MICROBES: OUR UNSEEN ALLIES IN THE BATTLE AGAINST POLLUTION

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MICROBES: OUR UNSEEN ALLIES IN THE BATTLE AGAINST POLLUTION

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Vice-Chancellor, Your Excellencies,
Distinguished Ladies and Gentlemen ;

It is my pleasant duty and honour to address this special gathering on this occasion in the series of the University of Lagos Inaugural Lectures.

My purpose in this lecture is to discuss what is known about environmental pollution, to identify the major known sources of pollution, to highlight the scientific, technical, economic and legal problems involved in efforts to combat pollution, and to emphasise the important role micro-organisms play to make the environment free of pollutants.

Introduction

What is pollution? Pollution is defined by the dictionary as the act of making foul or unclean; that is, the act of making dirty. To the bacteriologist who is interested in *stream pollution,* it means the discharge of wastes into a river with consequent increase in the bacterial count of the water to a degree that the water might be unfit for human consumption. The sanitary engineer considers pollution from the standpoint of water quality. The sportsman may interpret stream pollution by its effects on the aesthetic value of stream. The biologist, however, sees pollution as *the appearance of some strange, enviornmental quality for which the exposed community has inadequate information and is thus incapable of an adequate response* The strange environmental quality, usually referred to as the *pollutant,* is any substance which has a detrimental effect on man and his environment. In reality, all the above definitions are inter-related and are mere attempts at indicating the presence or expressing the degree of pollution.

Very few people seem to realise that the story of pollution dates far back into history. Ever since the existence of the Early Man, his course of civilisation has consistently involved the degradation of the environment. He used fire as a tool to drive game and to clear forest land for grazing. But unfortunately, he did not realise that fire had its non-desirable effects – the smoke polluted the air, and the incompletely-burnt materials got washed into streams and the streams consequently became polluted.

The earliest records of pollution included those of Otto Freising who wrote in the 12th Century that when Frederick Barbarossa's armies arrived in Rome in the summer of 1167, they found that the air in the entire city had become laden with *pestilence* and *death.* Otto Freising was clearly referring to the unhealthy state of the air in the city; a condition we nowadays describe as *air pollution.*

It is perhaps difficult to say how much of water pollution was known in medieval ages, but in 1800, Samuel Taylor Coleridge wrote of the River Rhine:

"The River Rhine, it is well-known,
Doth wash your city of Cologne;
But tell me, what power divine
Shall henceforth wash the River Rhine?"

Whatever poetic point Mr. Coleridge is making in this quotation, one message is clear. The River Rhine was, according to him, polluted.

This brief historical survey shows that the problem of pollution is not a recent phenomenon.

Although the existence of pollution was recognised as early as in the 12th Century, its effect was neither as apparent nor understood as it is today. The dangers of

pollutants to man and his environment are so real today that it requires no effort to explain to the non-technically minded what pollution involves. The abandoned carcasses of automobiles, empty beer cans, empty plastic containers, heaps of rubbish or garbage, streams and ponds and lagoons overloaded with *sewage* with its obnoxious *odours* and flavours, oceans with surface films of oil, and *dusty* cities arising from concentrated combustions are but few indications of gross environmental pollution. A less apparent but more pathetic example is that as a result of combined effects of the unfriendly environment and the stress of city life, a good percentage of the population in most cities is virtually indistinguishable from the inmates of mental hospitals.

The present dangerous, unhealthy condition of the environment has grown from three inter-related factors. The first is the rapidly expanding *population* of man on a planet that has a limited capacity to absorb its garbage. The second is man's spectacular *progress* in the technological and scientific fields during the present century; the third is the greater material expectations and *energy consumptions* of many societies which put pressure upon industries whose products and by-products contribute significantly to pollution.

Types of Pollution

There are various forms of pollution, chief among which are water, air, vegetation and soil pollution.

One of the impacts of a city on the environment is the dumping of wastes at a rate that exceeds the natural capacity of the ecosystem to degrade or breakdown these wastes by itself.

Water Pollution

From earliest times, streams, lakes, lagoons and seas have been a natural place to discard domestic sewage and industrial wastes. Aquatic environments are for this reasons often overloaded near cities where huge volumes of sewage containing a great variety of pollutants produced by man get into them directly or indirectly. The nature and sources of various types of water pollutants will be described briefly since such knowledge is essential for discerning water-pollution control measures.

Water pollutants originate from domestic sewage, industrial wastes, agricultural run-off, marine activities (including exploitation of seabed mineral resources), deliberate and accidental discharges by ships, and volatile compounds and particulates from the air.

The interesting thing about sewage is that it contains about 99.9 per cent water by volume, and 0.1 per cent non-water fraction. All the problems associated with sewage arise from the 0.1 per cent non-water fraction which contains suspended and dissolved organic compounds (e.g. carbohydrates, proteins and lipids) and also inorganic mineral ions. It also contains the pathogenic organisms found in sewage. The organic and inorganic components enrich the water and increase its productivity (i.e. its ability to support life). When the water is overloaded with sewage it becomes over-enriched. The water consequently becomes *eutrophic,* that is, it is able to support the growth of algae which are a nuisance in water. Further addition of excessive amounts of nutrients in water reduces the diversity being those which serve as food for herbivorous animals which in turn serve as food for some economic fish species. Thus, because of the elimination of algal species which serve as their food, most of the fish species disappear, and the main survivors are the

pollution-tolerant fish species including *Tilapia* and Catfish, which themselves are adversely affected on the long run.

The problem of entrophication as explained above is well-known in almost all developed countries. The experience in these places may serve as a model for what is likely to happen to the entire intricate system of waterways along the West African coast, if the present trend of indiscriminate discharge of domestic wastes into coastal waters continues.

Apart from the pollution caused by the discharge of sewage into water, another equally and, in fact, more important source of water pollution in oil-producing countries is the addition of crude and refined oil into water.

The quantity of oil entering the seas each year from all sources has been estimated by Blumer (1969) at about 10 million tonnes. Most of the influx occurs when an offshore oil well has a blow-out, a tanker breaks open, or an accidental oil-spill occurs. Other minor sources include the natural seepage of oil from underwater oil reservoirs, and oil wastes from garages during routine oil changes.

When first spilled, oil floats on water. Soon after, lighter fractions like those used for petrol and kerosine volatilise into the atmosphere, and through wave action the heavier or denser fractions break into tarry lumps which, depending on their density, may float or sink to the bottom of the sea. Because oil is a mixture of many compounds, and crude oils from various sources differ in composition as well as in the relative concentrations of their components, different oil spills are known to have different effects. Complete understanding of the toxicity and ecological effects of oil spill still require extensive studies of the effects of individual components of the original oil.

Despite the limitation in our knowledge of the effects of oil, certain generalisations can still be made:

(i) Up to 90 per cent sunlight is intercepted by the oil layer formed on the surface of water. The immediate effect of this is greatly reduced photosynthetic activity and growth rate of the plants in the shaded area.

(ii) Since all crude oils contain compounds toxic to marine organisms, extensive mortality of marine organisms occurs after each oil slick. For example, the natural water repellency of diving birds is destroyed and the birds drown. As an oil-soaked bird attempts to clean itself, it ingests some of the sulphur-containing oil. This changes the acidity of the gut of the bird, thus rendering it susceptible to a lethal fungal infection.

(iii) Also some shelf-fish — clams and oysters — are known to be able to filter out some oil lumps from water. Since such tarry lumps contain toxic heavy metals like lead, the shell-fish becomes inedible.

It must be re-emphasised that the evidence on the effect of oil-spill on living organisms, and on man in particular, is inconclusive. Even though some of the compounds in oil are thought to be potentially capable of producing cancer, further studies are still required to confirm such claim.

Other Sources of Water Pollution

The other sources of water pollution, although less known, contribute immensely to water quality. These are the detergents and agricultural chemicals.

Before the introduction of detergents in the early 1950s, soap served as the cleansing agent. The fat molecules combine with dirt particles and formed *suspensions* which were easily rinsed off with clean water. Hard water, however, provided a problem. Its mineral salts component formed a precipitate with the suspended dirt particles resulting in the presence of grey scum in water. The introduction of detergents which were capable of removing dirt and also able to prevent formation of scum in hard water was greeted with relief.

It is now known that the detergents in use today contribute about 60 per cent of the phosphorus content of sewage, leading to the problems of eutorophication. Algal blooms and later followed by die-offs occurred on a large scale in rivers and lakes. Another factor in detergents which needs serious consideration is the recent introduction of active enzymes in some washing powders. Although it has been claimed that the enzymes deteriorate rapidly in water, additional research is needed to critically evaluate the fate of these substances.

Agricultural chemicals, unlike the detergents, get into water through indirect sources because they are normally applied to the soil and vegetation directly. Several substances – fertilisers, insecticides, herbicides and rodenticides – are included in this group of chemicals. Even though these substances are applied to the soil, they sometimes leak into underground water table and from there get into nearby supplies of water. Occasionally, too, fertiliser run-offs find their way into streams, lakes, etc. Such water supplies will be rich in nitrates, phosphorus and potassium since fertilisers themselves are combinations of these chemicals. This leads again to the now well-known problem of eutrophication.

Both the fertilisers and pesticides have come into greater prominence in Nigerian agriculture recently. Since

the inception of the Operation Feed the Nation programme, huge quantities of fertilisers and pesticides have been imported into the country to improve crop yield, which may well mark the beginning of the Green Revolution in Nigeria. But it may also mark the beginning of new problems. This is because the pesticides, in particular the insecticide DDT and other chlorinated hydrocarbons, are unique man-made compounds differing greatly from other organic materials – they are not readily degraded in soil by bacterial action and thus persist in the environment for long periods of time. A persistent pesticide has no doubt some beneficial effects. It remains in the soil for years, and so gives plants long-lasting protection. But because it lasts so long, it tends to become more and more concentrated as it is passed from lower to higher consumer levels of the food chain. It is true that insecticide levels in foods are quite low, so low that they cannot cause immediate harm to the consumer. It should, however, be noted that an accumulation of these substances in the body over a long time shortens life. Although the liver can render toxic substances ingested in small quantities harmless, stimulation of liver cancer is known to be enhanced by increased incidence of intake of such substances.

The damage done by insecticides to organisms other than man is also well known. Many of the birds which spend most of their lives at sea, as well as some predatory birds (e.g., the osprey, the sea eagle) have had their populations drastically reduced because of the accumulation of DDT in their tissues. In ospreys, DDT applications have resulted in the production of thin, non-viable eggs which fail to hatch. This has almost led to the extinction of the species. Both freshwater and marine fish in most waters are almost always contaminated with DDT. It is on record that large quantities of California mackerel have been declared unfit for human consumption because they contain more than the permitted 5 parts per million (ppm) DDT residues. Although fish kills have not been directly attributed to

DDT effect, it has, however, been shown that a concentration of 5 ppm in the ripe eggs of fresh water trout causes 100 per cent failure in the development of the eggs.

Butler (1965) has shown that commercial species of shrimps and crabs are killed by exposure to DDT at concentration of less than 0.2 parts per billion (ppb) in less than 20 days.

It must be mentioned, for the sake of presenting a balanced account, that the short-term benefits of using pesticides are many. Malaria has been virtually eliminated from many parts of the world by using DDT to kill the female anopheles mosquito that transmits the malarial parasite. Also, the control of insect pests on commercial crops by means of insecticides has been dramatic. However, the pests being controlled are nowadays known to develop strains or varieties which are more resistant to DDT, so that the rate of application has to be increased in order to successfully eliminate the pests. Because of the damaging environmental effects, the use of DDT and chlorinated hydrocarbons in general is restricted and limited to critical public health needs in most countries, including the U.S.A. and Europe. However, in some developing countries, including Nigeria, DDT is still imported and it is used in large quantities because it is considered cheap, reasonably safe to man, and effective against many agricultural and medical pests.

Pollution by Solid Wastes

An account of pollution which does not include the disposal of *solid wastes* (a mixture of commercial and household garbage such as paper, bottles, cans, automobile carcasses, glass, aluminium and plastic) is far from complete in our own circumstances. The disposal of solid wastes has

become one of the most urgent and difficult problems of the crowded urban centres of the world, and of Lagos in particular. The unsightly heaps of garbage found in conspicuous places in Lagos City have long been known to constitute public health hazards. All efforts to rid Lagos of filth have failed, and many people have started to wonder if Lagos shall ever be a clean, healthy city.

In most parts of the world, solid wastes are being used as *land-fill,* but land for this purpose is becoming less available and more expensive in many cities; and in Lagos such land can be said to be nowhere to be found again. In many parts of the world, therefore, *sea disposal* of solid wastes has been used increasingly, but the impact of the disposal of such different materials into the sea is yet to be assessed fully. It has been suggested that, in order to avoid contamination of surface water of the oceans with these materials, all household and commercial wastes be compacted together in bales to a density greater than that of seawater so that they will sink, and no floatable objects will be released in the process of dumping into waters 1,000 metres deep or more. The ecological effects of such waste disposal into the sea are unknown and should be investigated before extensive dumping is undertaken; for it has been shown by Jannasch (1971) that the rate of decomposition of organic material at the high pressure of the deep sea is much slower than at atmospheric pressure. As concluded emphatically by the Fishery Resources Division of the FAO in 1971, "For a variety of reasons, waste disposal operations at sea should be considered a *temporary* and *interim* solution to the disposal problem. In the cases of garbage, sewage sludge and dredging spoils, . . . alternative methods of disposal should be searched for and used. Our use of the deep sea may be very different a generation from now to what it is today, and — as with all our natural resources — it should be preserved for future generations."

In many parts, and in fact in the Lagos lagoon, fishermen indulge in the disposal of old tires and of vegetation into the water in an effort to create *artificial reefs* which will improve fishing.

It must be emphasised once again that since it is not known how much of the material being dumped is decomposed, it is certain that at some stage the rate of delivery of the organic waste materials will exceed the capacity of the aquatic environment to recover. The water may deteriorate to an irreversible extent and it may not be able to recover through normal biological processes.

Pollution by Waste Heat

Pollution caused by the release of *hot water* or waste heat from power plants into rivers, estuaries and coastal waters needs some mention. The discharged hot water raises the temperature of water above levels characteristic of each location. This may lead to extensive fish kill, or selective elimination of species that cannot tolerate such high temperatures. An indirect effect of increase in water temperature on fish population is that the concentration of dissolved oxygen in water decreases with increase in temperature of the water, but the general activity of the fish, on the other hand, increases with temperature to some extent. Under such situation the dissolved oxygen in water cannot meet the oxygen requirement of the fish, and they *die.*

Pollution by Radioactive Substances

Another very important, although less known, form of pollution is pollution by radioactive waste substances. Atmospheric *testing* of *atomic bombs* by various countries — U.S.A., U.K., Soviet Union, France and China — is the main

source of these substances in the atmopshere although leaching of radioactive salts, e.g., Uranium salts from Uranium mines into streams and other bodies of water may supplement those present in the atmosphere as contaminants. Radioactive substances have the biological effect of damaging chromosomes, the vehicles of hereditary characters. Long exposures to radiation are, therefore, regarded as undesirable. The after-effect of the use of the atomic bomb on *Hiroshima* and *Nagasaki* in Japan in 1945 during the Second World War is visible until today. Two generations after the end of the war, children are being born severely handicapped as a direct result of genetic imbalances caused by the atomic fall-out.

Air Pollution

So much has been said about water pollution and its effect on life. Another form of pollution which has attracted much attention these days particularly in industrialised countries is *air pollution.*

The concern over the quality of the air we breathe assumed greater dimensions when the dangers of polluted air to the health and welfare of all individuals became increasingly evident.

Many people do not seem to realise that the pure atmosphere we inherited consisted of air made up of a mixture of a number of many gases. Air consists of about 78 per cent nitrogen, 21 per cent oxygen, a very small amount of carbon dioxide (0.03%), less than 1 per cent argon (an inert gas) and traces of a few other gases, most of which are inert, too. The air in its pure state also contains varying amounts of water vapour.

It may well be argued, and justifiably, too, that *air has never been pure.* That is true. Natural pollution of air by decomposing marshes, and the action of erupting volcanoes throwing their lava into the skies, have always been *defiling* the atmosphere. But these were natural phenomena and nature always has means of self-purifying the atmosphere to make it comfortably life-supporting. Either wind scatters the pollutant, and in the process mixes and dilutes it, or some natural processes like rain or/and snow eventually wash it out of the air into the soil or water. But, today, the atmosphere is so much laden with impurities that man is very close to suffocating himself.

In cities, because of the aggregation of people and their automobiles, concentrated combustion occurs and the air is burdened with the unburnt or partially oxidised fragments of the fossil fuel we use. These arose because, when petroleum oil and coal are incompletely burnt in automobiles, complex reactions take place. The products include not only heat and carbon dioxide, as would be expected in complete combustion of hydrocarbons, but also partially oxidised products like carbon monoxide, and unburnt hydrocarbon. When sulphur is present in the fuel as a contaminant, it is converted to sulphur dioxide. In addition to being undesirable itself, sulphur dioxide can combine with water vapour in the atmosphere to form sulphuric acid. Another pollutant produced at high temperatures, such as those found inside the cylinder of an automobile engine, is nitric oxide formed from the oxidation of nitrogen in air by oxygen, and then, after it leaves the exhaust of the car, becomes nitrogen dioxide. As we shall see later, nitrogen dioxide is a major source of *trouble* in developed countries. In the United States of America, recent statistics have shown that there are about 120 million motor vehicles burning about 500 billion litres of fuel each year. That works out at about 55 million litres per hour; this gives some idea of the large contribution made to air pollution by automobiles. *Automobiles* are now

accepted as important producers of *carbon monoxide*, and also are responsible for large portion of the *nitrogen oxides* and *hydrocarbons* entering the air.

In cities, *stationary sources* of air pollution include power plants, factories and incinerators for burning household or industrial garbage. They emit numerous kinds of particulate matter. In places where they are permitted to burn sulphur-containing coal, these sources discharge vast quantities of sulphur dioxide to the air.

At this juncture, it is pertinent to comment on the exercise of *gas-flaring* going on in many of our oil-fields in Nigeria. Besides the well-known facts that it adversely affects the life of vegetation in the immediate vicinity of the flare, and some huge source of revenue is allowed to waste, it should be realised that the flares have constituted a continuous source of atmospheric dumping of particulate material and toxic gases. Such an accumulation or continuous build-up of air pollutants should be viewed with serious concern not only in the immediate neighbourhood, where the flares go on, but all over the nation, since winds blow air and its toxic components to distant places.

Air pollution has effects on *weather* and *human health*. The effect on weather can be seen clearly if we compare city weather with that of the surrounding countryside. The very tall vertical buildings in cities obstruct the free flow of air and, consequently, a city usually absorbs most of the heat energy from the sun during the day and holds on to it longer at night. The resulting effect is the accumulation of hot air in the city, a phenomenon the meteorologists call the *"heat island"*. Finally, the hot air rises, carrying with it its load of pollutants, then it expands, spreads out over the edges of the city, cools and sinks at the city's periphery where it forms a distinctive ceiling known as *dust dome*. Cooler air from the countryside flows into the city to replace the rising air and

the process of heat island formation is repeated.. Meanwhile the particulates in the dust dome reflect heat back into space and into the city. That is why the city is always warmer than the surrounding countryside.

In addition to being heat islands, industrialised cities are notorious for their fogs. For centuries the inhabitants of London heated their homes with soft coal in open fire places. They got away with the atmospheric dumping because the wind blows away toxic gases and the rain washes them out of the air. The combination of the resultant *smoke* and *fog* from such combustion, now generally referred to as *"smog"*, become very notorious in the 1950s. London smog left a mark on the inhabitants during a five-day temperature inversion in December, 1952, when a layer of cool surface air was trapped by a layer of warmer air, and it left 4,000 people dead. For the London smogs occurring during these inversions contained high concentrations of sulphur dioxide which evoked *bronchial irritation.*

Today, the Los Angeles photochemical smog, which first appeared in 1940s, is as notorious as the London smogs were in the 1950s. The Los Angeles type of smog results from the action of the sun on the emissions of the automobile. The energy of the sun is absorbed by nitrogen dioxide in the presence of some hydrocarbons. In the process, nitrogen dioxide separates into nitric oxide and atomic oxygen. The atomic oxygen reacts with the oxygen molecules of the air and other constituents of automobile exhaustos to form a variety of products, including ozone. Ozone is harmful in itself and it also participates in a highly complex series of continuing reactions. The main effects of photochemical smogs are *eye irritation, reduced* visibility and consequently many accidents, and general damage to property.

The effects of air pollution on human health is probably due to the various concentrations of the particulate material and toxic gases present in such air. Although the human body is equipped with some natural defence lines against dirty air, occasionally the defences fail. Chronic exposure to polluted air inevitably takes place. Although correlation between illness and inhalation of air pollutants remains circumstantial, certain statements on the effect of pollutants on health can still be made. According to the American Lung Association (1974), it is well known that carbon monoxide attaches to haemoglobin thereby interfering with the normal transport of oxygen in the blood to the brain and other parts of the body. The effect could be anything from *minor irritability* to *mental retardation,* and if the circulatory system attempts to compensate for the deficiency by carrying more red cells, it could create an overload for heart and blood vessels. The result of this may be fatal. Other pollutants like ozone, sulphur dioxide, nitrogen dioxide and peroxyacyl nitrates (PAN) have been incriminated as causal factors in irritation of the eyes, damage to the bronchi (leading to diseases such as bronchitis and asthma) and collapse of the air sacs of the lungs.

Airborne particles like fragments of coal tar and fuel may, if inhaled, stimulate the abnormal proliferation of cells characteristic of lung cancer. Even though evidence for the effects are all circumstantial, one point is sure: air pollutants, whatever the source, do not improve the quality of life.

Pollution Abatement

Much has been written about environmental quality. International and national conferences and top-level seminars have been held in Nigeria, and in other countries, about the need to improve the quality of the environment. State governments also have made policy statements on environmental sanitation.

There is also ample proof of *local awareness* as evidenced by regular articles on pollution in the Science columns of our national newspapers. All these actions go to show that environmental problems are so great now that immediate effective action is needed.

Like in all pressing cases, the first line of action that comes to one's mind is *litigation* in the law courts. Joseph L. Sax, Professor of Law at the University of Michigan Law School, has interested himself a great deal on legal problems associated with pollution. According to him, the lawyer must apply common law and *invoke negligence, nuisance or trespass.* Victims of pollution have to establish that they have suffered real loss of property or direct bodily harm before they can make any claims on the polluter.

If I took the Federal Military Government to court over the land-filling exercise being carried out along the Marina for the construction of the proposed Ring Road, and swore to affidavits maintaining that such reclamation would cause seasonal inflow of salty sea-water through the Lagos lagoon, Ogun river and Iju river respectively and finally into the reservoirs of Iju Water Works, the judge would ask me what law has been broken by the defendants or what damage I could claim has been done to my person or whether any contract has been broken. The judge would be quite right to ask these questions. Because no direct personal damage as required in law has been done, no contract has been broken, in fact, no rule was violated by the highway plan.

The prosecuting law officer would certainly have difficulty in establishing guilt in cases in which the petitioner was trying to protect fish from hot water or faeces, or birds from such persistent pesticides as DDT.

Such are the problems involved in court cases on pollution. They are largely not amenable to judicial resolution.

As Professor Sax observed, "No conservation case has been won on the merits of the case, they are at the very most won on procedural grounds such as hearing irregularities." Realising the problems in getting pollution cases through law courts successfully and considering the difficulties that would be involved in enforcement of environmental laws by the various law enforcement agencies, it is suggested that environmental costs be made part of production costs. In this connection, every industrialist would be required to consider or predict the environmental consequences of his proposed or on-going project. If they outweigh the economic benefits from such a project it should either be halted, if already in progress, or be prevented from taking off, if still under contemplation.

Now that law courts may not be able to provide the solution to pollution abatement, other practical suggestions are being considered as possible alternatives in those countries in the *thick* of pollution problems.

There is no doubt that many of our environmental problems, including pollution, have been caused by the impact of new technologies. A shift to non-polluting technology is being suggested nowadays. It is proposed that if engineers, sociologists, economists, computer scientists and ecologists (ecologists are people who study the interrelationships between organisms on the one hand, and between organisms and their environment on the other) work together, they can *monitor* environmental pollutants, *postulate* on the probable or potential impacts of such pollutants on the environment and on life, and *advise* government accordingly. In pursuit of this idea, at the United Nations Conference on the Human Environment held in Stockholm in 1972, a monitoring system of the atmosphere, christened the *Earth Watch* , was set up. Some 10 stations, including one in Alaska, are to provide base-line information on unpolluted atmosphere. Additional 100 stations in areas known for

gross pollution of the atmosphere will similarly monitor changes in concentrations of carbon dioxide, ozone and dust. All the 110 stations will feed their data to a central computer facility at the Central Environmental Laboratory in Nairobi, Kenya. Information will also be collected by means of orbiting satellites and fed to the computer to make interpretations meaningful. It is hoped that through such joint studies valuable information, as to the true picture of the quality of the environment will be obtained on a continuing basis. It should be possible to issue alarm warnings when the allowable level of any pollutant is being approached.

Programmes similar to the "Earth Watch" for continuous sampling or surveillance for oceanic oil pollution are just being initiated. For example, 78 laboratories in 15 of the 18 Mediaterranean states are now working together in a three-year programme to monitor pollution in their sea. The co-ordinated Mediterranean pollution Monitoring and Research Programme (MEDPOL) was decided at Barcelonia early in 1975 at an inter-governmental meeting of Mediterranean Coastal States, as part of action designed to ensure the protection and development of the Mediterranean basin. There is no set-up of *water-watch* network to monitor the quality of fresh water. All most countries do now is to undertake unco-ordinated random sampling programmes, and that by untrained or unqualified staff.

Efforts are also being made to control pollution at source. These include introduction of devices to intercept the pollutants before they can spread.. For example, to prevent emission of poisonous gases from motor vehicles into the atmosphere, catalytic converters which oxidise incompletely burnt fuel into harmless carbon dioxide and water have been made in the United States of America, and lead-free fuel is made available to avoid lead poisoning of the converters. Unfortunately, in our own part of the

world, lack of skilled man-power, the necessary technology and funds will prevent us for a long time from attaining such level of sophistication. The easier way out of atmospheric pollution resulting from gaseous emissions from vehicles is mass transportation systems. In this regard, I have to congratulate the Lagos State Government for recognition of this point by making available, or rather having a plan to make available, a large number of buses that will convey workers from given points into Lagos. The introduction of a *water-bus* system between the Mainland Hotel and Marina, and between Mainland Hotel and Ikorodu via the Lagos Lagoon is also in accordance with the idea of mass transport.

As regards abatement of pollution by solid wastes, *recycling* is suggested *(Hickley, 1976).* Old *newsprint* may be pressed to make cardboard as is already being done by some paper-converting companies. *Cans* may be melted and used in making other household utensils. Preferably still, cans must be made of recyclable material as is the case in America now. *Car carcasses* may also be compressed and converted to metal sheets which can serve some useful purpose. Re-use of *bottles,* as practised at the moment, should be encouraged, and if a company so desires, it may melt down used bottles and make new ones out of them.

The pollution caused by utilisation of cola and fossil oil as fuel may be minimised if we cut down on our use of these resources and consider making use of solar energy. Although research has been initiated in this direction in many parts of the world, it must be recognised again here that technical and economic considerations will prevent developing countries from adopting the use of solar energy.

Sewage Management

The problem of waste management, particularly the disposal of *faeces,* has not been fully solved in many parts of the world. In Nigeria, most people still rely on cesspools, sanitary pails, septic tanks or other back-yard facilities. Sewage in Lagos, like in most coastal cities in the U.S.A., U.K., etc., is dumped *untreated* at sewage outfalls into the lagoon and the seas. The problems associated with discharge of untreated sewage into bodies of water have been mentioned earlier on in this lecture. In most cities, to avoid such problems, sewage treatment plants are used to get rid of the organic matter content, and possibly the inorganic components of sewage, before the effluent is finally discharged into water. Some cities provide only primary treatment plants, in which case some of the suspended organic and inorganic matter is removed. Other cities add secondary treatment in which more of the organic matter in suspension is removed and broken down together with dissolved organic matter. Very few countries have tertiary treatment facilities for removing dissolved inorganic nutrients before the effluent is discharged. It must be emphasised again that even after primary and secondary treatments, the effluent is still rich in nutrients, particularly nitrates and phosphates. Unless these nutrients are removed during tertiary treatment, problems of enhanced growth of blue-green algae will still occur. This solution certainly requires funds and necessary technology, if not to build, at least to maintain the treatment plants.

Various kinds of sewage treatment plants are in use today, but the process of waste treatment in all of them is based essentially on a common principle. They make use of micro-organisms – a large and diverse group of very small living organisms that exist as single cells or cell clusters – to slowly decompose the complex organic matter component of sewage. The products of decomposition are various simple substances including carbon dioxide, water, nutrients

like nitrates, sulphates and phosphates (which can be removed during tertiary treatment referred to earlier on). Methane is another component, produced when decomposition occurs under oxygen-deficient conditions.

Crude sewage contains, in addition to a small number of microbes causing infectious disease of man, a large quantity of non-pathogenic, decay-causing microbes. These relatively harmless, microbes are initially derived from soil, and get into sewage through infiltration water. Members of this group include some bacterial genera: *Bacillus, Pseudomonas, Achromobacter* and *Micrococcus;* and some fungal genera: *Fusarium, Mucor, Penicillium, Geotrichum* and a variety of yeasts. Other genera which may be involved in the dacay of organic matter under anaerobic conditions are *Clostridium, Bifidobacteium, Lactobacillus, actinomyces, Mathylococcus, Methanobacterium, Mathanobacillus* and *Methanococcus.* At low nitrogen conditions, the major genera responsible for organic decay are *Nocardia, Beggiatoa Thiothrix* and *Geotrichum.*

The major constituents of organic waste are polysaccharides (e.g., cellulose, hemicellulose, lignin, pectin, starch), polypeptides (e.g., protein) and fats. These have to be degraded to inorganic salts, carbon dioxide and water in any effective sewage treatment system. The prime function of the microbes involved in the decay of organic waste contained in sewage is to convert the large, insoluble polymers to soluble fractions. This is an extracellular reaction usually involving several types of enzyme systems. The microbes subsequently remove the soluble organic matter in the waste by oxidation. In the process, energy is released for their activities, and most of the products of oxidation are incorporated into the structural and storage materials of the microbes.

During the aerobic dreakdown and utilisation of the organic matter in sewage, the following changes occur:

(i) *Organic nitrogen compounds* (e.g., proteins) are broken down and ammonia is released. The ammonia is converted to nitrate by nitrifying bacteria;

(ii) *sulphur-containing compounds* are decomposed to form hydrogen sulphide which is converted to sulphate by some sulphur oxidisers.

(iii) *phosphorus-containing compounds* are broken down and inorganic phosphates are produced; and

(iv) *organic carbon compounds* are broken down to carbon dioxide, water with the release of energy.

In practice, anaerobic decomposition (i.e. decomposition in the absence of oxygen) is usually employed for the treatment of materials that have much insoluble organic matter, such as fibre and cellulose, or for concentrated industrial wastes. Here again, microbes by means of extracellular enzymes digest the complex organic material to soluble materials which are ultimately fermented to carbon dioxide and methane. Both the carbon diodixe and methane escape as gas.

By means of the processes described above, *microbes rid the environment of its complex wastes or pollutants.* These microbes are, therefore, our ready *allies* in our fight against pollution.

For years, the deterioration of Lagos Lagoon waters caused by the discharge of large quantities of various substances, including sawdust from sawmills located along the lagoon, waste products from various industries, and, most

important, untreated sewage at a site near the Carter Bridge, has been going on. The Lagos City Council alone in 1973, deposited about 26 million litres of untreated faeces into the Lagoon. It was believed by the city authorities and their advisers that wastes disposed into the lagoon would rapidly be washed out to sea by tide and dispersed, resulting in *"dilution to extinction"*. A team of researchers in the Department of Biological Sciences of the University of Lagos, comprising academic and technical staff and post-graduate students led by Professor J. A. Ekundayo, struck by the alarming deterioration of the lagoon water near the University, started in 1973 the project now known as *"the Lagos Lagoon Pollution Research"*. In other to study the extent of faecal pollution of the lagoon, sites have been selected along the whole length of the lagoon from the sea to the Ogun River. Sampling trips are undertaken on a regular basis and various data are being obtained indicating the level of total organic matter content, heavy metals (particularly mercury and cadmium), heterotrophic bacteria and fungi capable of breaking down organic components of faeces, various bacteria which indicate the presence of recent or distant faecal pollution, and pathogenic organisms which may constitute a health hazard.

It is hoped that the project will, on a continuing basis, monitor level of faecal pollution, pollution due generally to presence of organic matter, and presence of disease-causing micro-organisms in water.

Following the acquisition of additional modern and specialised equipments, the programme is being expanded to include monitoring of oil and petroleum hydrocarbons in Nigerian coastal waters; heavy metals; pesticides, DDT and other chlorinated hydrocarbons in marine organisms; and general coastal water quality control.

Our own present project is expected to complement the on-going Marine Research programme headed by Professor C. I. O. Olaniyan, Professor of Zoology at the Department of Biological Sciences, University of Lagos. It is the intention of the department that, by virtue of being situated on the lagoon coast, the department should serve as the Nigerian centre for marine research. To this end we are developing a new and well-equipped Marine Biology Laboratory to provide short-term training for serving fishery officers and post-graduate training for young graduates. It is, therefore, envisaged that the department will produce future high-level man-power for Marine Sciences Departments and Federal and State Institutes for Marine Research.

Points of general interest that have emerged from our studies so far are:

(i) The *tidal current* over the lagoon is *weak* all the year round. This means that the movement (into the sea) of the faeces discharged into water at Ebute-Ero near the Carter Bridge is very slow. A long retention of faecally-polluted water within the lagoon, therefore, occurs. It thus appears that the assumption that both organic matter and pathogens in faeces would be rapidly diluted out in the *infinite sink of the ocean* cannot be justified. Furthermore, there are seasonal and diurnal changes in the direction of movement of water from the lagoon into the sea. During the dry season and also at each high tide, the net movement of water is from the sea through the lagoon into the Ogun River. At such times, the faeces discharged into the lagoon may eventually appear in Ogun River and not in the sea as was imagined.

(ii) The Lagos Lagoon waters are *rich* in available organic matter. This fact, when combined with

the presence of large numbers of bacterial indicators of faecal pollution, means that the waters are extensively polluted with different substances, chief among which is faecal matter.

(iii) Some *pathogenic organisms* normally found in faeces are present in Lagos Lagoon waters, and the lagoon may serve as a reservoir of disease-causing organisms. The lagoon could, therefore, be a *health hazard.*

(iv) The Lagos Lagoon has not experienced serious over-loading with faecal matter, because the lagoon waters contain some *micro-organisms capable of decomposing faeces 'in situ'.* These organisms actually decompose the faeces discharged into the lagoon thereby reducing the level of faecal pollution at any point in time. Further studies are in progress to obtain pure strains of faeces-decomposing organisms that are capable of decomposing faeces rapidily. If such organisms are cultivated on a large scale and used to spray sewage disposal sites in the lagoon or the seas, problems of overloading the waters with faeces would be reduced.

(v) The fish and shrimps caught in faecally-polluted waters have been found to contain *bacteria associated with faeces.*

Conclusion and Recommendations

There is no doubt that our environment is heavily polluted with various types of pollutants, and that there is an urgent need for pollution control. As *Russell Train* put it while urging the United States to improve her

strategies for environmental management, *The real stake is man's own survival.* We, the older generation, can afford to talk and talk and not act; after all we all have spent some good time on a relatively clean earth and have a relatively few years to spend in a pestilence-laden environment. But we must remember that the younger generation has a life-time ahead of them, and if they are to enjoy their life in a clean environment, they must act now.

We can still assist the young ones if we adopt and improve on some of the new Federal and State laws being developed in the United States of America to combat environmental pollution. Laws must be made at all levels – local council, state and Federal – against pollution.

In addition, the government should, as a matter of urgency,

(a) set *standards* for air and water quality;

(b) seek to establish or improve sewage *treatment,* and improve on collection and processing facilities for solid wastes;

(c) set up national environmental laboratories that will do *research* on environmental problems, including pollution;

(d) establish an agency to *enforce* standards and monitor environmental factors;

(e) provide *funds* to National Science and Technology Development Agency (NSTDA) to finance researches based on environmental quality.

(f) insist on inclusion in school and university syllabuses, *courses* on environmental studies so that every individual citizen will be educated to understand and appreciate the import of having a clean environment.

(g) engage the various mass media in *campaigns* for maintenance of environmental quality. Furthermore, the government should consider the possibility of carrying out constructive utilization of some types of pollutants, for instance, nutrient wastes for aqua-culture which is contributing substantially, at the moment, to the production of animal protein in many countries.

All the above suggestions emphasise the need for encouragement of environmental research to provide the basis for formulation of relevant policies by government.

Mr. Vice-Chancellor, Your Excellencies, Ladies and Gentlemen, thank you all for your patience and attention.

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