UNIVERSITY OF ESWATINI
FACULTY OF EDUCATION
DEPARTMENT OF CURRICULUM AND TEACHING
RE-SIT EXAMINATION QUESTION PAPER, SEPTEMBER 2020

TITLE OF PAPER	**:**	**CURRICULUM STUDIES IN BIOLOGY II**
COURSE CODE	**:**	**CTE528**
STUDENTS	**:**	**PGCE**
TIME ALLOWED	**:**	**THREE (3) HOURS**

INSTRUCTIONS: **1.This examination paper has five (5) questions. Answer four (4) questions only.**

2. There is an attachment for one question.

3. Each question has a total of 25 points.

THIS PAPER IS NOT TO BE OPENED UNTIL PERMISSION HAS BEEN GRANTED BY THE INVIGILATOR

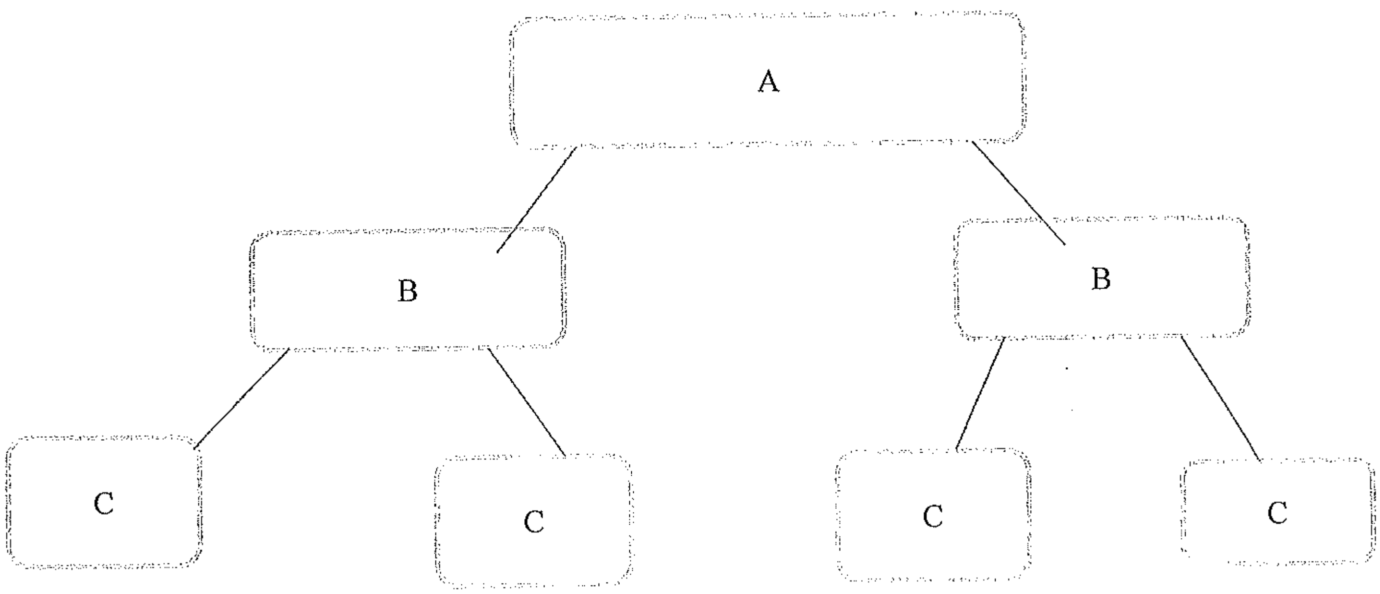
1. a) Compare and contrast the science curriculum before Sputnik and immediately after Sputnik. [10]
   b) In 1995 UNESCO classified Eswatini as high development country. What were the criteria for such a classification? [5]
   c) Most African countries, Eswatini included, invest less than 1% of GDP in Science, Technology and Innovation. Discuss, using concrete examples, how this has impacted on the state of science and technology education in Eswatini. [10]

2. a) Discuss the challenges faced by Eswatini science teachers in implementing the Swaziland Integrated Programme (SWISP). [10]
   b) What were the major problems teachers experienced with the Science in Everyday Life (SIEL) curriculum materials? [5]
   c) In your view, how have the Science Around Us (SAU) curriculum materials addressed these problems? [5]
   d) How are the curriculum materials organised in Science Across Africa to provide relevance to the learners? [5]

3. a) i) The SIEL curriculum follows a contextualised approach. Explain what is meant by this statement. [5]
   ii) Explain how this approach impacts on the learners' understanding of science concepts, principles and processes. [10]
   iii) Discuss the tenets of constructivist theory that support this approach. [10]

4. a) Explain how you would use the following resources when teaching a Form V class the topic Pollution. You may refer to the attachment for content.
   i)Chart
   ii) Data projector or Overhead projector
   iii) Internet
   b) Discuss how you would structure the lesson activities to ensure gender responsiveness. [10]

5. a) The figure below represents a concept map.



i)Label the parts A, B, and C [3]
ii) What is the role of A? [3]
iii) How do B and C relate to each other? [2]
iv) What does the hierarchical representation signify? [2]
v) How does concept mapping facilitate meaningful learning? [5]

b) Compare and contrast the activities and principles applied in cognitive and social constructivist classrooms. [10]

25 THE HUMAN IMPACT ON THE ENVIRONMENT

Food webs
Hunting, agriculture, pesticides, eutrophication.

Forests
Erosion, flooding, climate, biodiversity.

Soil
Erosion, pesticides.

Water
Sewage, chemical pollution.

Air
Sulphur dioxide, oxides of nitrogen, lead, smog, carbon monoxide, chlorofluorocarbons, greenhouse effect.

A few thousand years ago, most of the humans on the Earth probably obtained their food by gathering leaves, fruits or roots and by hunting animals. The population was probably limited by the amount of food that could be collected in this way.

Human faeces, urine and dead bodies were left on or in the soil and so played a part in the nitrogen cycle (p. 237). Life may have been short, and many babies may have died from starvation or illness, but humans fitted into the food web and nitrogen cycle like any other animal.

Once agriculture had been developed, it was possible to support much larger populations and the balance between humans and their environment was upset.

An increasing population has three main effects on the environment.

1 Intensification of agriculture
Forests and woodland are cut down and the soil is ploughed up in order to grow more food. This destroys important wildlife habitats and may affect the climate.

Tropical rainforest is being cut down at the rate of 111 400 square kilometres per year. Since 1950, between 30 and 50 per cent of British deciduous woodlands have been felled to make way for farmland or conifer plantations.

The application of chemical fertilizers can cause deterioration of the soil structure and, in some cases, results in pollution of rivers and streams. Application of pesticides often kills beneficial creatures as well as pests.

2 Urbanization
The development of towns and cities makes less and less land available for wildlife. In addition, the crowding of growing populations into towns leads to problems of waste disposal. The sewage and domestic waste from a town of several thousand people can cause disease and pollution in the absence of effective means of disposal.

When fuels are burned for heating and transport, they produce gases which pollute the atmosphere.

3 Industrialization
In some cases, an increasing population is accompanied by an increase in manufacturing industries which produce gases and other waste products which damage the environment.

The effects of the human population on the environment are complicated and difficult to study. They are even more difficult to forecast. In their ignorance, humans have destroyed many plants and animals and great areas of natural vegetation. Unless we control our consumption of the Earth's resources, limit our own numbers and treat our environment with more care and understanding, we could make the Earth's surface impossible to live on and so cause our own extinction.

The account which follows mentions just some of the ways in which our activities damage the environment.

The human impact on food webs

The hunting of animals

One obvious way to upset a food web is to remove some of the animals or plants which form part of it. If the tawny owls were removed from the food web in Fig. 1, we would expect the numbers of shrews to increase because fewer were being eaten by the owls. The numbers of woodlice and earthworms might then go down because there were more shrews to eat them. The effect of the rabbit disease, myxomatosis, on a food web, has been described on p. 234.

In 1910, in the Grand Canyon National Game Reserve (USA), an attempt was made to protect the deer population by shooting the animals which ate them. These were cougars, wolves, bobcats and coyotes. After fourteen years, the deer population had increased from about 4000 to 100 000, and the environment could not support them. The grass was overgrazed, the trees and young shrubs were destroyed by browsing and the deer were dying in large numbers from starvation. Ignorant human interference with the food web had not only destroyed hundreds of cougars, wolves and coyotes but threatened to lead to the destruction of the environment and the deer which lived there (Fig. 2).

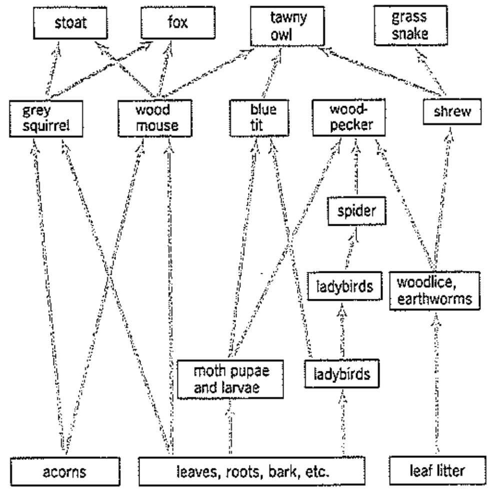


Figure 1 The food web of an oak tree (only a small sample of animals is shown)

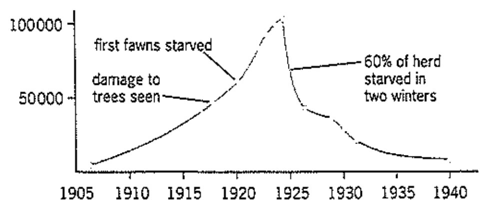


Figure 2 The result of human interference with a food web: changes in deer population after predators are killed

It is, of course, easy to be 'wise after the event', but it is not always obvious what should be done to conserve a population or its habitat. Arguments are currently taking place about the elephant population in some of Africa's game parks. Many conservationists believe that banning all trade in ivory will help reduce the level of poaching. Others think a ban will result in an increase in the price of ivory and an intensification of poaching.

Many animal populations are threatened because humans kill them for food, profit or 'sport'. Over-fishing has reduced some fish stocks to the point where they cannot reproduce fast enough to keep up their numbers.

Animals like the leopard and tiger have been reduced to dangerously low levels by hunting, in order to sell their skins or their bones for 'traditional medicine' (Fig. 3). The blue whale's numbers have been reduced from about 2 000 000 to 6000 as a result of intensive hunting.

The World Wide Fund for Nature (WWF) believes that 15–20 per cent of all species on Earth will disappear by the year 2000 if we do not change our patterns of destruction and consumption. This is one thousand times faster than the natural extinction rate.

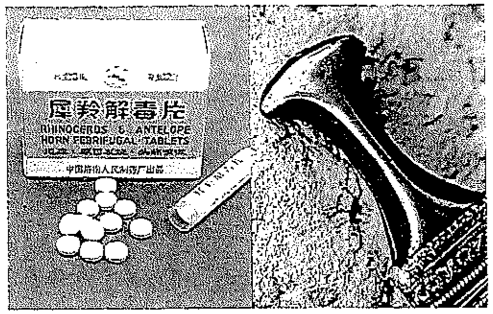


Figure 3 The rhinoceros is endangered because some people believe, mistakenly, that powdered rhino horn has medicinal properties, and others greatly prize rhino horn handles for their daggers.

Agriculture

Monoculture
The whole point of crop farming is to remove a mixed population of trees, shrubs, wild flowers and grasses and replace it with a dense population of only one species such as wheat or beans (Figs 4 and 5). This is called a **monoculture**.

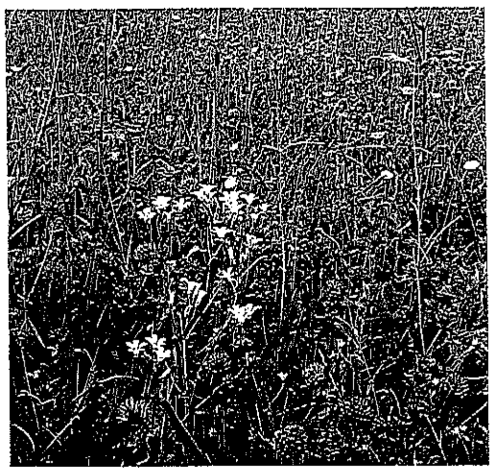


Figure 4 Natural vegetation. Uncultivated land carries a wide variety of species.

In Fig. 1 a simplified diagram of a food web which can be supported by a single oak tree is shown. Similar food webs could be constructed for grasses, wild flowers and shrubs. Clearly, a field of wheat could not support such a mixed population of creatures.

Indeed, every attempt is made to destroy any organisms such as rabbits, insects or pigeons, which try to feed on the crop plant.

So, the balanced life of a natural plant and animal community is displaced from farmland and left to survive only in small areas of woodland, heath or hedgerow. We have to decide on a balance between the amount of land to be used for agriculture, roads or building and the amount of land left alone in order to keep a rich variety of wildlife on the Earth's surface.

Figure 5 A monoculture. Only wheat is allowed to grow. All competing plants are destroyed.

Pesticides

Monocultures, with their dense populations of single species, are very susceptible to attack by insects or the spread of fungus diseases. To combat these threats, pesticides are used. A pesticide is a chemical which destroys agricultural pests or competitors.

For a monoculture to be maintained, plants which compete with the crop plant for root space, soil minerals and sunlight are killed by chemicals called **herbicides** (Figs 6 and 7). The crop plants are protected against fungus diseases by spraying them with chemicals called **fungicides** (Fig. 8). To destroy insects which eat and damage the plants, the crops are sprayed with **insecticides**.

Figure 6 Weed control by herbicide spraying. A young wheat crop is sprayed with herbicide to suppress weeds.

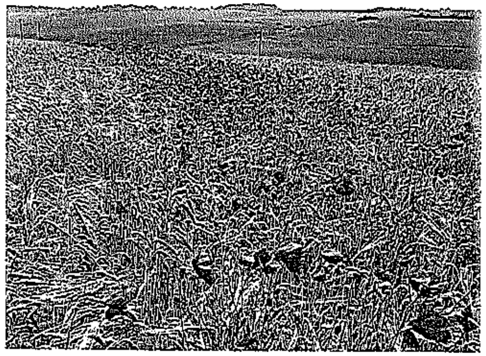


Figure 7 Effect of a herbicide spray. The crop has been sprayed except for a strip which the tractor driver missed.

Pesticide	*kills*
insecticide	insects
fungicide	parasitic fungi
herbicide	'weed' plants

The trouble with nearly all these pesticides is that they kill the harmless or beneficial organisms as well as the harmful ones.

Figure 8 Control of fungus disease. The tree bearing the apples on the right has been sprayed with a fungicide. The apples on the unsprayed tree have developed apple scab.

In about 1960, a group of chemicals, including **aldrin** and **dieldrin**, were used as insecticides to kill wireworms and other insect pests in the soil. Dieldrin was also used as a seed dressing. If seeds were dipped in the chemical before planting, it prevented certain insects from attacking the seedlings. This was thought to be better than spraying the soil with dieldrin which would have killed all the insects in the soil. Unfortunately pigeons, rooks, pheasants and partridges dug up and ate so much of the seed that the dieldrin poisoned them. Thousands of these birds were poisoned and, because they were part of a food web, birds of prey and foxes, which fed on them, were also killed.

The use of dieldrin and aldrin was restricted in 1981 and banned in 1992.

Pesticides in the food chain

The concentration of insecticide often increases as it passes along a food chain (Fig. 9). Clear Lake in California was sprayed with DDT to kill gnat larvae. The insecticide made only a weak solution of 0.015 parts per million (ppm) in the lake water. The microscopic plants and animals which fed in the lake water built up concentrations of about 5 ppm in their bodies. The small fish which fed on the microscopic animals had 10 ppm. The small fish were eaten by larger fish, which in turn were eaten by birds called grebes. The grebes were found to have 1600 ppm of DDT in their body fat and this high concentration killed large numbers of them.

A similar build-up of pesticides can occur in food chains on land. In the 1950s in the USA, DDT was sprayed onto elm trees to try and control the beetle which spread Dutch elm disease. The fallen leaves, contaminated with DDT, were eaten by earthworms. Because each worm ate many leaves, the DDT concentration in their bodies was increased ten times. When birds ate a large number of worms, the concentration of DDT in the birds' bodies reached lethal proportions and there was a 30–90 per cent mortality among robins and other song birds in the cities.

Even if DDT did not kill the birds, it caused them to lay eggs with thin shells. The eggs broke easily and fewer chicks were raised. In Britain, the numbers of peregrine falcons and sparrow hawks declined drastically between 1955 and 1965. These birds are at the top of a food web and so accumulate very high doses of the pesticides which are present in their prey, such as pigeons. After the use of DDT was restricted, the population of peregrines and sparrow hawks started to recover.

These new insecticides had been thoroughly tested in the laboratory to show that they were harmless to humans and other animals when used in low concentrations. It had not been foreseen that the insecticides would become more and more concentrated as they passed along the food chain.

Insecticides like this are called persistent because they last a long time without breaking down. This makes them good insecticides but they also persist for a long time in the soil, in rivers, lakes and the bodies of animals, including humans. This is a serious disadvantage.

Pesticides in food

Pesticides have to be poisonous in order to kill the target pests. In high doses they are also poisonous to humans. Many items of our food contain small amounts of residual pesticides. Some of these are suspected of causing cancer and other disorders but whether they do so in the very low doses we ingest is not certain. Some scientists think the levels are so low as to be negligible.

All pesticides have to be approved by the Ministry of Agriculture, Fisheries and Food (MAFF) and there are legal maximum residue limits for 62 of them. New European Union (EU) rules are being drawn up which will probably extend the list and lower the maximum residue limits, but hundreds of pesticides are not covered by these regulations. In 1990–91 MAFF tested food samples and found residues in 29 per cent of fruit and vegetables, 32 per cent of cereals, 48 per cent of potatoes and 55 per cent of milk, though only 1 per cent of all the samples had pesticides above the maximum residue limit.

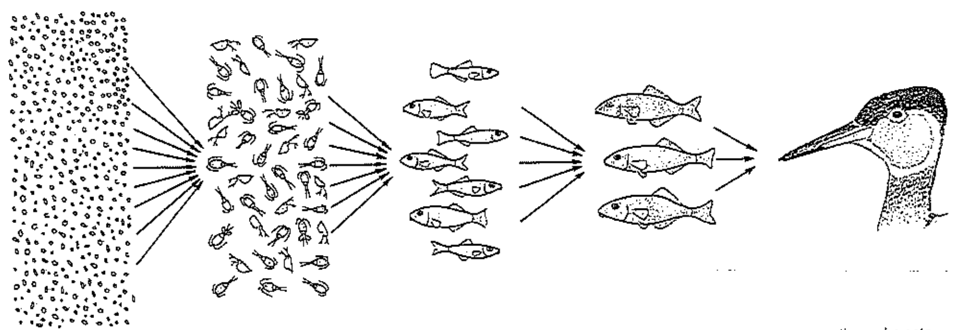


Figure 9 Pesticides may become more concentrated as they move along a food chain. The intensity of colour represents the concentration of DDT.

Peeling apples and potatoes removes most of the surface pesticides but there is not much you can do to reduce any residues on the inside. Cooking seems to have variable effects, depending on the particular residue.

Eutrophication

On p. 45 it was explained that plants need a supply of nitrates for making their proteins, and a source of phosphates for many chemical reactions in their cells. The rate at which plants grow is often limited by how much nitrate and phosphate they can obtain. In recent years, the amount of nitrate and phosphate in our rivers and lakes has been greatly increased. This leads to an accelerated process of **eutrophication**.

Figure 10 Growth of algae in a canal. Abundant nitrate and phosphate from treated sewage and from farmland make this growth possible.

Eutrophication is the enrichment of natural waters with nutrients which allow the water to support an increasing amount of plant life. This process takes place naturally in many inland waters but usually very slowly. The excessive enrichment which results from human activities leads to an overgrowth of microscopic algae (Fig. 10).

These aquatic algae are at the bottom of the food chain. The extra nitrates and phosphates from the processes listed below enable them to increase so rapidly that they cannot be kept in check by the microscopic animals which normally eat them. So they die and fall to the bottom of the river or lake. Here, their bodies are broken down by bacteria. The bacteria need oxygen to carry out this breakdown and the oxygen is taken from the water (Fig. 11). So much oxygen is taken that the water becomes deoxygenated and can no longer support animal life. Fish and other organisms die from suffocation (Fig. 12).

Figure 12 Fish killed by pollution. The water may look clear but is so short of oxygen that the fish have died from suffocation.

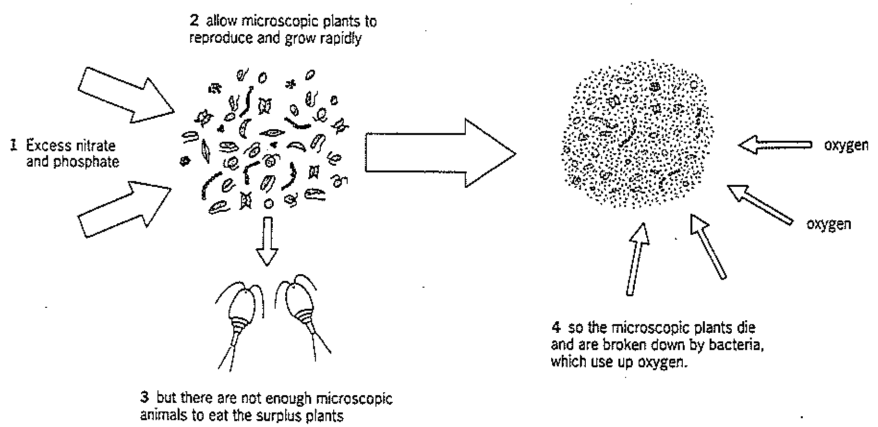


Figure 11 Effects of eutrophication

The following processes are the main causes of eutrophication.

Discharge of treated sewage

In a sewage treatment plant, human waste is broken down by bacteria (p. 256) and made harmless, but the breakdown products include phosphates and nitrates. When the water from the sewage treatment is discharged into rivers it contains large quantities of phosphate and nitrate which allow the microscopic plant life to grow very rapidly (Fig. 10).

Use of detergents

Some detergents contain a lot of phosphate. This is not removed by sewage treatment and is discharged into rivers. The large amount of phosphate encourages growth of microscopic plants (algae).

Arable farming

Since the Second World War, more and more grassland has been ploughed up in order to grow arable crops such as wheat and barley. When soil is exposed in this way, the bacteria, aided by the extra oxygen and water, produce soluble nitrates which are washed into streams and rivers where they promote the growth of algae. If the nitrates reach underground water stores they may increase the nitrate in drinking water to levels considered 'unsafe' for babies.

Some people think that it is excessive use of artificial fertilizers which causes this pollution but there is not much evidence for this.

'Factory farming'

Chickens, calves and pigs are often reared in large sheds instead of in open fields. Their urine and faeces are washed out of the sheds with water forming 'slurry'. If this slurry gets into streams and rivers it supplies an excess of nitrates and phosphates for the microscopic algae.

The degree of pollution of river water is often measured by its **biochemical oxygen demand (BOD)**. This is the amount of oxygen used up by a sample of water in a fixed period of time. The higher the BOD, the more polluted the water is likely to be.

It is possible to reduce eutrophication by using

1 detergents with less phosphates;
2 agricultural fertilizers that do not dissolve so easily;
3 animal wastes on the land instead of letting them reach rivers.

QUESTIONS

1 What might be the effect of the removal of earthworms from the food web in Fig. 1 on p. 243?
2 Give five examples of monocultures.
3 What might be the effect on the food web of Fig. 1 of spraying the tree with an insecticide?
4 DDT is a fat-soluble compound, so it was often stored in the fat depots of the birds which ingested it. The harmful effects were often unnoticed until a spell of bad weather occurred. Suggest reasons for this.
5 Explain briefly why too much nitrate could lead to too little oxygen in river water.

Humans and forests

Forests have a profound effect on climate, water supply and soil maintenance. They have been described as environmental buffers. For example, they intercept heavy rainfall and release the water steadily and slowly to the soil beneath and to the streams and rivers that start in or flow through them. The tree roots hold the soil in place.

At present, we are destroying forests, particularly tropical forests, at a prodigious rate (*a*) for their timber, (*b*) to make way for agriculture, roads (Fig. 13) and settlements, and (*c*) for firewood. At the current rate of destruction, it is estimated that all tropical rainforests will have disappeared in the next 85 years.

Figure 13 Cutting a road through a tropical rainforest. The road not only destroys the natural vegetation, it also opens up the forest to further exploitation.

Removal of forests allows soil erosion, silting up of lakes and rivers, floods and the loss for ever of thousands of species of animals and plants.

Trees can grow on hillsides even when the soil layer is quite thin. When the trees are cut down and the soil is ploughed, there is less protection from the wind and rain. Heavy rainfall washes the soil off the hillsides into the rivers. The hillsides are left bare and useless and the rivers become choked up with mud and silt which can cause floods (Figs 14 and 17(a)). For example, Argentina spends 10 million dollars a year on dredging silt from the River Plate estuary to keep the port of Buenos Aires open to shipping. It has been found that 80 per cent of this sediment comes from a deforested and overgrazed region 1800 km upstream which represents only 4 per cent of the river's total catchment area. Similar sedimentation has halved the lives of reservoirs, hydroelectric schemes and irrigation programmes. The disastrous floods in India and Bangladesh in recent years may be attributed largely to deforestation.

The soil of tropical forests is usually very poor in nutrients. Most of the organic matter is in the leafy canopy of the tree tops. For a year or two after felling and burning, the forest soil yields good crops but the nutrients are soon depleted and the soil eroded. The agricultural benefit from cutting down forests is very short-lived, and the forest does not recover even if the impoverished land is abandoned.

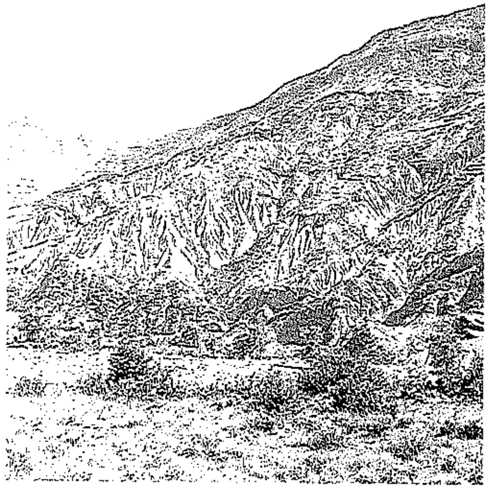


Figure 14 Soil erosion. Removal of forest trees from steeply sloping ground has allowed the rain to wash away the topsoil.

Forests and climate

About half the rain which falls in tropical forests comes from the transpiration of the trees themselves. The clouds which form from this transpired water help to reflect sunlight and so keep the region relatively cool and humid. When areas of forest are cleared, this source of rain is removed, cloud cover is reduced and the local climate changes quite dramatically. The temperature range from day to night is more extreme and the rainfall diminishes.

In North Eastern Brazil, for example, an area which was once rainforest is now an arid wasteland. If more than 60 per cent of a forest is cleared, it may cause irreversible changes in the climate of the whole region. This could turn the region into an unproductive desert.

Forests and biodiversity

One of the most characteristic features of tropical forests is the enormous diversity of species they contain. In Britain, a forest or wood may consist of only one or two species of tree such as oak, ash, beech or pine. In tropical forests there are many more species and they are widely dispersed throughout the habitat. It follows that there is also a wide diversity of animals which live in such habitats. In fact, it has been estimated that half of the world's 10 million species live in tropical forests.

Destruction of tropical forest, therefore, destroys a large number of different species, driving many of them to the verge of extinction, and also drives out the indigenous populations of humans. In addition, we may be depriving ourselves of many valuable sources of chemical compounds which the plants and animals produce. The US National Cancer Institute has identified 3000 plants which have products active against cancer cells and 70 per cent of them come from the rainforest (Fig. 15).

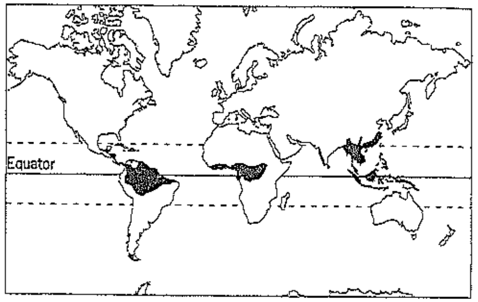


Figure 15 The world's rainforests

Agriculture and the soil

Soil erosion

Bad methods of agriculture lead to soil erosion. This means that the soil is blown away by the wind, or washed away by rain water. Erosion may occur for a number of reasons.

Deforestation

The soil cover on steep slopes is usually fairly thin but can support the growth of trees. If the forests are cut down to make way for agriculture, the soil is no longer protected by a leafy canopy from the driving rain. Consequently, some of the soil is washed away eventually reaching streams and rivers (Figs 14 and 17).

Bad farming methods

If land is ploughed year after year and treated only with chemical fertilizers, the soil's structure may be destroyed and it becomes dry and sandy. In strong winds it can be blown away as dust (Fig. 16),

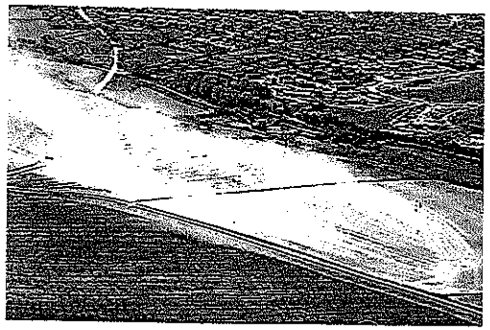


Figure 16 Topsoil blowing in the wind. A dry, sandy soil can easily be eroded by the wind.

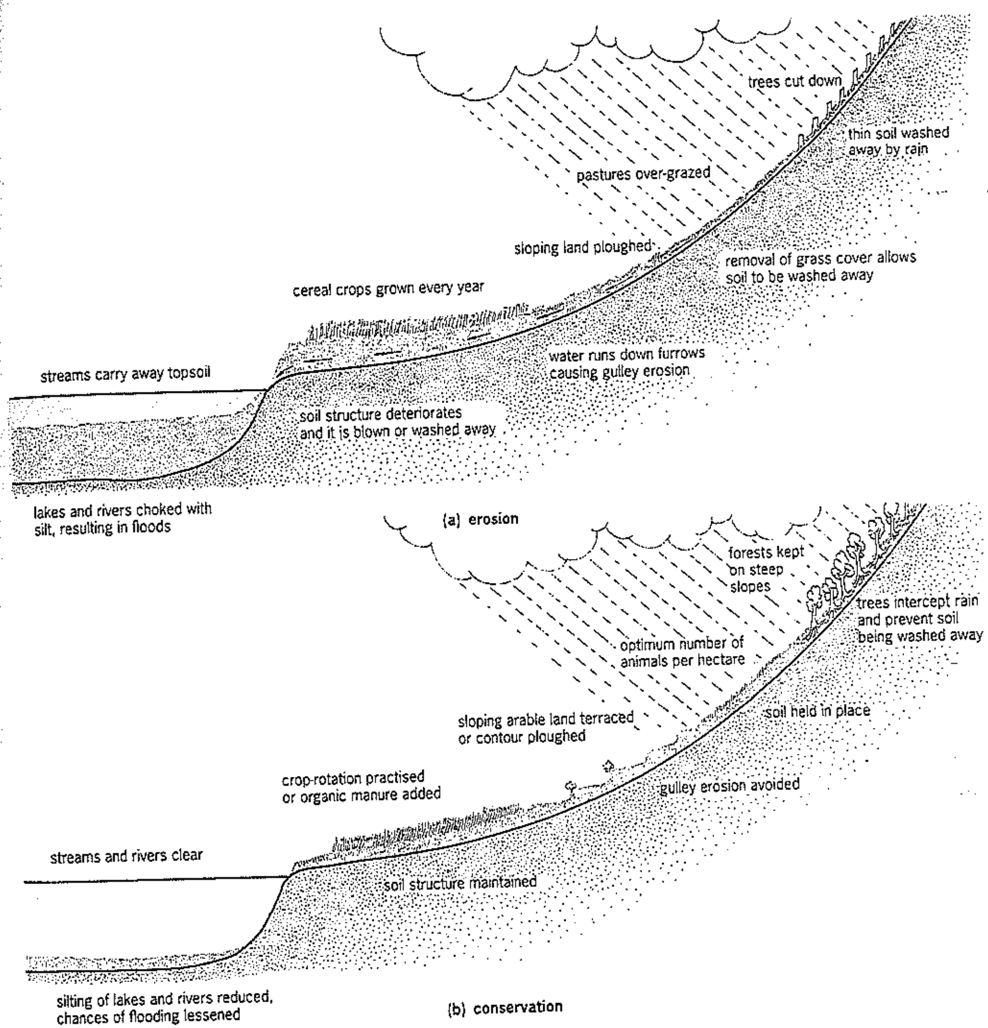


Figure 17 Soil erosion and conservation

leading to the formation of 'dust bowls', as in central USA in the 1930s, and even to deserts.

Overgrazing

If too many animals are kept on a pasture, they eat the grass down almost to the roots, and their hooves trample the surface soil into a hard layer. As a result, the rain water will not penetrate the soil and so it runs off the surface, carrying the soil with it.

QUESTIONS

6 What pressures lead to destruction of tropical forest? Give three important reasons for trying to preserve tropical forests.
7 In what ways might trees protect the soil on a hillside from being washed away by the rain?
8 If a farmer ploughs a steeply sloping field, in what direction should the furrows run to help cut down soil erosion?
9 The graph in Fig. 18 shows the change in the numbers of mites and springtails in the soil after treating it with an insecticide. Mites eat springtails. Suggest an explanation for the changes in numbers over the 16-month period.

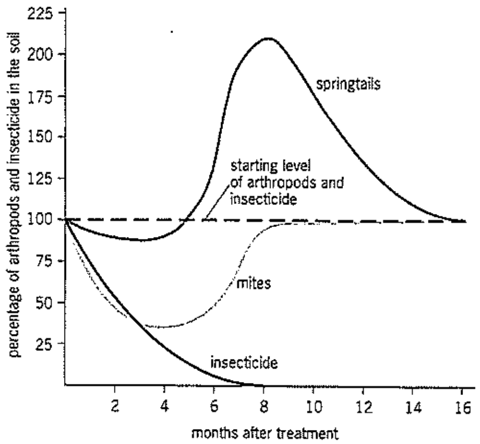


Figure 18 The effect of insecticide on some soil organisms

Use of pesticides

The effect of insecticides on food webs was described on p. 245. When insecticides get into the soil, they kill the insect pests but they also kill other organisms. The effects of this on the soil's fertility are not very clear. An insecticide called **aldrin** was found to reduce the number of species of soil animals in a pasture to half the original number. Ploughing up a pasture also reduces the number of species to the same extent, so the harm done by the insecticide is not obvious.

Water pollution

Human activity sometimes pollutes streams, rivers (Fig. 19), lakes and even coastal waters. This affects the living organisms in the water and sometimes poisons humans or infects them with disease.

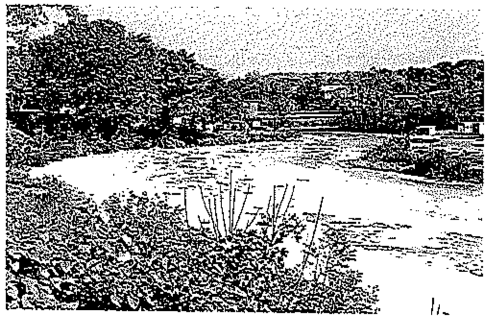


Figure 19 River pollution. The river is badly polluted by the effluent from a paper mill.

Sewage

Diseases like typhoid and cholera are caused by certain bacteria when they get into the human intestine. The faeces passed by people suffering from these diseases will contain the harmful bacteria. If the bacteria get into drinking water they may spread the disease to hundreds of other people. For this reason, among others, untreated sewage must not be emptied into rivers. It is treated at the sewage works so that all the solids are removed and the water discharged into rivers is free from harmful bacteria and poisonous chemicals (but see 'Eutrophication' on p. 246).

Eutrophication

When nitrates and phosphates from farmland and sewage escape into water they cause excessive growth of microscopic green plants. This may result in a serious oxygen shortage in the water as explained on p. 246.

Chemical pollution

Many industrial processes produce poisonous waste products. Electroplating, for example, produces waste containing copper and cyanide. If these chemicals are released into rivers they poison the animals and plants and could poison humans who drink the water. It is estimated that the River Trent receives 850 tonnes of zinc, 4000 tonnes of nickel and 300 tonnes of copper each year from industrial processes (p. 256).

In 1971, 45 people in Minamata Bay in Japan died and 120 were seriously ill as a result of mercury poisoning. It was found that a factory had been discharging a compound of mercury into the bay as part of its waste. Although the mercury concentration in the sea was very low, its concentration was increased as it passed through the food chain (see p. 245). By the time it reached the people of Minamata Bay, in the fish and other sea food which formed a large part of their diet, it was concentrated enough to cause brain damage, deformity and death.

High levels of mercury have also been detected in the Baltic Sea and in the Great Lakes of North America.

Oil pollution of the sea has become a familiar event. In 1989, a tanker called the *Exxon Valdez* ran onto Bligh Reef in Prince William Sound, Alaska, and 11 million gallons of crude oil spilled into the sea. Around 400 000 sea birds were killed by the oil (Fig. 20) and the populations of killer whales, sea otters and harbour seals among others, were badly affected. The hot water high pressure hosing techniques and chemicals used to clean up the shoreline, killed many more birds and sea creatures living on the coast. Since 1989, there have continued to be major spillages of crude oil from tankers and off-shore oil wells.

QUESTIONS

10 What are the possible dangers of dumping and burying poisonous chemicals on the land?

11 Before most water leaves the waterworks, it is exposed for some time to the poisonous gas, chlorine. What do you think is the point of this?

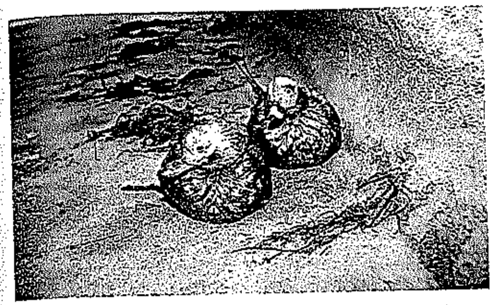


Figure 20 Oil pollution. Oiled sea birds like these long-tailed ducks cannot fly to reach their feeding grounds. They also poison themselves by trying to clean the oil from their feathers.

Air pollution

Some factories and all motor vehicles release poisonous substances into the air. Factories produce smoke and sulphur dioxide; cars produce lead compounds, carbon monoxide and the oxides of nitrogen which lead to smog (Fig. 21).

Figure 21 Photochemical 'smog' over Frankfurt

Smoke

This consists mainly of tiny particles of carbon and tar which come from burning coal either in power stations or in the home. The tarry drops contain chemicals which may cause cancer. When the carbon particles settle, they blacken buildings and damage the leaves of trees. Smoke in the atmosphere cuts down the amount of sunlight reaching the ground. For example, since the Clean Air Act of 1956, London has received 70 per cent more sunshine in December.

Particulates

Although smoke has been largely eliminated from our towns, vehicle exhaust gases (particularly from diesels), contain microscopic particles coated with hydrocarbons. These particulates are thought to be a cause of about 10 000 deaths per year, particularly of people already suffering from chronic lung diseases such as emphysema and bronchitis.

Sulphur dioxide and oxides of nitrogen

Coal and oil contain sulphur. When these fuels are burned, they release sulphur dioxide (SO_2) into the air. Although the tall chimneys of factories (Fig. 22) send smoke and sulphur dioxide high into the air, the sulphur dioxide dissolves in rain water and forms an acid. When this acid falls on buildings, it slowly dissolves the limestone and mortar. When it falls on plants, it reduces their growth and damages their leaves.

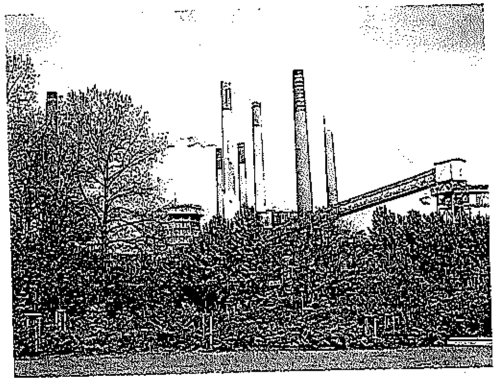


Figure 22 Air pollution by industry. Tall chimneys keep pollution away from the immediate surroundings but the atmosphere is still polluted.

This form of pollution has been going on for many years and is getting worse. In North America, Scandinavia and Scotland, forests are being destroyed (Fig. 23) and fish are dying in lakes, at least partly as a result of '**acid rain**'.

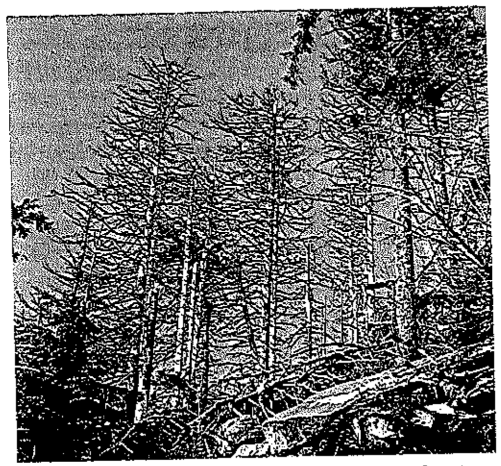


Figure 23 Effects of acid rain on conifers in the Black Forest, Germany

Oxides of nitrogen from power stations and vehicle exhausts also contribute to atmospheric pollution and acid rain. The nitrogen oxides dissolve in rain drops and form nitric acid.

Oxides of nitrogen also take part in reactions with other atmospheric pollutants and produce ozone. It may be the ozone and the nitrogen oxides which are largely responsible for the damage observed in forests.

One effect of acid rain is that it dissolves out the aluminium salts in the soil. These salts eventually reach toxic levels in streams and lakes.

There is still some argument about the source of the acid gases which produce acid rain. For example, a large proportion of the sulphur dioxide in the atmosphere comes from the natural activities of certain marine algae. These microscopic 'plants' produce the gas, dimethylsulphide, which is oxidized to sulphur dioxide in the air.

Nevertheless, there is considerable circumstantial evidence that industrial activities in Britain, America and Central and Eastern Europe add large amounts of extra sulphur dioxide and nitrogen oxides to the atmosphere (Fig. 24).

Smog

This is a thin fog which occurs in cities in certain climatic conditions (see Fig. 21). Smog is irritating to the eyes and lungs and also damages plants. It is produced when sunlight and ozone (O_3) in the atmosphere, act on the oxides of nitrogen and unburnt hydrocarbons released from vehicle exhausts. This type of smog is called 'photochemical smog' to distinguish it from the smoke plus fog that used to afflict British cities.

Carbon monoxide

This gas is also a product of combustion in the engines of cars and trucks. When inhaled, carbon monoxide combines with haemoglobin in the blood to form a fairly stable compound, carboxyhaemoglobin. The formation of carboxyhaemoglobin reduces the oxygen-carrying capacity of the blood and this can be harmful, particularly in people with heart disease or anaemia.

A smoker is likely to inhale far more carbon monoxide from cigarettes than from the atmosphere. Nevertheless, the carbon monoxide levels produced by heavy traffic in towns can be harmful.

Chlorofluorocarbons (CFCs)

These are gases which readily liquefy when compressed. This makes them useful as refrigerants, propellants in aerosol cans and in plastic foams. Chlorofluorocarbons are very stable and accumulate in the atmosphere, where they react with ozone (O_3).

Ozone is present throughout the atmosphere but reaches a peak at about 25 km, where it forms what is called the **'ozone layer'**. This layer filters out much of the ultraviolet radiation in sunlight.

The chlorine from CFCs reacts with ozone and reduces its concentration in the ozone layer. As a result, more ultraviolet (UV) radiation reaches the Earth's surface. Higher levels of UV radiation can lead to an increased incidence of skin cancer. It can also affect crops, damage marine plankton and even distort weather patterns.

The reactions involved are very complex. There are also natural processes which destroy or generate ozone.

CFCs are gradually being replaced with, so-called, 'ozone-friendly' chemicals, though some of these are still active against the ozone layer (p. 256).

Lead

Compounds of lead are mixed with petrol to improve the performance of motor cars. The lead is expelled with the exhaust gases into the air. In some areas of heavy traffic it may reach levels which are dangerous and may cause damage to the brain in children.

Although there are other sources of lead pollution, such as some canned food, or water from lead pipes, the main source of lead entering the body is leaded petrol.

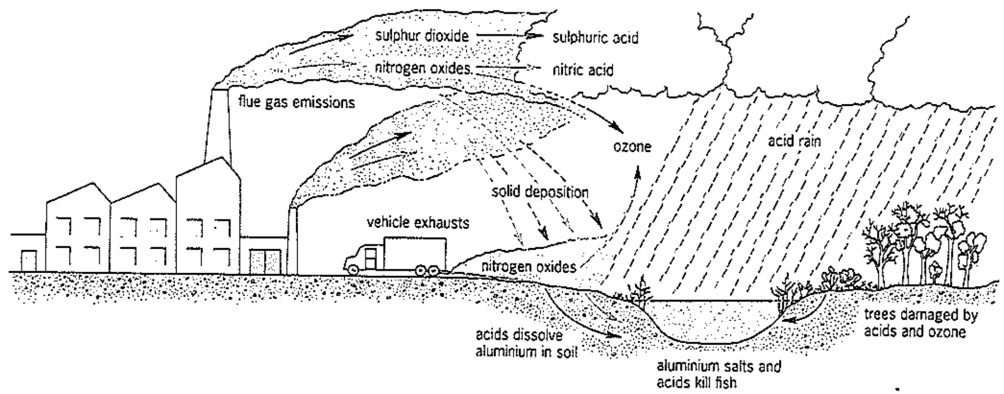


Figure 24 Unnaturally acid rain in Britain. The pollution comes from British factories, power stations, homes and vehicles. Most emissions start as dry gases and are converted slowly to dilute sulphuric and nitric acids.

Laws have been passed to reduce the level of lead in petrol and the results of such legislation in America are shown in Fig. 25. In 1985 in Britain, the lead content in petrol was reduced from 0.4 to 0.15 grams per litre by law and 'lead-free' petrol is now widely available. Unfortunately, some of the additives now used in unleaded petrol produce equally damaging pollutants.

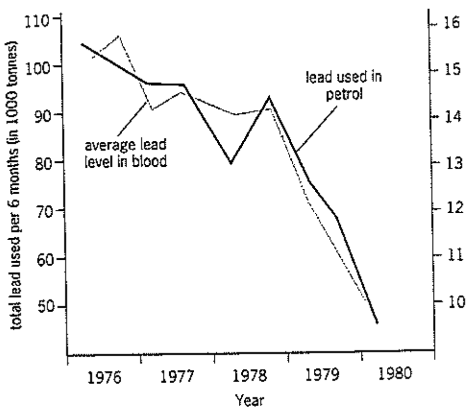


Figure 25 The effect of reducing lead in petrol. In 1975 the US government began to phase out the use of lead in petrol. This was subsequently followed by a fall in the levels of lead in people's blood. This suggests (but does not prove) a close connection between lead in exhaust fumes and the lead in the body.

The greenhouse effect and possible global warming

The Earth's surface receives and absorbs radiant heat from the sun. It re-radiates some of this heat back into space. The sun's radiation is mainly in the form of short-wavelength energy and penetrates our atmosphere easily. The energy radiated back from the Earth is in the form of long wavelengths (infrared or IR), much of which is absorbed by the atmosphere. The atmosphere acts like the glass in a greenhouse. It lets in light and heat from the sun but reduces the amount of heat which escapes (Fig. 26).

If it were not for this 'greenhouse effect' of the atmosphere, the Earth's surface would probably be at −18 °C. The 'greenhouse effect', therefore, is entirely natural and desirable.

Not all the atmospheric gases are equally effective at absorbing IR radiation. Oxygen and nitrogen, for example, absorb little or none.

The gases which absorb most IR radiation, in order of maximum absorption are water vapour, carbon dioxide, methane and atmospheric pollutants such as oxides of nitrogen and CFCs. Apart from water vapour, these gases are in very low concentrations in the atmosphere, but some of them are strong absorbers of IR radiation. It is assumed that if the concentration of any of these gases were to increase, the greenhouse effect would be enhanced and the Earth would get warmer.

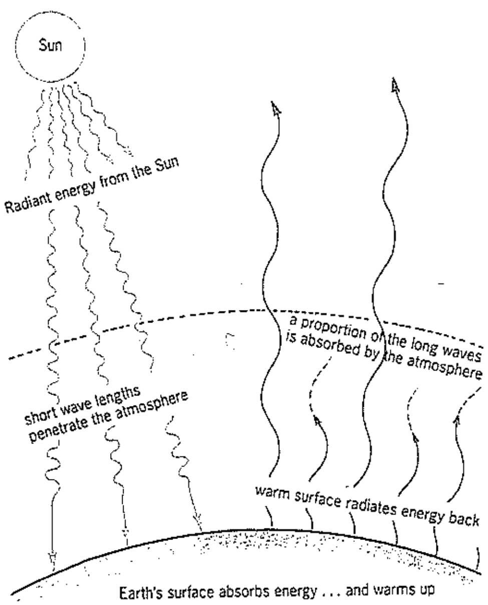


Figure 26 The short-wave energy (ultraviolet, visible light, short-wave infrared) from the Sun can get through the Earth's atmosphere and warms up the Earth's surface. The warm surface re-radiates the energy but in the form of long-wave infrared (radiant heat). About 30% of this energy is absorbed by the 'greenhouse gases' in the atmosphere. These are water vapour, carbon dioxide, methane and chloro-fluorocarbons (CFCs) mainly. Clouds reflect and absorb energy from both sources.

In recent years, attention has focused principally on carbon dioxide. If you look back at the 'carbon cycle' on p. 236, you will see that the natural processes of photosynthesis, respiration and decay would be expected to keep the carbon dioxide concentration at a steady level. However, since the Industrial Revolution, we have been burning the 'fossil fuels' derived from coal and petroleum and releasing extra carbon dioxide into the atmosphere. As a result, the concentration of carbon dioxide has increased from 0.29 to 0.35 per cent since 1860. It is likely to go on increasing as we burn more and more fossil fuel. Could this result in an increase in the Earth's temperature, i.e. global warming?

The answer is that we do not know. There are many computer models of the possible effects but they depend on the very complex and uncertain interactions of many variables.

Changes in climate might increase cloud cover and this might reduce the heat reaching the Earth from the sun. Oceanic plankton absorb a great deal of carbon dioxide. Will their rate of absorption increase or will a warmer ocean absorb less of the gas? An increase in carbon dioxide should, theoretically, result in increased rates of photosynthesis, bringing the system back into balance.

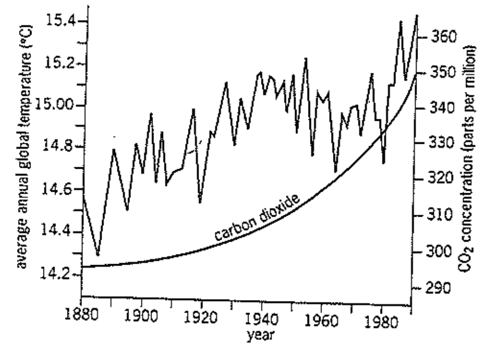


Figure 27 Annual average global temperatures since 1880

None of these possibilities is known for certain. The worst scenario is that the climate and rainfall distribution will change, and disrupt the present pattern of world agriculture; the oceans will expand and the polar ice-caps will melt causing a rise in sea level; extremes of weather may produce droughts and food shortages.

In fact, it is not possible to produce figures which show that the global temperature is rising. An average of temperature records from round the world suggests that, since 1860, there has been a rise of 0.5–0.7 °C, most of it in the last 10 years, but this is too short a period to draw any conclusion about long-term trends (Fig. 27). There is evidence that there have been far more extreme fluctuations in the distant past. If the warming trend continues, however, it could produce a rise in sea level of between 0.2 and 1.5 metres in the next 50–100 years.

Despite the uncertainties, many scientists think that there is a threat of global warming. Governments are sufficiently concerned to be getting together to discuss ways of reducing the output of carbon dioxide and other greenhouse gases such as methane, CFCs and nitrogen oxides. Current estimates are that the output of greenhouse gases will have to be reduced by 50 per cent over the next 50 years if the atmospheric temperature is to settle down at 2 °C warmer than it is now.

If the whole concept of global warming turns out to be ill-conceived, it is still worth taking certain precautions which have value for other reasons. It is a good idea to save energy and reduce pollution by burning less fuel and to reduce output of pollutants which are potential greenhouse gases.

The cost of cleaning up

Most of the forms of pollution described in this chapter could be prevented provided we were prepared to pay the cost of the necessary measures. For example, removal of sulphur dioxide from the waste gases of power stations might increase our electricity bills by 5 per cent. It is probably essential to bear these extra costs if we are to preserve our environment. Furthermore, when the costs of reducing pollution are compared with the costs of environmental damage and human ill-health, the difference may not be all that great.

QUESTIONS

12 To what extent do tall chimneys on factories reduce atmospheric pollution?

13 What are thought to be the main causes of 'acid rain'?

14 If compounds of lead and mercury get into the body, they are excreted only very slowly. Why do you think this makes them dangerous poisons even when they are in low concentrations in the air or the water?

15 It costs money to prevent harmful chemicals escaping into the air from factories and cars. The effects of pollution also cost a great deal of money. List some of the ways in which the effects of pollution **a** affect our health and **b** cost us money.

Checklist

- The plants and animals in a food web are so interdependent that even a small change in the numbers of one group has a far-reaching effect on all the others.
- Hunting activities and farming upset the natural balance between other living organisms.
- Pesticides kill insects, weeds and fungi that could destroy our crops.
- Pesticides help to increase agricultural production but they kill other organisms as well as pests.
- A pesticide or pollutant which starts off at a low, safe level can become dangerously concentrated as it passes along a food chain.
- Eutrophication of lakes and rivers results in the excessive growth of algae followed by an oxygen shortage when the algae die and decay.
- Soil erosion results from removal of trees from sloping land, use of only chemical fertilizers on ploughed land and putting too many animals on pasture land.
- The conversion of tropical forest to agricultural land usually results in failure because forest soils are poor in nutrients.
- Removal of forests can lead to erosion, silting-up of lakes and rivers and to flooding.
- We pollute our lakes and rivers with industrial waste and sewage effluent.
- We pollute the sea with crude oil and factory wastes.
- We pollute the air with smoke, sulphur dioxide and nitrogen oxides from factories, and lead and nitrogen oxides from motor vehicles.
- The acid rain resulting from air pollution leads to poisoning of lakes and possibly destruction of trees.
- The extra carbon dioxide from fossil fuels might lead to global warming.