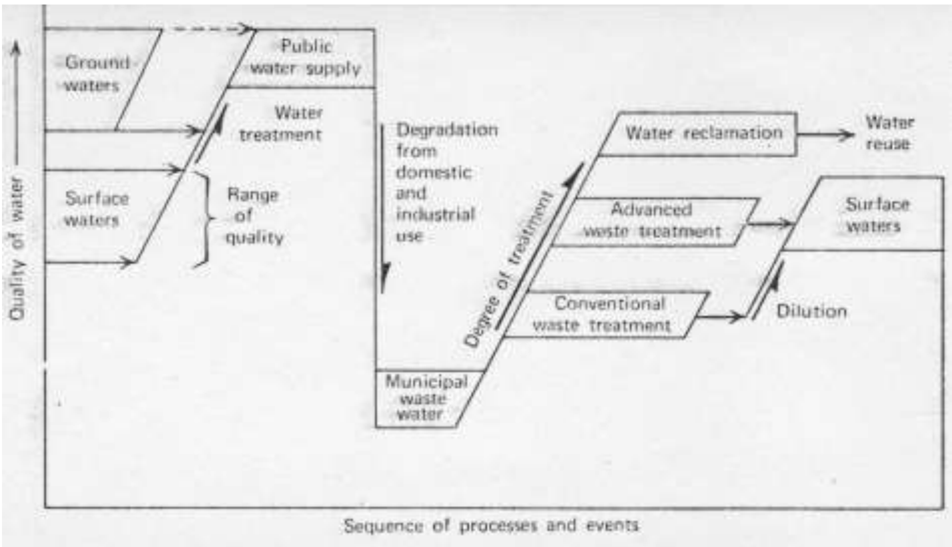

Figure 3 - QUALITY CHANGES THROUGH WATER USAGE

3. WATER TREATMENT.

There are 3 main reasons for the treatment of water prior to it being used : They are: aesthetic, chemical, and microbioloqical.

3.1 Aesthetic Reasons.

Consumers of water are suspicious of water has a taste, odour, colour or turbidity and will sometimes turn to a supply that looks and possibly tastes good but which may be contaminated.

Taste can originate from decomposing organic materials, volatile substances liberated from algae, from soluble iron compounds The absence of dissolved air in water gives the water a "flat" taste, which is replaced by a "fresh" taste on aeration of the water. The presence of certain industrial wastes in the water can give rise to tastes.

In order to ensure that consumers use and accept the intended supply, it is important to produce a wholesome, clear, odourless and tasteless water at all times.

Odours can originate from similar sources from which tastes are derived. Colour can originate from the decomposition of organic materials or from the presence of certain industrial wastes such as turbidity, or cloudiness of the water, immediately leads a consumer to think that the water is contaminated. The presence of turbidity in water can provide a physical shield for small micro organisms against the effects of chlorination. For these reasons it is important that the supplied water has as low a turbidity as possible. Turbidity comes from silt, clay and other minerals suspended in the water.

The presence of bacteria and othe micro organisms can also cause turbidity. Turbidity is caused by the presence of suspended solids in the water. The latter is a measure of the total mass of solids suspended in the water, whereas turbidity is an optical effect which is effected by the types, colour, size etc. of the suspended material. One usually talks about suspended solids for the higher values and about turbidity for the low values, but there is no linear relationship between the two.

3.2 Chemical Reasons.

From the time that the rain or snow lands on the earth, the water starts to dissolve minerals and organic materials. Depending on circumstances, the quantity of these materials present in the water may the exceed the suggested limits for the maximum acceptable concentration or even the limit for the maximum allowable concentration.

Chemical reasons for treatment of water are usually concerned with reducing the concentration of the material or materials considered, occasionally the treatment is concerned with increasing the concentration of one or more materials in the water eg. the addition of fluorides or of hardness producing substances to very soft water.

Among the groups of material reduced in concentration are :

3.2.1 Iron and Manganese These metals are objectionable in water because they stain clothing and bathroom fixtures and can affect the taste of the water.

3.2.2 Calcium and Magnesium. The salts of these metals cause hardness in water. Hard water is satisfactory for drinking purposes, but leads to extra soap consumption and can make rinsing difficult. Scale will build up inside hot water cylinders and kettles.

3.2.3 Fluorides. When water supplies contain excess fluorides, the teeth of most consumers over a period of several years become mottled with a permanent gray to black discoloration of the enamel. Children who have been drinking water containing 5 mg/l of fluoride as F develop fluorosis to the extent that the enamel becomes severly pitted and this can result in loss of teeth.

3.2.4 Dissolved Solids. The higher the dissolved solids content of a water supply, the less useful is that supply. Certain industrial processes cannot tolerate a high dissolved solids content as it interferes with the processes. A high dissolved solids content in an irrigation water can result in reduced crops and if excess, to crop failure. The sulphates of magnesium and sodium if present in excess act as a laxative. Chlorides in concentration of above 600 mg/L tend to give the water a salty taste. Nitrates, when present in concentration above 45 mg/L as NO_3 (about 10 mg/L as N) can cause methaemoglobinaemia in babies.

3.2.5 Carbon Dioxide. Water from deep boreholes can contain large amounts of dissolved carbon dioxide (20 mg/L or more), this makes the water corrosive and can result in iron being dissolved out of iron pipes, zinc being dissolved out of brass fixtures and lead being dissolved out of lead pipes.

3.2.6 Organic Materials. Water passing through vegetation can dissolve organic material such as humic acid that will give the water colour and taste, and may also precipitate in hot water cyclinders and kettles. Although these humic acids do no harm, they do detract from the appearance of the water. Certain other organic materials such as insecticide residues are harmful in drinking water even in trace amounts. This may be due to their high toxicity or due to their cumulative effect in the body.

In certain cases chemicals may have their concentrations purposefully increased during treatment:

3.2.7 Hardness. In certain cases where the raw water is very soft, it may be necessary to add hardness to the water to reduce its corrosiveness. This may or may not coincide with a high carbon dioxide content.

3.2.8 Fluorides. Certain authorities have advocated the addition of fluoride to water containing less than about 0.5 mg/l as F as a measure to reduce tooth decay.

3.3 Microbiological Reasons.

Many diseases of man can be carried by water, and thus ingestion of untreated or poorly treated water can result in the person concerned being infected. It is not necessary for the water to be drunk for a person to become infected, one can become infected in any of the following ways: cooking food in contaminated water, eaten food irrigated with contaminated water, swimming or walking in polluted water and drinking milk from cows grazing on grass irrigated with contaminated water.

PART 4

THE NEED FOR WASTEWATER TREATMENT

4. WASTEWATER TREATMENT

There are four main reasons for the treatment of wastewater prior to it being discharged into a river, lake or sea or before it is used for irrigation.

4.1 Aesthetic Reasons.

Wastewater contains many solids from the bathroom and kitchen of houses. Besides being unpleasant to see in rivers, lakes and at sea, the larger lumps take much longer to decompose. Industrial wastewaters can contain rags, oil, pieces of hair and a multitude of other solids. Effluents from dyehouses can be highly coloured.

4.2 Chemical Reasons.

The organic materials in wastewater, if discharged untreated or insufficiently treated into a river, lake or the sea;would when being decomposed consume much of the dissolved oxygen in the water. How much oxygen is consumed depends on the following factors :

4.2.1 the oxygen demand of the effluent being discharged;

4.2.2 the rate of reaeration of the receiving water;

4.2.3 the dissolved oxygen content of the effluent being discharged.

The minimum allowable oxygen content must be established. If it is required that the river be kept stocked with game fish such as trout,then the dissolved oxygen content must not be allowed to drop below 5 mg/L at any time. If it is not necessary to maintain such a high quality water, then the dissolved oxygen content may be allowed to drop down to about 3 mg/L.

Besides the oxygen released by green plants during photosynthesis, the oxygen dissolved in streams and other bodies of water is derived from the atmosphere above the water. Although photosynthesis may make considerable amounts of oxygen available, oxygenation by green plants is confined to :

4.2.4 waters that are not so heavily polluted that green plants die;

4.2.5 waters that have recovered enough to re-establish the growth of green plants;

4.2.6 the hours of sunlight;

4.2.7 the warmer i.e. growing seasons of the year.

The interplay of the deoxygenation of the receiving water by the oxygen demand of the discharged effluent, and their reaeration from the atmosphere creates a spoon-shaped profile of the dissolved oxygen deficit along the path of water movement. The dissolved oxygen deficit is the difference between the saturated dissolved oxygen content at a particular temperature and pressure and the actual dissolved oxygen content at that same temperature and pressure. A typical dissolved oxygen sag profile is shown in figure 4.

The rate of reaeration of a particular receiving water will depend on the following factors:

4.2.8. the water temperature;

4.2.9 the rate at which new interfaces are presented to the atmosphere i.e. the turbulence of the water. This turbulence may be as a result of wind and wave action or by the actual flow of the river.

If the dissolved oxygen content of a river is allowed to drop too low then fish die-off occurs first and if it drops still further then plant die-off can occur. When the plants die off they sink to the bottom of the water and then exert an additional oxygen demand. See also below under biological reasons.

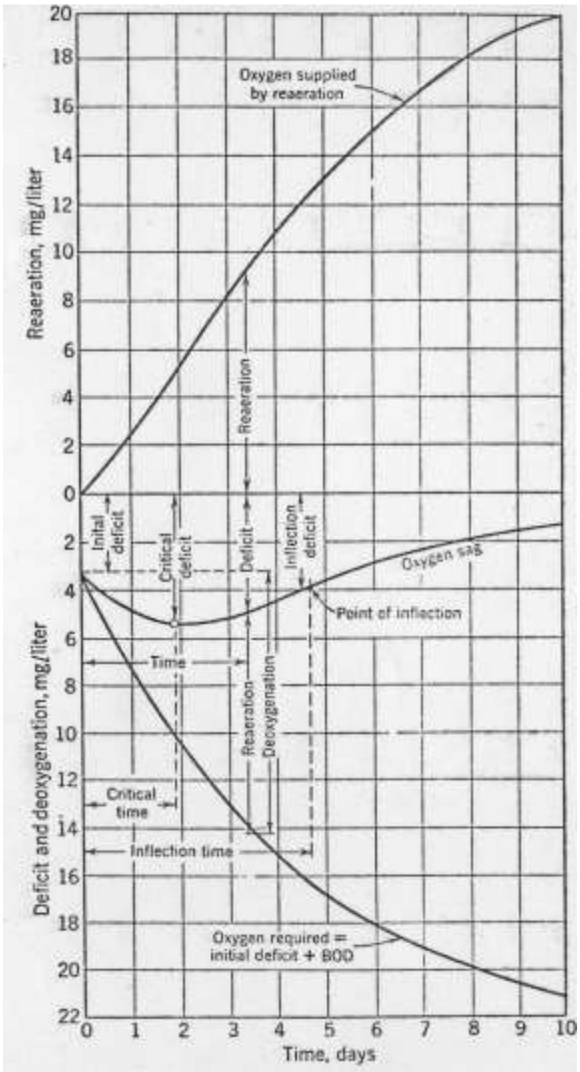

Figure 4 – TYPICAL OXYGEN SAG PROFILE

If the dissolved oxygen content of a river is allowed to drop too low then fish die-off occurs first and if it drops still further then plant die-off can occur. When the plants die off they sink to the bottom of the water and then exert an additional oxygen demand. See also below under biological reasons.

The treatment of wastewater removes the larger solids, the suspended solids and the colloidal material. The discharge of untreated wastewater into a river would mean that a person drawing water from a point downstream might have to treat the water before he could use it - even for non-drinking purposes, by removing the suspended solids. It can be seen that in such a case the discharge of untreated wastewater would render the water in the river “less fit for use”. cf Water Act - 1956.

The treatment of wastewater means that in many cases certain industries could use the treated effluents instead of precious drinking water for some of their processes.

4.3 Biological Reasons.

An untreated or poorly treated wastewater being discharged into a water course carries a large amount of nutrients. The availability of these nutrients means that the aquatic growths such as algae, weeds, grass and water hyacinth, will grow much faster.

The nutrients that are usually growth limiting are nitrogen and phosphorus. The algae take up and store nitrogen and phosphorus. Oon dying, they settle to the lake bottom, the bottom deposits become devoid of dissolved oxygen. This releases the nitrogen and phosphorus back to the water and in spring when the water heats up; the nitrogen and phosphorus is carried to the surface layers of water where they promote the growth of a new crop of algae.

In many cases it is phosphorus that is growth limiting because some blue-green algae can fix nitrogen i.e. they can abstract the needed nitrogen from the atmosphere and the lake water can usually dissolve enough carbon dioxide from the atmosphere, from decaying organic matter or from the bicarbonate alkalinity to supply the required amounts of carbon.

When treated effluents are discharged directly into the sea or into rivers a short distance from the sea, it is usually not necessary to remove nitrogen and phosphorus from the effluents. In inland areas where effluents are discharged into water impoundments or into rivers that discharge into water impoundments, then it is necessary to remove most of the nitrogen and phosphorus.

Water impoundments have a capacity for self-purification depending on their size and on special characteristics. The basic characteristics are determined by the volumes of water flowing through and by factors depending on the nature of the surrounding country, and on the composition of the water especially with regard to inorganic constituents, including trace elements. The types of biological activity are controlled by these and by other ecological factors. Algal blooms may result from over – fertilization of the impoundment water. These occur most often just after the spring turn - over when the nitrogen and phosphorus are carried to the surface layers of water.

In the course of time, natural and man - made pollution changes oligotrophic lakes into mesotrophic lakes and mesotrophic lakes into eutrophic bodies of water. Man plays an important role in determining this rate of change.

The need for ammonia removal has been well established. In many areas it has become necessary to remove the nitrates and phosphates to slow down the rate of eutrophication of the receiving waters. The nitrate and phosphate removal will be covered in more detail in Volume 3 – Wastewater Treatment

4.4 Micro-biological reasons.

Untreated wastewater contains enormous numbers of bacteria, viruses and parasitic ova. If the wastewater was discharged insufficiently treated into a watercourse, then persons or animals using the watercourse downstream run the risk of disease. Incidents of unsanitary disposal of wastewater causing epidemics have been recorded for more than 100 years. Not all bacteria in wastewater are harmful, many are essential for the breakdown of organic material in the wastewater.

Pathogenic, i.e. disease causing, organisms discharged by persons suffering from infectious diseases, notably typhoid, the dysentries, and other gastro-intestinal infections, or by carriers of these diseases, are always potentially present in wastewater. These organisms die away slowly in wastewater. Their removal is effected in part by the various processes of wastewater treatment, and their destruction may be hastened and increased by disinfection eg. by chlorination.

Wastewater can be disposed of readily and without nuisance if the volume of wastewater is small and relatively large volumes of receiving waters or areas of land are available for direct disposal. The demands of proper sanitation are then limited to local problems of hygiene, the control of bacterial and other infectious diseases and of odours and aesthetic nuisance, which can be achieved by proper house drainage and sewerage.

The denser the population of an area and the higher the standard of living and the development of industry, the more important is the proper disposal of its solid, liquid and gaseous wastes. The public nuisance which may otherwise develop may interfere with or cause damage to industries, water supply and conservation, waterways, harbours and beaches, to residential and recreational areas, to agriculture, pastures, fisheries, and so on. The sewerage and drainage of part of an area, though satisfactory from a local view point, may result in unsatisfactory conditions elsewhere, and in general the sanitation of a country can only be regarded as soundly and safely established if all units of all communities in a rivercatchment area are sewered and drained to the same standard. The problem of satisfactory disposal of solid, liquid and gaseous wastes from any one community may, therefore, involve technical disposal problems of much wider extent.

4.5 Water Reclamation.

In passing through the four stages of wastewater treatment, namely preliminary, primary, secondary and tertiary, the treated water will have improved in quality such that it may be discharged into almost any receiving water without unduly upsetting the ecology of that receiving water.

However when the treated water is discharged into a sensitive receiving water, it may be necessary to improve the quality still further. In areas when there are limited water supplies, it may be warranted to treat at least some of the wastewater to an advanced degree to reclaim that water for use in certain industries, or even to potable standard. The title water reclamation implies that the water is reclaimed to its original quality.

In practice, this may not necessary be the case as most chemical treatment processes increase the dissolved solids content of the water and unless some dissolved solids removal is practiced, the reclaimed water will have a slightly higher dissolved solids content than the original feed water. The actual increase will depend on the original use of the water and the types of processes used to reclaim the water.

A brief introduction to the removal of certain consituents is given below.

The following quality improvements are possible using advanced treatment processes to reclaim the water.

4.5.1 Nitrogen Removal.

Nitrogen removal in conventional wastewater treatment processes can vary from less than 20% when high rate secondary processes are used, up to greater than 95% when nitrification / denitrification stages are used.

Ammonia passing into a receiving water is toxic to fish and has an appreciable dissolved oxygen demand. 1 mg of ammonia as nitrogen requires 4.6 mg of oxygen to be completely oxidised to nitrate. It has been seen before that nitrate encourages the growth of plants in the receiving water. Nitrate discharged directly into the receving water does not have the dissolved oxygen demand of ammonia, but has the same ultimate effect in encouraging plant growth.

4.5.2 Phosphorus Removal.

In many cases, phosphorus is the nutrient responsible for the eutrophication of a receiving water. The usual biological processes are not very efficient in removing phosphorus and so chemical methods are needed to remove the remaining quantity. Phosphorus removal by chemical precipitation is often considered as a tertiary stage of treatment and will be covered in in Volume 3 - Wastewater Treatment.

4.5.3 Suspended Solids Removal.

Most biological processes do not reduce the suspended solids content sufficiently and an extra physical separation stage is often required. It is often colloidal matter in the effluent that is responsible for the suspended solids content and some process to coagulate these colloids is necessary.

4.5.4 Organic Material Removal.

Dissolved organic materials that give rise to residual oxygen demand, colour taste and odour producing compunds are not completely removed by the conventional biological treatment, if their removal is required then an additional process step is required. Certain organic chemicals such as pesticides when in low concentration can pass right through a conventional wastewater treatment works.

As the long term effects of trace quantities present in drinking water are not yet known, in many cases where trace quantities are known to be present, steps are taken to remove the pesticides.

4.5.5 Dissolved Solids Removal.

In virtually all uses to which water is put, the water is discharged after use with a dissolved solids content that is higher than in the feed water. This may be as a result of a chemical or chemicals being added to the water such as soduim chloride in water used for cooking, salts in dyeing processes and detergents in water for washing or as a result of evaporation taking place and causing concentration such as in cooling towers. Depending on the use to which the water has been put, the number of times that the water has been used and on the dissolved solids content at the original point of abstraction, the dissolved solids content can build up to such a concentration as to reduce the number of uses to which the water may be put.

If the water cannot be blended with water having a sufficiently low dissolved solids content, then it may become necessary to reduce the dissolved solids content of the treated water.

4.5.6 Removal of Pathogens and Other Micro-organisms.

The pathogen and other micro-organisms die-off through a treatment works is dependent on the processes used.

Wastewater that has been treated up to the tertiary stage could contain low concentrations of pathogens, viruses etc. If the reclaimed water is to be used for potable uses or in food processing factories, more sophisticated disinfection processes would have to be used to ensure that the water is safe for use.

PART 5.

AIR POLLUTION CONTROL.

5. Air Pollution and the Community.

5.1 General Effects of Air Pollution.

Air pollution effects upon people, vegetation and material objects are not an innovation of modern technology; air pollution is as old as the earth. When prehistoric man built a fire in a cave home, one fire probably did not cause too much deterioration in the quality of the air. However when friends or relatives built several fires in the same cave, even prehistoric man was subject to the effects of air pollution.

Air pollution is a people problem. By crowding too many people and too much industry into too small an area, air pollution is created by the things that people do and by their demands for industrial products and electricity. People suffer from air pollution as is shown by the effects on human and animal health, damage to vegetation and to deterioration of material objects.

One way to show that people generate air pollution is to look at pollution levels along a line transecting a populated area, which starts in a rural area on the one side, passes first through the suburbs, then through the city centre, then through the suburbs on the other side of the city centre and finally into the rural area on the other side of the town. It is seen that on an annual average basis (taking into account wind from all directions), the pollution concentration is highest in the city centre, lower in the suburbs and lowest in the surrounding rural areas. Figure 5.

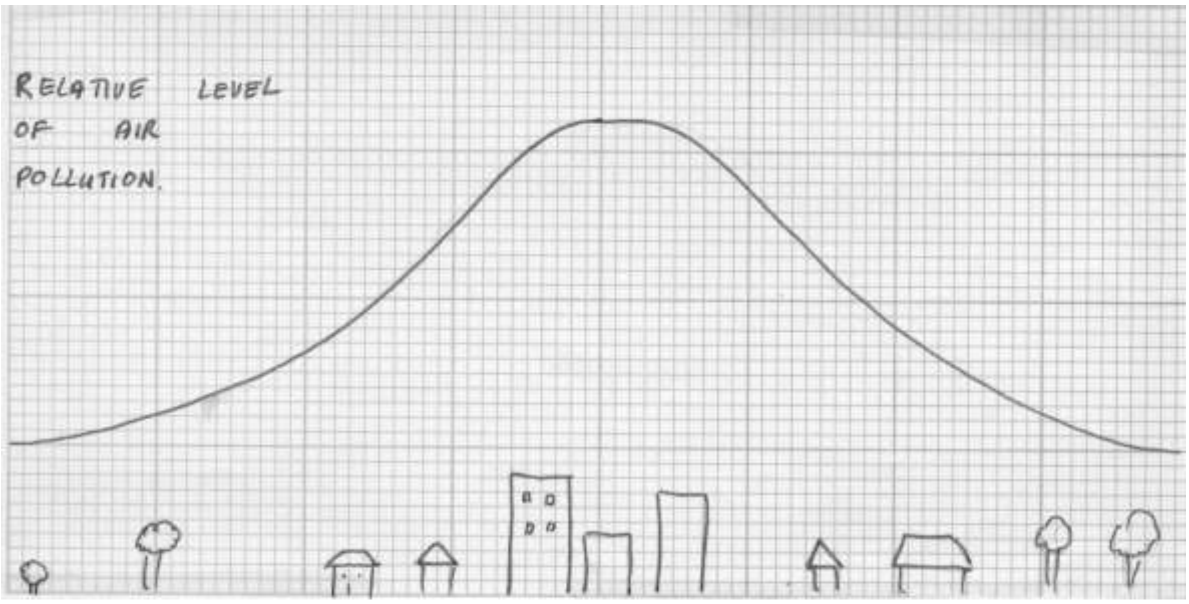

Figure 5 – RELATIVE LEVEL OF AIR POLLUTION FROM RURAL TO URBAN AREAS.

The problems of air pollution have become apparent in areas where the rate of emision of the air pollutants has increased above the capability of the air masses to cleanse themselves. Compare with self-purification of water masses and the problems that occur when the rate of pollution exceeds the rate of self-purification.

The places from which pollutants emanate are called sources. There are natural as well as man-made sources of pollutants. Amongst the natural sources are plant and animal respiration, the decay of what was once living matter, volcanoes and naturally caused forest fires.

The places to which pollutants disappear from the air are called sinks. Sinks include soil, vegetation, structures and bodies of water. The mechanisms whereby pollutants are removed from the atmosphere are called scavenging mechanisms.

The receptor is that which is adversely affected by polluted air. The receptor may be a person or animal that breathes the air and whose health may be adversely affected thereby, or whose eyes may be irritated or whose skin made dirty. It may be a tree or plant that dies, or the growth, yield or appearance of which is adversely affected. It may be some material such as paper, leather, cloth, metal, stone or paint that is affected.

Finally, some properties of the atmosphere itself such as its ability to transmit radiant energy or its transparency may be affected; or it may be soil or water bodies that are the adversely affected receptors.

5.2 Town planning Aspects.

It will be seen in the next sections that there are many factors which will influence the spread, dilution and resultant effects of discharges of polluted air. Most of these factors are naturally occurring over which man has no control. Although he has no control over these factors, this does not stop him using at least some of these factors to his advantage in order to lessen the effects of the discharge of polluted air from a source or sources.

It will be seen that it gets more and more expensive to remove the remaining pollutants in the air or gases discharged into the atmosphere. It may not be possible to trace all sources of air pollution in an area. In order that the effects of air pollution from industrial areas on residential area be zero, one would have to put the industrial area very far away from the residential area. For practical reasons this is not possible. However, by taking cognizance of the parameters dealt with in later sections, it is possible to reduce the impact of air pollution from industrial areas on the residential areas.

The siting of the industrial areas or areas relative to the residential areas should be studied in depth.

Among the factors relating to air pollution are :

5.2.1 The direction and frequency of wind from each direction;

5.2.2 The effect of hills etc in the area causing wind shadows or otherwise modifying the wind effects;

5.2.3 The depth and frequency of inversions;

5.2.4 The vertical temperature profile i.e. the temperature lapse rate;

5.2.5 The relative elevations of the industrial and residential areas.

Not all industrial processes create air pollution, and some are more polluting than others. Certain industrial processes such as rendering of fat and abbatoirs produce such unpleasant odours that the siting of such industries must be dealt with in great detail. It is usually advisable that these so called noxious industries be sited in a specially proclaimed zone.

There is usually heavy vehicular traffic in industrial areas and there will be air pollution as a result of this.

In order to reduce the drift of exhaust gases and their related noise, toward the residential area, having a wide belt of tall trees between the industrial area and the residential area will help.

The judicious siting of an industrial area relative to a residential area can be decisive in reducing the effects of air pollution originating from the industrial area on the residential area.

5.3 Metereological Conditions and Air Pollution.

Wastes released to the atmosphere consist of particles and gases. Some of these materials stay for only a few hours, or even minutes, while others may stay in the atmosphere for years.

Regardless of the length of stay the movement of the particles and gases is governed by movement of the atmosphere - over which man has no control. Large scale atmospheric movements determine the paths to be followed by these materials, while the small scale motions determine the extent to which pollutants will be diluted. The science devoted to the study of these atmospheric movements is meteorology.

Most pollutants originate from sources in the first 100 metres above the ground and virtually all receptors for atmospheric pollutants are located in this same layer. A knowledge of elementary meteorology will assist a person in making an assessment of the extent to which this layer of air can be effectively utilized to dispose of pollutant materials. In certain conditions the atmosphere will disperse sufficiently the material discharged into the air whereas in other all discharged material will be trapped. It is advantageous to have a knowledge of what is likely to occur at a certain place or under certain conditions.

5.3.1 Stable Air Conditions.

When stable atmospheric conditions exist there is little turbulent mixing in the vertical plane. This is caused by horizontal stratification. In this case the temperature of the air will either remain constant with increase height (isothermal condition) or will increase with increase in height (inversion condition). Take, for example, a small parcel of air; as this parcel of air rises, the pressure drops and so the parcel expands, as it expands the air will cool.

If there is no exchange of heat with the surrounding air, this temperature drop will be about 1°C for each 100m rise in elevation. This decrease in temperature with increase in height is called the **dry adiabatic lapse rate**.

If the temperature of the parcel of air that has risen is now lower than the surrounding air, then the relative density of the parcel of air will be greater than the surrounding air and it will then sink down again until equilibruim is attained.

5.3.2 Unstable Air Conditions.

When unstable air conditions occu,r there is mixing in the vertical plane. Taking the above parcel of air; if after rising and expanding, the temperature of the air is the same as that of the surrounding air then no further independent movement of the air will take place. If, however, the temperature of the parcel of air is still higher than that of the surrounding air then the air will rise further until its temperature becomes equal to that of the surrounding air. The rate of change of temperature of this parcel of air with height may be greater than, equal to or less than the dry adiabatic lapse rate of 1°C per 100m. If the rate is faster then it is called, **superadiabatic**, if it is equal then it is called **neutral** and if it is less then it is called **subadiabatic**.

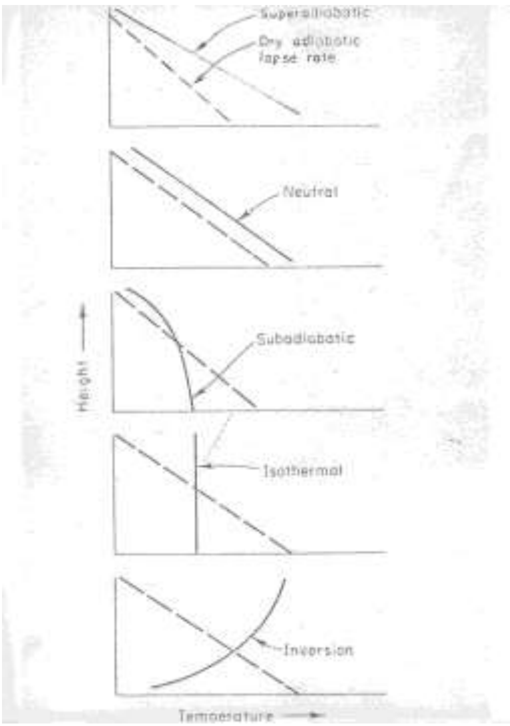

Figure 6 – VARIOUS TEMPERATURE VERSUS HEIGHT PROFILES

5.4 Diffusion and Dilution.

When stable air conditions exist, there is no vertical mixing and thus polluted air in the lower layers of the atmosphere cannot escape, and so little diffusion and dilution will take place.

Often the air has a very stable layer at a height of a few hundred metres and this acts as a lid to the ascent of plumes of pollution from hot sources. There is often an accumulation of pollution beneath this stable layer during the night, and during the following morning when the ground becomes warm, thermal convection gradually extends up to it.

When the air is thoroughly stirred some of the accumulated pollution is carried down to the ground. This sudden increase in pollution in the morning is called fumigation. These stages are shown in figure 7.

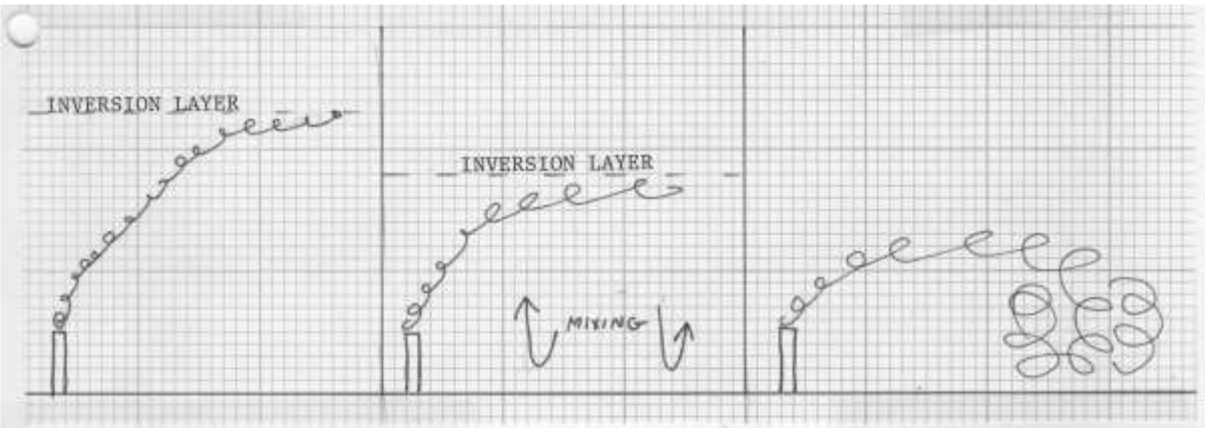

Figure 7 – EFFECT OF INVERSION LAYER ON DISPERSION.

The rate at which diffusion and dilution takes place is dependent on several factors, amongst these are :

5.4.1 Air movement and temperature effects

5.4.2 Topography

5.4.3 Wind effects

5.5 <u>Air Movements and Temperature Effects</u>.

Air movements takes place in three scales of magnitude:

5.5.1 The micro scale where turbulence is as a result of eddies and thermals, and wind profiles i.e. the changes in wind velocity above the ground level. One of the important effects on the micro scale is plume behaviour. The shape of the plume from a chimney can usually be shown to be one of five types:

1. fanning
2. fumigating
3. looping
4. coning
5. lofting

These are illustrated in figure 8 that shows plume nomenclature related to thermal stability of the atmosphere below and above the source height. Below source stability decreases from top to bottom. Above source stability decreases from left to right.

 written by P B King 1981

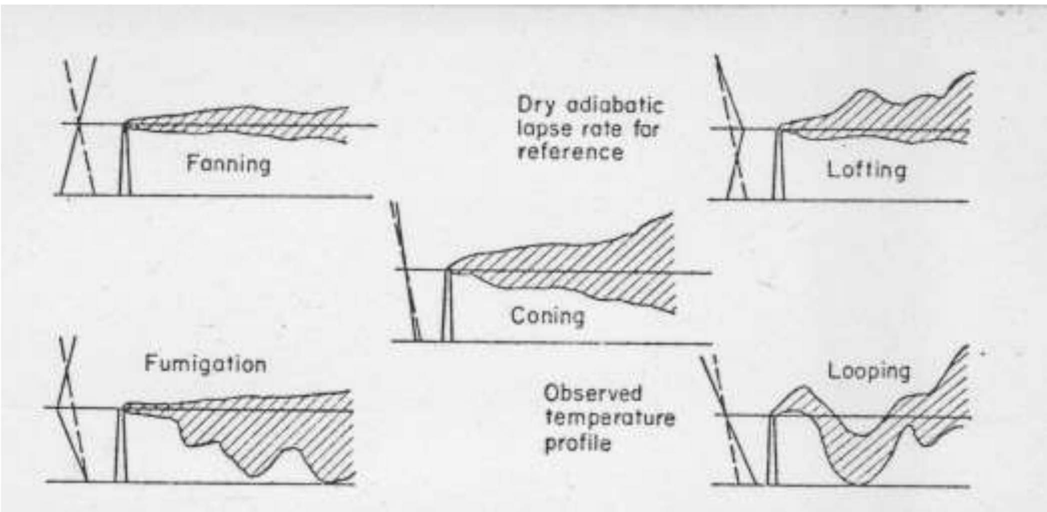

Figure 8 – SHOWING VARIOUS FLUME FORMATIONS

Fanning usually occurs under conditions of a strong inversion, when there is little turbulence, this can turn into the fumigating types when the ground heats up, as seen above.

The looping type usually occurs when the sun is bright and the wind is light.

The coning type usually occurs when the skies are overcast and the heating of the earth's surface is slight or when the wind is light.

The lofting type occurs when there is turbulence in the air above the level of the point of emmission and stable air below the level of the point of emission.

The temperature of the gas emitted from the stack, the height of the stack, as well as the efflux velocity effect the rate of diffusion and dilution. The higher the temperature, the height or the efflux velocity, the greater the rate of diffusion and dilution, and the lower will be the ground level concentration in the vicinity of the stack.

The height of the stack relative to nearby structures can also influence the rate of diffusion.

If the stack is not high enough or the efflux velocity is not high enough downwash can occur in which case ground level concentrations near the stack can become unacceptably high as shown in figure 9.

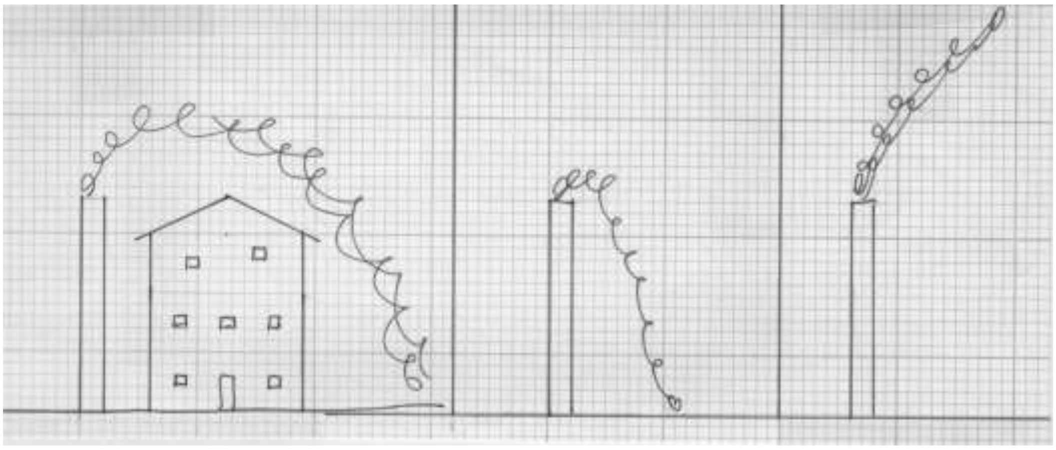

Figure 9 – VARIOUS PLUME PATHS.

5.5.2 The mesoscale - this relates to local winds which arise as a result of the topography and is covered in section 5.6

5.5.3 The macroscale - this relates to the global winds and is covered in section 5.7

5.6 <u>Topography</u>

In the above sections, the eddies and turbulence have been discussed as resulting from temperature effects or air movements independent of the shape of the land.

The effect of the topography can have a major effect on air pollution. The topography of an area can have an effect on the development of local winds. The sea breeze and the land breeze from the different rate of heating of the land and water masses. During the day the land warms faster than the sea, and the wind blows from the sea to the land, while during the night the land cools faster than the sea and the wind blows from the land to the sea. These local effects can be modified by the global winds. Figure 10.

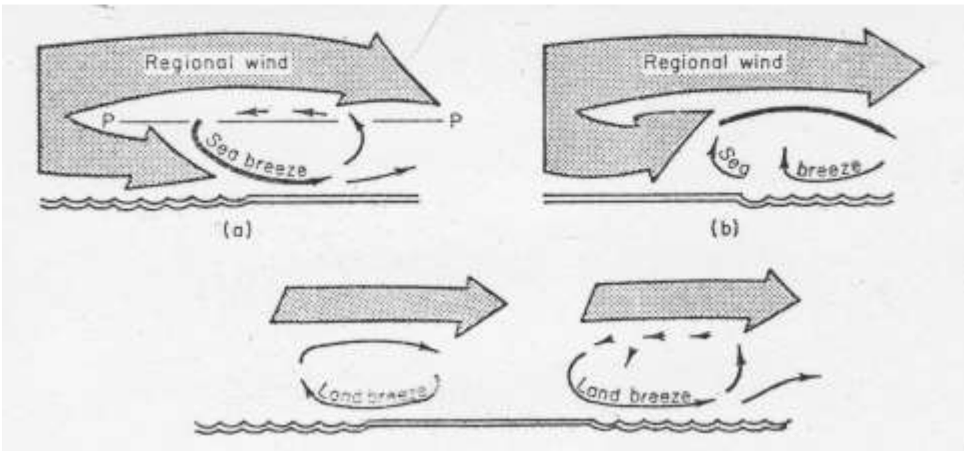

Figure 10 – SHOWING VARIOUS WIND DIRECTIONS

(a) Onshore flow during daylight – The sea breeze and the land breeze for a west facing shoreline
(b) Same for an east facing shoreline
(c) Off shore flow at night – the land breeze or shore breeze

Other forms of local wind can be found in valleys. At night time, cooling takes place by radiation. The air near the top of the valley cools first and on cooling becomes more dense, it then sinks down into the valley. If there are any sources of air pollution on the slopes of the valley then these katabatic winds carry this pollution down into the valley. During the day, the opposite can happen and the anabatic winds flow up the slope and can carry polluted air with it as shown in Fig. 11.

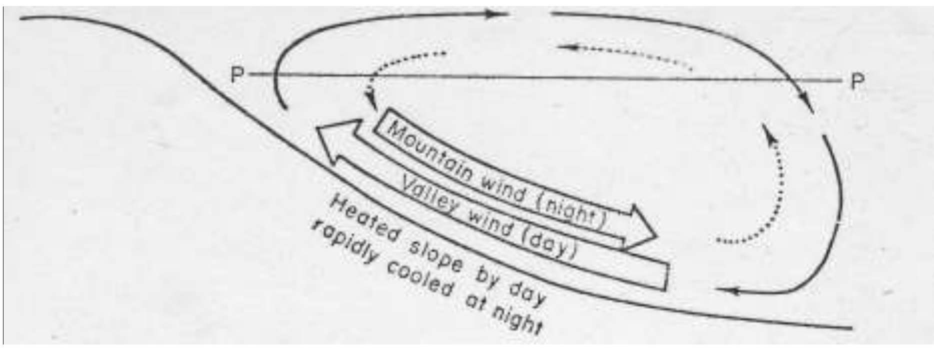

Figure 11 – SHOWING LOCAL WINDS

When there is a general drift of air, pollution may still be trapped below inversions and carried into contact with the ground if there is an inversion below the highest ground. When an airstream moving over a flat, homogeneously rough surface encounters an isolated obstacle, the wind stream becomes deformed near the obstacle and later at some distance downstream recovers its former characteristics. If the obstacle is small such a building the effects can be small, but if the obstacle is a mountain there can be a large area in the lee of the mountain where polluted air can become trapped. Some of these topographical effects are seen in figure 12.

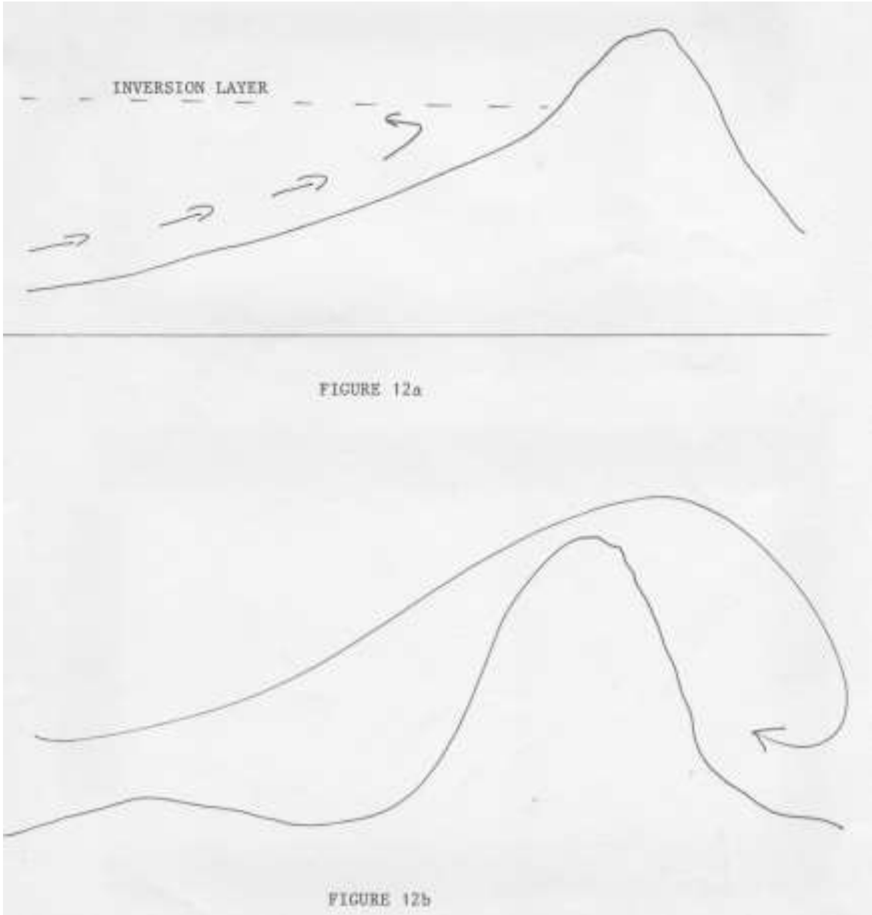

Figure !2 – TOPOGRAPHICAL EFFECTS.

5.7 Wind Effects.

The local winds covered above, are generated as a result of local conditions. Their influence does not normally cover a very wide area, nor do they extend high into the atmosphere. The global winds on the other hand, cover very large areas and can be responsible for carrying air pollution from one country to another.

Under certain conditions high level inversions can occur. These can occur as the result of subsidence of high level air i.e. an upper air high pressure area. In subsiding the air is heated by compression, the air will subside until its relative density is the same as that of the surrounding air and then remain at that level until some other influence alters the situation.

The high level inversions set a limit to the upward dispersal of pollution. Since this is the most important single mechanism for getting rid of pollution emitted at ground level or first above ground level, they can have a very important influence on the effects of large sources of air pollution.

5.8 Weather Forecasting.

This section is concerned with using the information obtained from a weather forecast to predict the effects of the forecasted weather on the air pollution potential of a certain area or areas.

It has been seen above that inversion conditions can aggravate the effects of air pollution by preventing the diffusion and dilution of the polluted air. Inversions are most likely to occur when the wind is light and the sky is clear at night. If this occurs in a high pressure area then the chances of a strong inversion forming are that much better as the subsiding air suppresses the upward movement of the polluted air and opposes the formation of clouds. In the absence of clouds, nighttime radiation is greater and this results in cooling of the lower levels of air and increasing the possibility of an inversion forming.

When strong winds are forecast, i.e. the isobars are close together on the synoptic chart and a strong pressure gradient exists, the chance of an inversion are reduced as large scale mixing will take place in the atmosphere and this will hasten the dispersion of the polluted air.

5.9 The Effects of Air Pollution in General.

The effects of air pollution vary between the very rapid destruction of nylon by a sulphuric acid aerosol to the slow deterioration of rock by the sulphur dioxide content of the air. It is virtually impossible to put a monetary value to the cost of air pollution, to South Africa but it will certainly run into tens of millions of rands annually.

The effects of air pollution are very variable as the concentration of the pollutants in the air is continuously varying. Both the concentration of the pollutant and the duration of contact with the article concerned have an effect on the amount of damage done.

5.10 The Effect of Air Pollution on Health.

The continued physical and mental well - being of its citizens is most important to a country. Studies of air pollution episodes as well as other research have shown that air pollution is associated with the occurence and worsening of manv serious respiratory diseases including asthma, chronic bronchitis, lung cancer and emphysema.

The sites of air pollution effects on man few in number, a fully dressed person has more than 90% of his body area covered. There is no general effect of pollutants on skin at normal ambient air concentration. There are exceptions, such as salt spray and ultra violet light at the seashore. The external coatings of the eye come into direct contact with gaseous and particulate air pollutants. Eye irritation is a major effect of photochemical air pollution. There appears to be no permanent eye injury in these cases, but this could be due to the rapid flushing away of the pollutants by the eyes watering.

In the human respiratory system, air usually enters through the nose and particles greater than 10μm are filtered out. During passage through the respiratory system, soluble gaseous pollutants are almost completely removed by the moist mucus membrane lining. Particulate matter between 2 and l0 micrometre, settles or impinges upon the walls of the trachea or windpipe,the bronchi and the bronchioles - these foreign particles are escalated by ciliary action to the mouth and are swallowed. Particles between 0.1 and 2 micrometre may reach the alveoli where they may stay for weeks or even years. Here they may damage the alveoli and cause emphysema and other diseases. Particles of less than 0.l micrometre are generally passed out with the expired air.

Several major air pollution episodes have occured during the past 50 years and these have resulted in the death of thousands of people. No single pollutant or groups of pollutant responsible for the episodes has been isolated - although sulphur dioxide and particulate matter are the most suspect. These episodes have occurred when there has been an inversion for at least 3 days, during which very high levels of air pollution were recorded.

There have been several studies done to try to determine the long term effects of moderate levels of air pollution on a persons health. Some conclusions made are:

1. there is a wide variation of susceptibility of different persons to air pollutants;
2. pre-existing or underlying disease conditions augment stresses added by air pollution;
3. air pollution is an additive factor aggravating effects of other substances in initiating disease;
4. under some conditions, some types of air pollution can actually initiate structural and persistent disease in healthy persons;
5. different types of air pollution may produce quite different physiological responses.

5.11 The Effect of Air Pollution on Plant Life.

Vegetation may be either injured or damaged by air pollutants. When the plant is injured it may lose some of its leaves, but these leaves can grow again, or replaced by new leaves. A plant is said to be damaged when its economic value has been reduced as a result of air pollution e.g. a reduced yield of crop. This can also be as a result of extensive injury to the plant.

Some plants are more sensitive to air pollution than others. The same plant may be more sensitive to a certain pollutant under one condition than under another. Some examples are:

1. pollutant injury generally decreases with increased light intensity;
2. plants are less sensitive at lower relative humidities;
3. most plants are more resistant at night time when the stomata are closed;
4. injury is more severe during the growing season.

Symptoms of injury to leaves as a result of air pollution include : bleaching. spotting, chlorosis (loss of chlorophyll), and burning.

5.12 The Effect of Air Pollution on Materials.

The cost of the consequences of air pollution on materials is very difficult to calculate. Estimates vary very widely. The number of materials affected by air pollution is limitless, so only a few example will be given.

5.12.1 Metals.

Metal corrodes as a result of air pollution because small electric cells are set up on the metal surface. In the presence of moisture, an electric current results. For the a current to flow, there must be an electrolyte on the surface, air pollutants combine with the moisture to form this electrolyte. The amount of sulphur dioxide in the air plays a dominant role in the corrosion of metals.

5.12.2 Building Stone.

Pollutant action on stone is principally that of an acid dissolving a carbonate. Sulphur dioxide is the prime pollutant as its dissolves in water to form sulphurous acid which is oxidised to sulphuric acid. To a lesser extent, carbon dioxide dissolved in water will attack a carbonate type stone. Silicate type stone is less readily attacked in this manner. Building bricks are not attacked but the cement between the bricks is. The decomposition products are relatively soluble in water and are washed waway by rain, thus presenting a new surface for attack. Particulate matter can stick on the surface of stone and brick, and soil the surface.

5.12.3 Fabrics and dyes.

The soiling and fading of textiles is apparent to the general public. In addition to the loss of aesthetic appeal, the functional life of the fabric is reduced because of the required additional cleaning. Fabrics and dyes are affected by particulate matter, sulphur dioxide and the oxidants such as ozone and the higher oxides of nitrogen. Deterioration by pollution is additive and may accelerate fabric deterioration caused by biological processes, sunlight, oxygen, humidity and changes in temperature. When textile materials are exposed to polluted air, large particles may settle by gravity while smaller particles may be filtered from the air. Static electricity generated by the fabric may play a role in particulate deposition. Gases may be adsorbed directly on the fabric fibres or onto the particulate matter attacked to the fabric fibres. The breaking strength of certain fibres is reduced by some air pollutants.

5.12.4 Paper and Leather.

The effects of air pollutants inside a building are not as marked as when the material is exposed to the weather. Both paper and leather adsorb sulphur dioxide and other pollutants and become brittle. Leather can accumulate a surprising quantity of sulphur and sulphuric acid.

5.12.5 Paint.

Paints are designed to decorate and protect surfaces. During normal wear, the paint chalks moderately to present a new surface, this process can be accelerated under certain conditions. Lead based paints are rapidly darkened by hydrogen sulphide. Painted surfaces are dirtied by particulate matter which can adsorb other pollutants which hasten the deterioration of the paint.

5.12.6 Rubber.

Natural rubber is attached by oxidising air pollutants, and loses its elasticity. Synthetic rubbers are more resistant depending on their formulation.

5.13 The Effect of Air Pollution on the Physical Properties of the Atmosphere.

Although interactions between pollutants and the atmosphere have been mentioned in previous sections, there are other factors that deserve special attention.

5.13.1 Visibility.

The most noticeable effect of air pollution on the physical properties of the atmosphere is the reduction in visibility. This visibility reduction is caused by the forward scattering of light from liquid and solid matter in the size range less than l micrometre in diameter. Larger particles scatter light poorly and are thus not a major factor in visibility reduction. In the atmosphere, visibility reduction ismost severe when the particle size is in the size range of 0.3 - 0.8 micrometre and when the relative humidity is above 70%.

5.13.2 Odour.

The biggest source of complants regarding air pollution is odour. Odours in themselves are not causes of physical illness or disease, even though many people believe the contrary. The psychological effects of odours are, at times, surprising. All sorts of unrelated happenings have been blamed on odours. Odours are an obvious nuisance because of the low concentration of most chemicals necessary to trigger a sensation response.

An occassional whiff of, for example, roasting coffee may be pleasant, but after a relatively short period of time one would begin to detest the smell.

Odours are very subjective, partly because a persons attitude to the cause of the odour affects his view of the smell itself. One can become used to certain odours.

5.13.3 Noise.

One may also consider noise as a form of air pollution. As cities become more crowded, noise is becoming of major environmental concern. Excessive noise for long periods can impair the hearing. There is evidence that high noise levels can be injurious to one's health in general.

5.13.4 Radiation.

A great deal of interest has recently been generated in regard to the possible effects of man's activities on the stratosphere. The exchange of air between the stratosphere and the lower atmosphere is slow - mixing being a matter of years - so that there is time for pollutants injected into the stratosphere to accumulate. There is, of course, no scavenging of pollutants by cloud and rain as helps to clean the lower atmosphere.

Until a few years ago, this poor mixing of the stratosphere and the low atmosphere meant that pollutants discharged at or near the surface of the earth had to pass through many kilometres of atmosphere before reaching the stratosphere and much of the pollutant was removed by the various scavenging processes available. Since the advent of supersonic aircraft flying at up to 17 000 metres, the status has altered somewhat. What effects these aircraft will have on the ozone layer and the absorbance of ultra violet light is not yet known.

Another change in radiation that might be occurring, is the so called "greenhouse" effect. Here the slowly increasing carbon dioxide content of the air, formed as a result of combustion of carbonaceous materials, is thought to be reducing the radiation of heat from the earth and so causing an increase in temperature of the earth. Some authorities believe that the increasing particulate matter content of the atmosphere is increasing the albedo, or reflectivity, of the earth and that the two effects are to some extent balancing each other.

5.14 The Effects of Air Pllution on Animals and Birds.

The effects of air pollution on animals and birds come under two headings - that pertaining to the air that they breathe and that pertaining to the food they eat.

5.14.1 The air that they breathe.

These effects are similar to those dealt with in section 5.10 above.

5.14.2 The food that they eat.

In section 5.11, the effects of air pollution on plant life were covered in respect of injury or damage to the vegetation itself. However, there are cases where the effects of air pollution may not be injurious to the plant itself, but may be injurious to any person or animal that eats the plant or parts of the plant. This can be due to an accumulation of a specific pollutant in the plant. In addition to consuming pollution affected vegetation, carnivores (man included) consume animals that may have ingested and accumulated exotic chemicals.

Increasing environmental concern has pointed out the importance of the complete food chain for the physical and mental well - being of man.

5.15 Odours.

Odours as such do not cause any direct damage. Certain materials are corrosive while being odourous, and example is sulphur dioxide, whose effect in damaging materials was seen above.

5.15.1 Sources of Odours.

The list of sources of odours is limitless. Certain industries process or use organic materials with high vapour pressures. Combustion of materials can cause odours, particularly if the combustion is not complete. The combination of two chemicals with a low odour "rating" may produce a compound that has a high odour "rating". This could occur when the plume from one industry contacted the plume from another industry.

Many organic materials when decomposing give rise to unpleasant odours, this can happen in abbatoirs or in wastewater treatment works. In the latter case this usually occurs when decomposition takes place in the anaerobic process. Here the sulphur in the organic compounds may be reduced to hydrogen sulphide, and certain proteins may be reduced to skatole and cadaverin, both unpleasant smelling compounds. Fatty materials can decompose into butyric and valeric acids. Refuse tips can also give rise to odours.

Some people may consider farmyards as odourous places, it all depends what one is used to. As seen earlier, one can often be acclimatised to a certain odour. In some cases, for example hydrogen sulphide, the olfactory senses do become numb to the odour and this can be dangerous.

5.15.2 Measurement of Odours.

The measurement of an odour is a subjective process. An odour cannot be quantified in the same way that, for example, the chloride content of a sample of water can be. Among the reasons why this cannot be done are :

1. the odour may consist of many odourous compounds;

2. the odour may result from the interaction (not necessarily chemical) of two or more chemicals;

3. the chemical composition of the odourous compounds may not be known so that absolute standards cannot be prepared;

4. the concentration of the compounds in the air may be very low, they can be less than

1mg/m^3.

For the detection and intensity of odourous substances, the nose is still the instrument usually relied upon. Since odours are gaseous, they may be sampled by simply collecting a known volume of effluent and performing some manipulation to dilute the odourous gas with known volumes of "pure" or odour-free air. The odour is detected by an observer or prefably a panel of observers. The odour-free air for dilution can be obtained by passing air through activated carbon. The odour-free air is treated by adding more and more of the odour gas until the observer just detects the odour. The concentration is then recorded as the threshold odour number as noted by that observers.

The threshold odour number is the number of times the sample must be diluted with odour - free air for the odour to be just detectable. (A similar procedure is used to determine the threshold odour number for water). Using this method, it is quite likely that panel members will give different threshold odour numbers to the same sample or that the same member with different values to an identical sample at different times. This is due to the subjective nature of odour detection.

If the compound causing the odour is known, it may be possible to use a specific method to analyse for the compound. The gas chromatograph may prove to be suitable. Even if the concentration of the odourous chemical can be shown to be X mg/m^3, it does not mean that each person would be affected to the same degree by the smell. What may be extremely unpleasant to one person, may not worry another person.

5.16 Control of Odours.

Control methods fall into 2 main groups :

5.16.1 The prevention of odour.

Prevention is always better than cure, so if it is possible one should not let the odour develop. In many cases the odour cannot be prevented, but good housekeeping can often reduce the odour. Where readily decomposable organic materials are handled such as food, refuse, wastewater, etc there should be good housekeeping and one should allow the decompostion to take place only in the intended areas. The judicious use of bacteriostats may be advisable.

5.16.2 The removal of odour.

Odours may be decreased or eliminated in several ways. Ssome of the more common ways are :

1. The odourous gas may be diluted with a clean gas;

2. The odour may be suppressed with a less objectionable additive, in this case the "less objectionable" odour will overpower the original. However an odour that may be less objectionable to one person may be just as objectionable as the odour it was intended to mask;

3. The odourous components of the gas may be oxidised by burning to odourless products. This will usually involve passing the gas, through a burner fuelled usually by LPG (liquified petroleum gas), coalgas or diesel fuel. The combustion temperature may be lowered using a catalyst;

2. The odourous component may be neutralised or masked by the addition of a reactive material that "balances" or "cancels out" the objectionable odour. In the ideal case, no residual odour does remain;

3. The odourous component may be absorbed, e.g. on activated carbon, or an acidic gas may be absorbed on or by a basic material. If the main gas stream is at an elevated temperature and the odourous component has a high boiling/condensation temperature, then by lowering the temperature of the gas streams, the odourous component may condense to a liquid and may be removed from the gas phase;

4. The odourous component may be oxidised to a less odourous form by using chlorine or some other oxidant.

5.17 Sources of Air Pollution.

The list of sources of air pollution would be limitless, but it is possible to classify the sources into groups. There are many ways of doing this. One such method is presented below, where the primary division is into natural sources and man made sources. The man-made sources are subdivided into industrial, domestic and agricultural sources.

5.17.1 Natural Air Pollution.

An erupting volcano emits particulate matter such as ash and gases as sulphur dioxide, hydrogen sulphide and methane. The emission from an eruption may be of such magnitude as to cause harm to the environment for a considerable distance from the volcanic source. Clouds of volcanic particulates and gases have remained airborne for very long periods of time.

A forest fire may be started by lightning and this is regarded as a natural source of air pollution. Whether a forest or veld fire started either deliberately or accidently by man should be regarded as a natural source of air pollution, is debatable. A fire emits large quantities of pollutants in the form of smoke, unburned hydrocarbons, carbon monoxide, oxides of nitrogen and ash.

Dust storms that entrain large amounts of particulate matter are a common source of natural air pollution in many parts of the world. Even a relatively small dust storm can result in suspended particulate readings one or two order of magnitude above ambient air-quality standards. Man can play a part in worsening the air pollution by removing the natural vegetation and planting a different and less suitable type. Ploughing the ground and over-grazing can lead to greater losses of soil by wind erosion.

The oceans are an important natural source of pollutant material. The oceans are continually emitting aerosols to the atmosphere, in the form of salt particles, which aid the corrosion of metals and paints. The action of the waves on the rocks reduces them to sand which may eventually become airborne. Even the shells washed up on the beach are eroded by wave and tidal action until they are reduced to such a small size that they too become airborne.

An extensive source of natural pollutants is the plants and trees of the earth. Even though these green plants play a large part in the conversion of carbon dioxide to oxygen through photosynthesis, they are still the major source of hydrocarbons on the planet. The familiar blue haze over forested areas and the aromatic smell result from the volatile organics given off by the trees of the forest. Another air pollution problem, that can be attributed to plant life, is the pollens which cause so much respiratory distress and allergic reaction among humans.

5.18 Man - made Air Pollution.

As mentioned above this can be divided into 3 sections.

5.18.1 Industrial Sources.

The reliance of modern man upon industry to produce his needs has resulted in transfering the pollution sources from the individual to industry.

In many cases this has meant one large source of air pollution instead of lots of little ones. Although this has the disadvantage of concentration the sources into one small area, it does have the advantage that air pollution control equipment can be installed at the large source, whereas it could not be afforded at the small sources.

There are basically two types of industry :

1. That which manufactures products from raw materials - iron from ore, timber from trees, petrol and diesel from crude oil and stone from quarries. Each of these

manufacturing processes produces a product along with several waste products, gaseous, liquid or solid which we call pollutants. Sometimes some or all or the polluting material can be recovered and converted into a useable product. The generation of electricity may be included in this section since the product is electricity and the raw material, is coal, oil or nuclear fuel.

2. That which converts products into other products - cars from steel, furniture from timber, paint from solids and solvents and premix asphalt from stone and bitumen. Again during the production processes there is wastage, some of the wastage can after processing be made into the same product, for example off-cuts of steel can be melted and re-rolled into steel plate or the waste can be processed into some other product for example wood off-cuts can be made into chip-board.

5.18.2 Domestic Sources.

Even though society has moved towards centralised industries, there are still many domestic sources of air pollution. Among these are : the car and other petrol powered engines such as lawnmowers, indoor fires and gas heaters, cooking of food and braais and burning garden refuse. Generally, in a city the total mass of air pollution from domestic sources exceeds that from the industrial sources, and a very large percentage of the domestic comes from the use of a motor car.

In order to reduce air pollution in the cities and suburbs, some authorities have prohibited the burning of garden refuse. In some areas smokeless zones have been proclaimed, in these zones only special types of liquid or solid fuel heaters may be used.

Some work has been done in trying to reduce the air pollution from the motor car. Some of the methods employed are:

1. using a catalytic converter in the exhaust system to ensure complete combustion of the hydrocarbons in the fuel. This requires a lead-free fuel as lead would poison the platinum based catalyst;

2. using positive crankcase ventilation and passing the fumes, consisting of the blowby gases, through the engine for combustion;

3. incorporating a fuel system evaporation loss control device.

5.18.3 Agricultural Sources.

It has been seen above that poor agricultural practices can worsen the effects of natural pollution, particularly as far as the wind blowing away the topsoil.

The aerial spraying of crops is a source of air pollution. The effects of the spraying can be controlled if spraying is done taking note of the drift of the spray, and if the spraying is done at the lowest possible altitude. The chemical that remianed in the air, due to its small particle or droplet size, was quickly diluted and dispersed to what was thought to be a harmless concentration. Recent research has shown that these previously thought harmless concentrations may not be harmless after all. The chlorinated hydrocarbons such as DDT have a long half-life and are accumulated in the body of man, birds and animals. DDT has been found in Eskimos of Alaska, but whether this DDT got there by virtue of air pollution or as a result of run-off from sprayed areas and via animals or birds is not clear.

Where possible the more resistant chlorinated hydrocarbons have been replaced by the more easily decomposable organo-phosphates.

5.18.4 Wastewater Treatment Works.

It was seen above that a wastewater treatment works can be a source of air pollution as far as odours are concerned. There can also be a source of air pollution in another form, and that is in the form of wind borne droplets of raw, in-process or treated wastewater. It will be seen in Volume 3 – Wastewater that there are two main types of mechanical biological treatment systems - the biological filtration system and the activated sludge system. In the former the source of air pollution can be from the moving distributor arms on top of the filter, the wind can blow droplets of water beyond the boundaries of the treatment works area. In the activated sludge system the process of aerating the liquid can cause the formation of an aerosol, particularly if the surface aeration method is used.

The droplets or aerosols contain all the impurities of the wastewater as far as the bacteria and viruses are concerned. One could become infected by inhaling the aerosol emanating from a treatment works.

On some treatment works, screenings and even sludge are incinerated. Due to the continuously varying quality of the material being burnt, it is very difficult to prevent smoke and particulates from being discharged from the incinerator. Air pollution control equipment of the types to be described later can help, but the varying load on the equipment can result in the equipment being overloaded now and then.

The gases of decomposition of wastewater namely carbon dioxide, methane and hydrogen sulphide are a source of air pollution. These are usually only a source of concern in sewers, sumps and pumphouses.

5.19 Air Pollution Control Equipment For Removal Of Particulate Matter.

In this section, an indication will be given as to what types of air pollution controyequipment are available. Brief descriptions of the various types will be given as well as the size range and removal efficiencies usually attributed to each type. Some types are suitable for removing particulate matter only, whereas some will remove particulate matter as well as droplets.

5.19.1 Systems utilizing gravitation or centrifugal force.

1. Settling chambers use gravitation to separate the particulate matter from the gas. Settling chambers for anything other than very coarse particles usually become too large to be economical. It is possible to increase the separating efficiency and thus decrease the size of the settling chamber by installing a series of louvres to change the direction of the gas stream. The greater the relative density of the solid being removed, the greater the removal efficiency. The settling chamber could be used for pretreatment upstream of a more efficient unit.

2. Cyclones use centrifugal force to separate the solid particles or liquid droplets from the main gas stream. Here the gas is given a spiral motion by using baffles, guide vanes or inlet design. The gas stream carrying the pollutant is accelerated as it descends into the separator centrifuge to be removed at the bottom. At the bottom of the vortex, the gas stream turns and the cleaned air moves axially upward and out of the separator. The larger the particle the better the separation efficiency, usually some of the smaller particles will leave with the exit air.

   Small cyclones are more efficient than large cyclones and it is common to find arrays of small cyclones. Cyclones are often used as the first stage of a two stage cleaning operation. Sometimes it is possible to improve the removal efficiency of a cyclone by injecting a liquid (usually water) in with the feed gas, or by running a thin film of water down the inside surface of the cyclone. This can however present a water pollution problem.

5.19.2 Filtration.

A filter removes particulate matter from the carrying gas stream because the particle impinges upon and then adheres to the filter material. As time passes, the deposit of particulate becomes greater and the deposit then acts as the filtering medium. When the deposit becomes so thick that the pressure necessary to force the gas through the filter becomes excessive, or the flow reduction severely impairs the process, the filter must either be replaced or cleaned.

The filter media can be fibrous such as cloth, a rigid solid such as a screen or a mat such as a felt pad. A wide variety of materials can be used depending on the application. The fabric filter is the most common and consists of a finely woven material through which the gas flows. The fabric is often made in the form of a bag with the air flowing either along the inside or the outside of the bag.

5.19.3 Electrostatic Precipitation.

Here the gas is made to pass between two electrodes that have a potential difference of between 20kV and 100 kV DC. The dust particles become electrically charged and are deposited on the collection surface from which they are removed periodically.

As the electrostatic precipitator works best on small particles, pretreatment ,for eg, with a cyclone, is often done. The units may be operated in series when very high removal efficiencies are required. Not all dusts can be removed by this method. This method can be used to remove very small droplets of certain liquids.

5.19.4 Gas Scrubbing.

Here there are two main types, the first where particulate or droplet collection takes place by impingement on a wetted surface, the second in which the particulate matter comes in contact with a spray of droplets.

The first type may be sub-divided into units to remove particulate matter and units to remove droplets. An irrigated cyclone, as mentioned above, maybe used to remove particulate matter and the flat plate impinger may be used to remove droplets.

In the second type, a liquid (usually water or a solution of some chemical in water) is sprayed into a chamber through which the gas to be scrubbed is passed. The particulate matter will impinge on the droplets and will be removed by gravitation.

Both these types have the disadvantage that the discharge gas is saturated with respect to water vapour. This will result in the discharge plume being visible.

5.20 Air Pollution Control Equipment For Removal of Gaseous Pollutants.

The control systems detailed above are intended for the removal of particulate matter and droplets of liquids. In the wet processes above, there will be some removal of certain gaseous compounds when these compounds are soluble in the liquid being used in the unit.

5.20.1 Gas-Liquid Absorbtion.

Here a unit similar to a scrubber would be used. The liquid used would depend on the gas required to be removed. If an acidic gas such as sulphur dioxide was to be removed, one would use an alkaline liquid such as a magnesium oxide slurry. In this case the magnesium oxide is recovered and reused and the collected sulphur dioxide gas may be used to make sulphuric acid.

5.20.2 Gas-Solid Adsorption.

Certain gases may be adsorbed onto certain solids. The adsorption effect is usually reversible, so when the adsorbent becomes saturated with the adsorbate, the former maybe specially treated to release the adsorbate. The latter would be recycled or treated for disposal as required. Among the adsorbents used are activated carbon, alumina or silica gel.

5.20.3 Condensation.

When the pollutant gas has a condensation temperature above that of the carrier gas, it is possible to pass the gases into a condenser kept at a temperature just below that of the condensing gas. The condensing gas will form droplets which can be removed. This method is not often used as the cooled carrier gas will not disperse as well as the uncooled gas on discharge from the stack, as the relative density will be higher and upward movement of the gas will be reduced.

5.20.4 Combustion.

When the pollutant gas is combustible, it maybe burnt in an afterburner. In the direct flame afterburner, additional fuel and air are fed in to raise the temperature to burn the pollutant. In the catalytic combustion system, the gases are passed over selected catalysts that oxidise the pollutants in the presence of air.

5.21 The Efficiency, Application and Choice of Equipment.

Before the choice of the most suitable air pollution control unit is made, a detailed study of all factors must be made. Among the factors to be considered are :

1. the concentration of the pollutant in the gas to be discharged;
2. the concentration allowed in the discharge gas;
3. the volume of gas to be treated;
4. the pollutants to be removed;
5. the value of the pollutant if it was recovered;
6. the compatibility of the unit with the existing process, stack etc.;
7. the finance available.

It is not possible to state exactly what removal efficiency can be expected from a particular unit. The table below gives an indication of the particle sizes that can be removed by the various methods available for the removal.

TABLE 7: COMPARISON OF VARIOUS TYPES OF GAS CLEANING EQUIPMENT.

TYPE	MINIMUM PARTICLE SIZE in Microns	TOTAL ANNUAL COST	PRESSURE LOSS FOR 90% REMOVAL
Settling Chamber	50	Low	Very Low
Cyclone	5 – 25	Medium	Medium
Scrubber	1 – 10	High	Medium
Fabric Filter	1 – 10	High	Medium to High
Electrostatic Precipitation	1 – 10	High	Low

5.22 Water Pollution Aspects.

Whenever water is used in the processes of air pollution control, a liquid effluent is produced that must be disposed of. Usually this liquid will need treatment before disposal into a receiving water and will often need treatment before discharge into a municipal sewer. It may be seen that the attenuation of an air pollution problem may produce a water pollution problem.

Among the water pollutional aspects of effluents from air pollution control equipment are :

1. The suspended solids content. As the object of using water in some air pollution control units is to capture solid particles it is obvious that the effluent will contain these solids;

2. The dissolved solids content. Depending on the gases or solids being removed from the gas stream, some or all of these solids may dissolve in the water and so increase the dissolved solids content.

3. The oxygen demand. Again depending on circumstances the suspended or dissolved materials added to the water may impose an oxygen demand on the receiving water or on the wastewater treatment works. This oxygen demand will have to be satisfied by chemical or biochemical means.

4. The content of inhibitory substances. Certain effluents may contain materials that will inhibit

the biochemical oxidation of either the effluent itself or inhibit the treatment process used to treat a mixture of that effluent and any other effluent

The overall effect of the effluent from an air pollution control unit on the process used to treat the effluent either alone or in admixture with other effluents will depend on the following factors :

5. the concentration of the impurity in the water;

6. the nature or chemical properties of the impurities;

7. the process used to treat the effluent;

8. the ratio of the particular effluent to the total volume of effluent being treated (where applicable);

9. the cyclical variation in quantity and quality of the effluent, etc.

In certain cases, such as where as magnesium oxide slurry is used to absorb sulphur dioxide, the bulk of the absorbant liquid will be recycled. There will often be a need to waste a small percentage of the absorbant liquid to prevent an irreversible deterioration taking place in the quality of the absorbant. When this is the case it is preferable that if the wasted liquid is accepted into the sewer, that this liquid be wasted continuously at a small rate over a long period.

5.23 The Control of Air Pollution.

The effects of air pollution have been detailed in earlier sections. A number of sources have been listed as well as the equipment that can be used to reduce the air pollution potential of these sources. It was mentioned that before one instals an expensive piece of equipment to reduce the air pollution, one must know to what quality the air need to be cleaned. To do this, standards must be laid down. In order to ensure that these standards are maintained, monitoring of the air is essential. In order to force compliance with the standards, effective legislation is required.

5.23.1 Legislation.

The enforcement of air pollution control can only be achieved through legislation and a body to administer this legislation. In theory, a person whose property has been damaged as a result of air pollution caused by another person has recourse through private law. In practice this has certain problems, amongst these are: it is usually almost impossible to attribute the damage to only one person or source, the damage may be due to the end product if the reaction between the contaminant discharged and other substances in the air.

The Public Health Act 36 of 1919, classified air pollution as a statutory nuisance to be dealt with by local authorities. Enforcement has been rendered difficult since proof that a particular source cause of the air pollution and that the air pollution was injurious to health, is often very difficult to obtain.

The Air Pollution Prevention Act 45 of 1965, defines scheduled processes. Control is established in that no person may carry on a scheduled process unless he is the holder of a registration certificate. This certificate is granted by the Chief Air Pollution Control Officer of the Dept. of Health, if he is satisfied that the best practical means are being adopted for the control of air pollution caused by the scheduled process concerned. Best practical means may be summarized as being the measures which are technically feasible and economically possible, bearing in mind the well-being of the people in the area of the plant.

5.23.2 Standards.

With the exception of the density of smoke emitted from a fuel burning appliance there are no emission standards in this country. It was considered impractical to introduce a system of emission standards to control industrial air pollution because this would depend on the techniques that were available. For this reason, the concept of Best Practical Means (BPM) was introduced in the Act and in its amendment Act 17 of 1973.

In the USA, the Clean Air Act of 1970, the Environmental Protection Agency is charged with drawing up the Natural Ambient Air Quality Standards. Once the standards are set, each state must develop a plan for achieving and maintaining the prescribed ambient air quality

5.23.3 Administration.

The installation and maintenance of a control programme.

The first step in any programme is to determine which processes are scheduled processes in terms of the Act 45 of 1965, or which could cause a public nuisance or have an adverse health effect. For the scheduled processes it will be necessary to obtain the registration certificate referred to in section 5.23.1.1 If a person fails to comply with the conditions of the certificate, the Chief Air Pollution Officer may suspend or cancel the certificate. To ensure that this does not happen. it is important that the holder of the certificate initiates and maintains a control and monitoring programme.

This will entail checking that the air pollution control equipment is maintained in a satisfactory operating conditioning. Sampling of the discharge gases and analysing for the appropiate pollutants is a highly specialised task and needs to be done properly or not at all.

5.24 Dissemination of Information and Education Programmes.

The long term effects of air pollution have been studied and some answers have been obtained but there is still much to be learnt. Each person living contributes to air pollution, some more than others. It is unjust to blame only industrialists for air pollution when one drives a car or burns garden refuse.

Water for drinking purposes can be produced from water of virtually any quality, although the less pure the source, the higher the treatment costs. However with air, once it is polluted in bulk there is nothing one can do to purify it, only nature has this ability. If necessary, one can do without water for several hours or even one or two days, but one cannot survive without air for more than a minute or so.

As much air pollution is attributable directly to the man in the street, it is important to make one aware of costs and the detriment to health of air pollution. The earlier in a person's life that he is made aware of this the better. It is important not to become a prophet of doom, the facts must be separated from the sensationialism.

5.25 The Measurement of Air Pollution.

The sampling of pollutants and their subsequent analysis are the corner stone of air pollution control. The time and effort expended to define the purpose of the sampling and the method of analysis are amply rewarded by productive results. Inadequate sampling or incomplete analysis of pollutants produce results that may not be reliable in defining the whole problem and may in fact give results that are totally incorrect.

5.26 The Purpose of the Measurement of Air Pollution

These are 2 main purposes of air pollution measurement :

1. to determine the quality of the air, as a mass;

2. to determine if the air pollution control equipment is working satisfactorily.

The quality of the air as a whole is being determined this can be out in the open, in the basement of a parking garage, inside a factory or even in a manhole of a sewer. If the air in the sewer contains more than a trace of hydrogen sulphide, then one must not enter that sewer until the gas has been removed. If on the factory floor the concentration of a certain gaseous material exceeds the safe value then one must install better ventilation. In the extreme case, one may have to consider the evacuation of an area if the concentration of one or more pollutants exceeds the safe value.

When a specific air pollution source is being monitored and the pollutant concentration of the discharged gas measure, this can be used to show whether or not a specific source is a source of concern or not. The measurements can also be made to determine the efficiency of a unit of air pollution control equipment and to see if the unit does what its makers claim it would do.

5.27 Monitoring a Source.

The purpose a source sampling is to obtain as accurate a sample as possible, of the material entering the atmosphere, at a minimum cost.

Monitoring a source meaningfully is actually a very difficult task. Among the problems encountered are:

1. getting a sample that is representative of the total flow. Samples are usually of the order of 1 to 100 litres, whereas the source could have a discharge rate of 50 000 m^3/hour;

2. deciding which is the best method of sampling to use;

3. having a sufficiently precise and accurate method of determining very low concentrations of solid, liquid or gaseous material;

4. ensuring that the materials in the sample are not altered in any way between the taking of the sample and the analysis of the sample;

5. ensuring that the gas composition and flow rate are representative of the time period chosen.

5.28 Measurement of Selected Pollutants.

Brief details of the methods available to determine the concentration of certain pollutants are given below:

5.28.1 Smoke.

This will usually be analysed for by determining the opacity of the smoke. The first schedule to the Act 45 of 1965 gives examples of 0 to 100% blackness in steps of 20%, but no indication is given of how to use this schedule. There are smoke meters available commercially, with the Hartridge being perhaps the best known.

5.28.2 Dust.

This can be measured in two main ways. The one is to collect the dust that settles on a known area and weigh it. The other is to draw a sample from a stack and through a filter and determine the gain in mass.

5.28.3 Sulphur Dioxide.

For gaseous pollutants, the analysis of the sample is more time consuming than sample collection because chemical solutions are used in the collection of the sample rather that a filter. As the gas goes through the sampling apparatus, other sulphur containing compounds such as sulphuric acid and sulphur trioxide are removed, the sulphur dioxide is absorbed in hydrogen peroxide and the sample volume of gas is determined. The sulphur dioxide to oxidised to sulphuric acid and its concentration is determined acidemetrically.

5.28.4 Nitrogen Oxides.

A similiar piece of apparatus to that used above is used here, the nitrogen oxides are absorbed in a solution of hydrogen peroxide and sulphuric acid. The nitrogen oxides are oxidised to nitrate and are determined as such and expressed as NO_2. Nitrogen dioxide may be determined using a nondispersive ultra-violet analyser.

5.28.5 Carbon Monoxide.

The carbon monoxide is determined using a non-dispersive infra-red analyser. Since water vapour and carbon dioxide interfere, they must be removed before analysis.

5.30.6 Hydrocarbons.

Here a gas chromatograph using a flame ionisation detector may be used.

5.29 Radioactivity and Resultant Pollution.

5.29.1 Types of radioactivity.

All radioactivity is associated with some form of energy emission which causes ionization i.e. the breakup of an atom into negatively and positively charged particles called ions.

In the natural decay of unstable atoms, energy is produced. Such decay of an atom to a more stable form is accomplished by the emission of either an α particle with some associated gamma radiation, or a ß particle with associated gamma radiation. From a practical standpoint, material that is naturally decaying may have both a parent and daughter atom decaying at the same time, thereby making it possible for materials such as radium to show emissions of α, ß and gamma radiation. The decay of one single atom cannot release α and ß particles simultaneously. The most commonly considered types of radioactivity are : α particles, ß particles, gamma ray, neutrons and x rays.

5.29.2 The alpha particle.

This is similiar to the nucleus of a helium atom and has a mass of 4 A.M.U. and a charge of + 2. It has a high degree of specific ionization, i.e. it gives up its energy very rapidly. It will penetrate only about 0.1 mm into the skin. It is thus most critical internally where it can cause damage in a very localised area. From an external point of view, it does not resent a real hazard.

5.29.3 The beta particle.

This is similiar to the electron (ß particle), but the + particle can also be found. The latter is of a similiar mass to the electron but has a positive charge and is called the positron.

Nearly all naturally occurring particles are the particles i.e. electrons. These particles will travel up to 10 mm in skin. Externally, it can cause ulceration of the skin and is primarily responsible for radiation burns.

5.29.4 The gamma ray.

This is a photon of energy and is part of the electromagnetic spectrum having a very short wave length of between 0.l and 0.000l nanometre - . (visible light being 400 to 700 nanometre). It does not have an electric charge. It can travel a long distance and can pass through a persons body. The gamma ray is similar to the x ray. The major differences are that the radiation is born within the nucleus of an atom whereas x rays are associated with the kinetic energy imparted to the electron located in the outer orbit of the atom. X rays have a slightly longer wavelength and are not quite as penetrating

5.29.5 The neutron.

This is one of the elementary particles found in the nucleus of an atom. Its mass is similar to that of a proton but it does not have an electric charge. This lack of a charge enables it to pass through matter more easily than the charged particles. It can induce radioactivity by transmutation of the elements.

5.30 Sources of Radioactivity.

Radio-active materials which are the source of radioactivity are either naturally occurring or man-made.

5.30.1 Naturally occurring radioactivity.

Probably the best known naturally occurring radio-active material is uranium. Actually, the naturally occurring uranium is 99.3% of atomic mass 238 and only 0,7% of atomic mass 235, which is capable of sustaining a chain reaction. Radium is used to make luminous dials.

Polonium has been used as a static eliminator, although its use is declining. The naturally occurring radioactivity may be used to estimate the age of an article or rock etc. Among the methods used are : Carbon -14, Potassium-Argon, and Uranium-Lead.

5.30.2 Man-made radioactivity.

Over 1 000 radio-active isotopes have been made. Many of these were probably at one time naturally occurring but done to their relatively short half-life they have already disappeared from the earth. The enrichment of uranium i.e. increasing the proportion of U235, could be considered as man-made radioactivity. Specially made radio-active materials such as iodine -131 and phosphorus -32 are used to diagnose and treat diseases. Radio-active sources can be used to sterilise sludges.

The major source of man-made radioactivity is presently from nuclear power stations. Plutonium -239 is used in some nuclear reactors. Some years ago, many countries tested various types of nuclear weapons in the atmosphere. These resulted in the formation of large quantities of radio-active materials being lifted into the atmosphere. The materials were dispersed over a wide area and eventually fell to earth as fallout.

There is no dout that this atmospheric testing has raised the background level of radiation to which all materials on earth are affected.

5.31 The Biological Effects of Radiation.

The public health significance of any source of radiation is associated with the biological damage to the cells due to ionization. This is true regardless of the type of radiation causing the damage. These effects are categorized as:

1. somatic damage that occurs to the individual within his life span;

2. genetic effects to our future generations as a result of changes in the mutation rates of the genes.

5.31.1 Damage to the body and to cells.

Somatic effects may be associated with acute, heavy doses received over a relatively short period of time as that associated with a nuclear accident. The potential for the general population receiving massive doses of radiation is fairly remote and therefore poses no real public health problem. Since these notes written originally written 3 Mile Island and particularly Chernobyl have changed this somewhat.

Light, chronic exposure over long periods of time is always a possibility with the expanding use of ionizing radiation. The effects of such exposures, chronic or acute, are dependent directly on the total radiation dose. Such effects may be manifest as an increase in cancer or cataract formation or shortening of life span. For example, within a year after the discovery of the x-ray tube, medical reports appeared of severe erythema of the skin and cases of epilation (loss of hair) resulting from prolonged exposure to x-radiation. Continued case reports of overexposure to ionizing radiation identified not only destructive skin changes, but systemic injuries which included damage to the blood-forming organs, production of malignancies, possible reduction in fertility and life span, as well as genetic changes. Cause and effect relationship of radiation exposures is complicated by the fact that similar effects may be caused by nonradiation influences in our environment.

The biological effect of radiation is basically related to the damage that may be done to a living body cell which is the fundamental unit of life itself. Two of the effects that should be considered are the internal radiation hazard and the external radiation hazard.

The internal radiation hazards are basically related to some system or mode of entry where radioactive material may be taken inside the body and thereby allowed to do damge to living cells. There can be a reduction in the leucocyte population. There can also be an increase loss of water via the kidneys which can lead to naseau and vomiting etc. Such internal radiation effects are accomplished by the following.

1. The breathing of particulate matter that may be associated with ionizing radiation such as the radioactive devris from fallout of a nuclear weapon explosion or the radioactive particluates emitted from the stack gases of a nuclear reactor plant;

2. Radioactive material that may not be inhaled could find its way inside the body by means of food supplies that have become contaminated by radioactive fallout. Plant life may pick up radioactive material and transmit it to the eating table unsuspected and unidentified.

3. Radioactive material may be absorbed through the skin into the bodys system and lodge in areas where the effect of ionizing radiation may do damage to living cells.

4. Entry through cuts or abrasion of the skin may allow radioactive particulates to travel through the bloodstream, lodging in portions of the body where ionizing radiation can do damage depending on its energy and half-life.

   The external effects include loss of hair, a darkening, blistering or burning of the skin depending on the dosage received. Cataracts of the eyes may be caused. Higher doses can cause blindness.

5.31.2 Genetic Effects.

Genetic effects are basically related to the alteration of the mutation rate of the genes carried by man's reproductive cells referred to as "biological blueprints". Any change in the mutation rate is considered to be harmful.

The inheritance mechanism is by far the most sensitive to radiation of any biological system in the human body.

Geneticists are generally agreed that :

1. A threshold dose is apparently not required to produce a deleterious effect;

2 Once damage is done, it is largely irreversible;

3. The effects are probably cumulative over the years;

4 The result of genetic damage is to produce deviations from the norm in the offspring of the irradiated parents and these deviations or mutations are almost always undesirable. Their offspring are called mutants;

5. The mutants are characterized in general as follows: decreased longevity, increased susceptibility to disease, decreased fertility and usually recessive or masked effects so that the first-generation off spring do not bear the full brunt of the genetic damage. Some of these effects are already seen in man as a result of large exposures of persons surviving the nuclear explosions at Hiroshima and Nagasaki. Radioactive materials is a method used for consideration of disposal by holding such materials for a specific number of half-lives until the total radioactivity has decayed to an insignificant amount and can thereby be disposed of safely. This concept may also be used for the disposal of radioactive Iodine, which has a half-life of 7 days by holding it for a specified number of half-lives for safe disposal.

5.32 The Measurement of Radioactivity.

Radiation is not detactable by our normal sensory apparatus. It cannot be seen, heard, felt, smelled, or tasted. Furthermore, it is not too easy to construct instruments that can measure radiation directly. It has, therefore, been necessary to develop a system for the design and construction of radiation detection instruments that basically measure the effects of radiation on matter. The most easily identified effect is that of ionization. That is the production of charged particles or ion pairs which can be quite readily detected. All instruments used for the detection of radiation are basically designed along two fundamental lines.

One type of instrument provides for the rate at which radiation is received at a point where the detector may be located; these are known as rate-type instruments, and will read in terms of milliroentgen per hour, counts per minute, or disintegrations per second. The other type of instrument will measure cumulative doses of radiation received for the period of time that the device may be used. These are known as dose-type instruments. Rate-type instruments are dependent on the applied voltage and the ability to collect ion pairs formed in the media being ionized. The minimum required voltage for the construction an instrument of this type is the ionization chamber region with a required applied voltage of 200 V. Here the ion pairs are collected by the electrodes.

Depending on applied voltage, radiation rate-type instruments go through a zone of proportionality, up into the Geiger-Mueller region utilizing applied voltage of 900-1 000 V. Another rate-type radiation detection instrument depends on the transfer of energy from radiation to a phosphor that may be responsible for the reemitting of energy in the form of visible or near-visible light. Such instruments are known as scintillation detectors. The phoshphors that may be utilized in such instruments for light emission become very specific for the measurements of the different types of radiation that may be encountered such as α, ß and gamma.

Dose-type instruments measure the accumulated received by the device without relation to time. The most commonly used dose-type instrument is the film badge utilzed by personnel working in fields of ionizing radiation to evaluate the effect of such body exposure. Such film badges or photographic emulsion plates can be utilized by different absorbers to measure α, ß, gamma or x-radiation. Neutrons are measured with special type film that will separate the sulfur from the emulsion leaving sulfur-iodized tracks won a film. These tracks can then be counted and related to neutron exposure. A more sophisticated type of dosimeter for personnel and environment monitoring, the thermal luminescent dosimeter (TLD), has come into use in more recent years. This device has the characteristics of accepting radiation on a specific material which, when heated to a specified temperature will release the stored information by the emission of a light that can be read and thereby indirectly relates to the radiation dose received.

PART 6

SOLID WASTES

This section deals with the various sources of solid waste and the various aspects of their disposal

6.1 Domestic, Garden and Recreational Site Waste.

Household or domestic solid wastes are a mixture of both organic and inorganic compounds. Among the organic wastes are reject and left-over food, paper wrapping, plastic bags, and newspapers. Among the inorganic wastes are tins, bottles, and discarded household items such as toasters, plates and the remains of coal fires.

Garden wastes will consist of weeds, leaves, grass cuttings, branches, stones and even whole bushes.

Wastes from recreational areas will be similar to domestic solid wastes with the accent on food, food containers and drink containers.

Usually more than 50% by mass of the wastes will be organic. The rate at which these organic materials will decompose will vary from a matter of days in the case of sugars and starches, to weeks in the case of meat, months in the case of branches and many years in the case of plastics. Whether this decomposition will proceed nuisance-free or produce vile odourss, will depend on whether aerobic or anaerobic conditions are maintained. This aspect will be covered later in composting.

6.2 Industrial and Commercial Wastes.

Industrial wastes will vary very widely in character and composition. Examples of industrial wastes are; used packing materials, broken or reject tins and bottles, paper, dust and other particulate matter from air pollution control plants, and sludges from industrial effluent treatment plants. The latter two examples illustrate the link between air pollution, water pollution and solid waste pollution. Here one can see that in trying to reduce one form of pollution one can create another form. In the next section, it will be shown that the unsatisfactory disposal of solid wastes can give rise to air pollution and/or water pollution.

Another form of industrial waste which can create major problems is that from mining operations. These problems can range from the sheer mass of solid to be handled, to the air pollution problem of dust being generated and blown about, to the water pollution problem of acid leachate.

The reference above to decomposition rates of various materials is equally applicable to industrial and commercial wastes.

Commercial wastes can be of a type similar to domestic e.g. food wastes from restuarants etc., or similar to certain industrial wastes e.g. wastepaper, wrapping materials, computer print-outs etc.

6.3 Water and Wastewater Sludges.

There are several sources of solid or semi-solid wastes that are generated as the result of treatment of water or wastewater.

6.3.1 From a water treatment works, these are likely to include:

1. branches, leaves etc retained on the inlet pipe screens;
2. silt and sand collected from the bottom of pre-settlement basins or tanks;
3. coagulated and settled solids from the main sedimentation.

6.3.2 From a wastewater treatment works, these are likely to include :

1. screenings;
2. grit;
3. grease;
4. primary, secondary and tertiary sludges either untreated or treated.

These solids have been removed from or created from processes of improving the quality of either the water or the wastewater. It is important that these solids are safely disposed of in order that they do not cause pollution elsewhere, perhaps even in the catchment area from which they were first removed.

6.4 The Pollutional Effects of the Disposal of Solid Wastes.

No matter how carefully a solid waste is disposed of, there will always be resultant pollution. Take the simple example of burying a lump of concrete in the back garden. The mere action of removing the ground cover and in digging the hole has disturbed the area and therefore pollution has taken place. Admittedly in this case the amount is negligible and is unlikely to affect anyone, except possibly the next person who tries to plant a tree in exactly the same spot. At the other end of the scale, the dumping of a drum of weedkiller near a river bank can in the future cause the death of a large number of fish kilometres downstream from the spot where the drum was dumped.

The purpose of the safe disposal of solid wastes is to reduce the amount of pollution, derived from the disposal of such wastes, to a most practical minimum.

6.5 Resultant Water Pollution.

The liquid passing out from a solid waste disposal site is called leachate. The leachate will be generated both from excess moisture in the materials being tipped and from rainfall passing through the tip.

The leachate may move vertically or horizontally. The careful site selection and attention to design considerations can prevent or minimize leachate contamination of groundwater and surface water. The leachate can be highly polluting. The following table gives the range of constituent concentrations that can be found.

TABLE 8: TYPICAL VALUES FOR CERTAIN CONSTITUENTS OF LEACHATE

PARAMETER	TYPICAL CONCENTRATION RANGE
COD mg/l	1 000 - 50 000
Total Nitrogen as N mg/l	5 - 1 000
Total Phosphorus as P mg/l	1 - 100
Total Dissolved Solids mg/l	500 - 50 00
Iron as Fe mg/l	1 - 1 000

The quantity and quality of the leachate depends on several factors which will affect the area that is polluted by the leachate. The steps that can be taken to restrict the movement of this leachate will be discussed later.

6.6 Resultant Air Pollution.

Gases are produced by the decomposition of organic matter in the material being tipped. The major gases will be methane and carbon dioxide. Traces of ammonia, hydrogen sulphide and certain volatile organic decomposition products will also be found. The amount and composition of the gases produced depends on the quantity and characteristics of the waste being tipped and the mode of operation of the tip site.

The gases may be move vertically through the tipped material and disperse into the atmosphere. Odours may occur when the concentration of the volatile organic vapours is high. The gases may also move horizontally if horizontal impervious layers are present in the tip. The horizontal movement of gases may be stopped by installing ventilation trenches on the perimeter of the tip site.

6.7 Disposal Methods for Various Types of Waste.

6.7.1 Domestic Waste.

The two most commonly used engineering methods are the area method and the trench method. While other methods of landfill operation do exist, they may be considered as modifications or combinations of the two basic methods of operation.

1. The trench method.

   This is sometimes called the cut and fill method, because a trench is excavated below the ground surface and the solid waste is placed into the trench and covered. There are many modifications of the trench method which depend on the topography of the land.

2. The area method.

   Here the waste to be dumped is tipped above the ground level. There could be some excavation to provide soil to form compartments or to provide the final soil cover. The need to form compartments is elaborated in section 6.10.

In both cases, as much compaction as possible should be made as this both increases the life of the site and reduces gas migration and reduces the rate of leaching.

6.7.2 Industrial Wastes.

As was seen earlier these can vary from domestic-type wastes such as paper, cardboard, cans etc. to toxic or hazardous substances. The domestic type wastes and the non-hazardous wastes may be disposed of in a manner similar to the domestic wastes. The disposal of hazardous wastes is covered later in section 6.11.

6.7.3 Public Resorts.

These wastes are also basically domestic-type wastes, but will consist mainly of paper, bottles and tins. Where the public resort is near a town, the normal domestic methods will be suitable. Where the public resort is out in the country, one can use the trench method except that a hole will be more suitable. It may often be advantageous to burn each load of waste collected to prevent scavenging by animals or persons.

6.8 Land Filling.

The principles covered in this section apply equally well to domestic, industrial or public resort wastes irrespective of whether they are tipped using the trench method or the area method. There are many factors that have to be considered before the final choice of the site is made. Amongst the factors that must be considered are:

6.8.1 The Choice of Site.

As most tip sites are designed to be used over a period of years and more particularly because the effects of a badly sited or badly operated tip may be felt for many years even after the closure of the tip; it is most important that the tip be sited in a suitable place.

6.8.2 Site Life and Size.

The life of the site is determined by the size, the quantity and charateristics of the solid being tipped and the tipping procedure. Allowance must be made for access roads and soil stockpiles.

6.8.3 Topography.

Since a relatively flat site could pond and an excessively steep site could erode and cause operational difficulties, a tip site is usually limited to areas that have slopes between 1 and 20%. The landfill method could be adapted to the prevailing topography.

6.8.4 Surface Water.

The amount and nature of surface body waters near the area to be used are a significant factor in site selection as they can affect the quantity of leachate produced.

6.8.5 Soils and Geology.

The role of soil in a landfill is to provide cover, alternate potential contaminants and to control runoff and leachates. The chemical and physical properties of the soil will determine how effective it will be in performinq these roles. A clay soil would have a low permeability such as 10^{-7} cm/second, whereas a coarse sand could have a permeability of 10^{-2} cm/second.

6.8.6 Groundwater.

The depth of the groundwater table relative to the base of the tip site is most important. If the water table rises into the material that has been tipped, then as the water table drops again the water will extract soluble materials out of the tip. As was seen in 6.5 above, this leachate can be highly polluting.

It is most important that the tip be sited so that the groundwater never enters the tip. If the groundwater is abtracted for drinking purposes, it is important that the tip site is not built within the recharge zone of the aquifer. Some authorities recommend that the distance between the bottom of the tip and the highest level of the groundwater should be at least 5 metres.

6.8.7 Vegetation.

The amount and type of vegetation, on a prospective site should be considered. Although the vegetation can serve as a buffer and reduce dust, noise and odour as well as conceal the site; excessive vegetation on the site can increase operating costs.

6.8.8 Site Access.

In order to reduce operating costs, it would be preferable to use existing roads as far as possible. Hauling material over hills will increase costs.

6.8.9 Land Use.

The use of the land after closing down the site can influence the procedure of filling to be adopted.

6.8.10 Costs.

Both the capital and the operating costs must be considered in order to determine the total annual costs of running the tipsite.

68.11 Distance from Human Habitation.

No matter how carefully a tip is operated it is impossible to prevent fly breeding and odours being generated. The distance relative to the nearest houses, at the end of the life of the tip, must also be, considered. The wind directions must be taken into consideration.

6.9 Stormwater Diversion.

In order to reduce the quantity of leachate produced by a tip site, it is necessary to limit the amount of water entering the tipsite. Although the amount of rainfall falling on the tipsite cannot be controlled, the stormwater can be led off the tip in such a way as to reduce ponding on the tip. It is also important to prevent soil erosion and loss of the soil cover on the tip.

Rainwater falling adjacent to the tip must be prevented from running onto the tip. This maybe done using stormwater diversion ditches.

6.10 Compartmentalization.

In order to reduce the movement of gases and leachate, it is advisable to deposit the solid waste in numerous compartments or cells. The wall, floor and roof of each compartment being of soil.

Due to the varied nature of solid waste it is generally not possible to compact it to the degree that soil may be compacted. This results in solid waste usually being more permeable than soil. By building compartments, the horizontal and vertical movement of gases and leachate is reduced. The more impervious the soil used in the construction of the compartments the better.

6.11 Hazardous Substances.

Certain wastes, usually of industrial origin, should not be tipped into solid waste tipsites in the same manner as normal domestic wastes. Amongst the reasons for this are :

1. the material may pass out of the tip in the leachate and pollute the underground water and render the water useless for drinking or industrial purposes or harmful to aquatic life;

2 the material may react with substances in the tip and produce toxic materials, or may cause a fire or explosion.

Depending on the nature and quantity of the material to be disposed of, there are several disposal procedure available.

6.11.1 Detoxification of Hazardous Substances.

Some substances may be modified or detoxified by reaction with other substances. In some cases they may then be tipped in the normal manner.

6.11.2 Special Disposal Sites.

Some substances may be tipped in special clay or plastic-lined disposal areas. The lining prevents any leachate from passing out of the tip. One must be sure that the area inside the lining does not become saturated with water and cause an overflow of contaminated water.

6.11.3 Incineration.

Some substances can be incinerated and the residue may then be disposed of in one of the other listed methods.

6.11.4 Burial in Watertight Containers.

Some substances may be placed in stainless steel drums which may or may not have a concrete shell cast around them. They may then be disposed of by one of the listed methods.

6.12 Liquid or Semi-liquid Wastes.

Where the liquid contains water, it may be allowed to evaporate in specially constructed evaporation pans in order to reduce the volume to be further treated. Prior to disposal the liquid may be absorbed into a suitable solid.

In the sections above, one has been concerned with disposing of the solid waste. No thought has been given to the possibility of recovering some value from the waste. A large percentage of the solid waste is organic in nature, the exact proportion depending on the source of the waste. There are two main ways in which it is possible to recover some value from the organic fraction of the waste. These are by composting the waste and separating this compost and selling it for use on land and by buring or pyrolysing the waste and putting the recovered heat to some useful purpose. These two aspects are dealt with in sections 6.13 and 6.14 below.

Other materials worth recovering are paper, cardboard, wood, metals, plastics and glass. In all cases it is advantageous if these recoverable commodities could be separated at source. This is often done in the industrial areas, but almost never in the residential areas. Unfortunately the cost of separating and recovering these products often exceeds their salvage value.

6.13 Composting.

Materials such as paper, wood, food-scraps, garden waste and wastewater treatment works sludges will compost readily and will usually render a useful product. Provided the time and temperature of the composting are sufficient virtually all pathogenic and parasite organisms will be killed off and a harmless product will be produced.

The use of a well composted material is beneficial to the soil. It is unlikely that the sale of the compost will entirely cover the cost of producing it, but one advantage is that the life of the tipsite is extended since less material is tipped.

6.14 Burning and Pyrolysis.

Burning may be undertaken as a means to reduce the volume of the material to be tipped. Burning of solid waste is usually results in air pollution because of the inhomogeneity of the waste. Provided the organic content is high enough and the moisture content is low enough, the waste will be autothermic i.e. once ignited it will continue to burn without supplementary fuel being needed in the main burning area. Supplementary fuel may be needed in the afterburner.

As the cost of fuel rises so the costs of burning or incineration where supplementary fuel is required becomes less attractive, unless heat recovery is possible. A process that is receiving more attention these days is the use of refuse - derived fuel (RDF) where refuse is pulverised and then used as a fuel to fire a boiler,produce steam for heating or for the generation of electricity.

Pyrolysis may be defined as chemical decomposition by means of heat. In this process the refuse is heated in the presence of less than the theoretical amount of air needed for complete combustion. The discharge gases consist of combustible gases, tars and oils. The residue consists of a solid char. Both the discharge gases and the solid char have appreciable heating value and can be used to produce steam.

Pyrolysis is a sophisticated process that uses expensive equipment and is usually suitable only for larger cities.

6.15 Closing Down of a Tipsite.

It is advantageous if the area occupied by the tipsite could be put to a beneficial use. Due to settlement and the possibility of methane permeating into basements, it is not usual to erect buildings on an old tip site. It is usually feasible to lay out a park or a public open space. Here the odd area of settlement will not be a nuisance unless rainwater ponding occurs.

The amount of settlement likely to occur is very difficult to predict as this depends on many factors.

Amongst these are :

1. the bulk density of the material tipped;
2. the soil cover;
3. the depth of material tipped;
4. the nature of the material tipped, etc.

Before a tip site is finally grassed, it will be necessary to grade the area to prevent ponding.

It is important that the final soil cover be at least 300 mm and preferably 500 mm deep.

It will be necessary to replant vegetation on the top soil. This will enhance the beauty of the site, prevent soil erosion and reduce the infiltration into the tip. Leachate can cause pollution of underground and surface water if not properly controlled, while gas can stunt or kill vegetation.

6.16 The Monitoring and Control of a Tipsite.

In order to monitor the effect that the operation of a tipsite has on the environment it is essential that background information be obtained.

Most of the information required will relate to the underground water. The information needed in respect of groundwater will include :

1. the depth of the groundwater and the seasonal fluctuations;
2. the quality of the groundwater and the seasonal fluctuations;
3. the groundwater stream line patterns.

It is essential to sink boreholes around the tipsite and to regularly monitor the groundwater to determine if the leachate is affecting the qroundwater. This is particularly important when someone is using that groundwater for drinking purposes.

When a leachate collection system is installed, this must also be regularly monitored to determine if the leachate needs be treated.

If it is found during the use of tip that the leachate is affecting the groundwater, then it may be necessary to modify the tipping procedure.

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