HIGHFIELDS PUBLISHING SAMPLE SCIENCE

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HUMAN EFFECTS ON THE ENVIRONMENT

Human Effects on the Environment

Content

- The causes and effects of deforestation and desertification, with particular emphasis on communities, biodiversity and sustainable management.
- Atmospheric pollution (acid rain and greenhouse effect)
- Water pollution (effect of raw sewage and fertilisers on water quality, oxygen content and biodiversity, eutrophication, algal blooms).
- European legislation to control air and water quality.

Deforestation

Every year, large areas are deforested in order to create land for cultivation and to provide wood and charcoal for cooking. Once removed, overcultivation, overgrazing and the accompanying soil erosion change the soil conditions irreversibly so that regeneration of natural forest is impossible. It is estimated that the erosion of bare soil by wind and rain is 25 times more rapid than for land covered by a cotton crop, 4000 times more rapid than grassland and 32 000 times more rapid than forested land. In hilly regions, deforestation results in silt washing down with the rainwater into rivers, so that the river levels rise year by year causing annual floods in the plains and estuaries. Deforestation also has a major impact on local climate. Up to 50% of the water vapour of clouds above forests is contributed by transpiration. Without the trees, this water runs off into streams and rivers carrying with it valuable nutrients, leached from the soil. It is not recycled into the atmosphere.

The loss of natural vegetation and the accompanying loss of soil fertility affects the whole **community** of organisms which make up the biotic component of natural ecosystems. As you have seen (3.2), each individual population within a community is dependent on, and important to, a number of others. Intricate systems relate predators to prey, pollinators to flowering plants, consumers to producers. The loss of a single component can have dramatic knock on effects. For example, pollinating mechanisms can be so specific that the loss of a single pollinator in the ecosystem can result in the local extinction of an entire population of plants.

Biodiversity is the term used to describe the number of different interacting species supported by a particular habitat. In general, the richer the vegetation cover, the greater the biodiversity, but each community has complex interactions and different weak spots and these need to be understood if effective conservation management strategies are to be devised. At present the usual response of governments to the loss of wildlife habitats is the creation of living museums in the form of nature reserves and wildlife parks. The important question is rarely addressed, namely, how big does a nature reserve have to be to preserve biodiversity?

The answer is, much larger than is generally expected. Wandering herds require massive grazing areas and uninterrupted freedom of movement within these areas. The wildebeest and zebra which

migrate up and down the Great Rift Valley of East Africa between Tanzania and Kenya are threatened much more by human settlement than by the notorious crocodiles of the Mara river. Many of the animals most at risk of extinction are at the top of food chains. The hunting area of top carnivores such as tigers or eagles is very large but the reproductive area is much larger still. For populations to survive, genetic diversity through outbreeding is essential and isolated national parks do not answer this problem

Desertification

Natural deserts like the Sahara are created by global climate changes and are defined by the amount of annual rainfall received (less than 50mm). Settled human existence is not possible in such hostile conditions because the soil can not support food crops. However human settlement does occur on the fringes of these areas, although attempts to gain food and support from soils which are poor in nutrients to start with, and which suffer a combination of heat and drought often result in an expansion of the desert, a process called **desertification**. Desertification is the result of using arid and semi arid soils in non-sustainable ways to produce crops, and the underlying cause is the pressure of expanding human populations. The areas most at risk are tropical grasslands receiving between 200 and 600 mm rainfall per year in one short wet season.

The pressure for food and cash crops from overpopulated land results in too many crops being planted and harvested from the same soil, leaving insufficient time for the natural restoration of fertility. Overcultivation also leaves the soil bare for extended periods when it is vulnerable to erosion. The effect is particularly severe on hillside plots where sudden rains can create gulleys and land slips. As more land is used for cultivation, less is available for grazing livestock. Overgrazing eliminates the natural regeneration of trees and shrubs and it reduces the population of native grasses which are so important in binding and trapping soil particles. These tend to be replaced by temporary, shallow rooted species which appear and disappear with the rains.

One way of increasing food yields from arid soils is to irrigate the soil, but this invariably leads to a build up of salt deposits in the soil (**salinisation**) and, in solving one problem, it creates another. Irrigation water leaves a crust of salt as it evaporates from the soil surface and, over a period of time, this salt deposit is leached downwards by drainage until it reaches the water table. The only way to remove the surface crust is periodically to flood the soil, and provide adequate underground drainage channels to take away the accumulated salt along with the flood water. Without adequate drainage, flooding may raise the water table to the level of plant roots bringing with it toxic concentrations of salt. If proper concern is shown for the environment, desalination installations may be needed to treat the drainage water before it can be returned safely to a river, so, even in highly technical projects such as those in California, the real costs of irrigation can easily escalate beyond economic viability.

Pollution

A pollutant is any substance released into the environment as a result of human activities which causes harm. Some pollutants are directly toxic to humans and other organisms: others become harmful as they accumulate in unnatural quantities. Nitrate applied to a crop in the form of fertiliser, for example, is valued as a mineral nutrient: it becomes a harmful pollutant only if it leaches out of the soil into aquatic ecosystems.

Carbon dioxide and the greenhouse effect

Carbon dioxide is a major component of a layer of gases called 'greenhouse gases' which accumulate in the atmosphere. Other greenhouse gases include methane (ref 3.5), chlorofluorocarbons (CFCs), nitrous oxide and ozone. In a greenhouse, light energy passes through the glass and warms up the contents. Heat is prevented from escaping by the glass panels and, as a result, the space inside warms up. In a similar, but not identical way, the layer of greenhouse gases serves to warm the earth. It is calculated that without the greenhouse layer, the earth's average temperature would drop by up to 30ºC.

Radiant energy from the sun is made up of a number of different wavelengths, from ultra violet (less than 400nm) to infra red (more than 700nm). Visible light includes all the wavelengths between these two i.e. 400 - 700nm. Light energy passes relatively easily through the gas layer to warm the earth's surface but heat energy radiating back from the earth consists of much longer wavelengths (4000 - 100 000nm) which do not pass through so easily. Much of this energy is instead absorbed and re-radiated back to earth, hence the warming effect.

There is no doubt that the amount of carbon dioxide in the atmosphere has increased dramatically over the last few decades, and records show distinct evidence of global warming, but it should not be assumed that there is a direct connection between the two - correlation between two factors is not proof of a cause and effect relationship. The risk is, as yet, unknown and unquantifiable, but the wisest policy is to take steps to minimalise the risk by developing alternatives to fossil fuels.

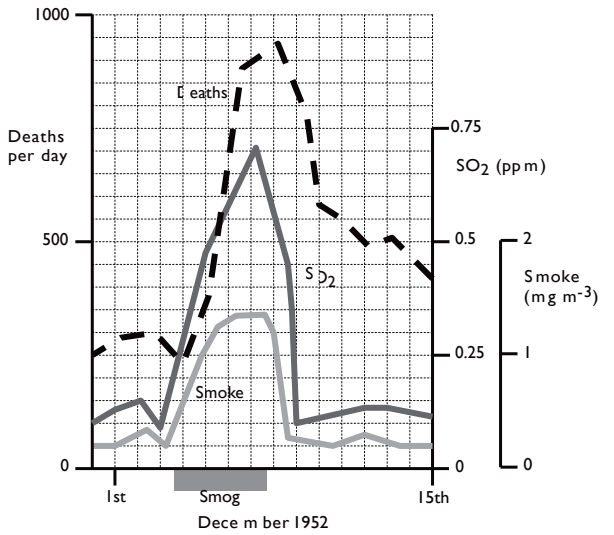
Acid rain

Rain is always slightly acidic. It contains carbon dioxide which dissolves to form carbonic acid creating a normal pH of about 5.6. The term acid rain is defined as rainfall with a pH below 5. It is formed as sulphur dioxide (SO_2) and nitrogen dioxide (NO_2), originating from the combustion of coal and oil, react with moisture in the air to form sulphuric and nitric acids respectively. The rain in central Europe has an average pH of 4.1 whilst water droplets in fog may be as low as pH 2.5. At these levels, acid rain can cause serious harm to human health. In December of 1952, for example, London was enveloped in a notorious fog which remained static due to unusual air currents.

The pH was estimated to be about 1.6 and 4000 people died from related illnesses. The cause of this disaster was identified as smoke form the countless chimneys of London but, in fact, the major source

of sulphur dioxide pollution is from coal fired power stations. Sulphur occurs as an impurity in coal (up to 3% by mass). Furthermore, the smoke from industrial chimneys may carry these gases hundreds of kilometres away from the original source so the effects of pollution extend over whole continents.

Pollution levels in the London smog of 1952



Acid rain lowers the pH of the soil solution where the excess H^+ ions tend to replace ions such as Ca^{2+}, K^+ and Mg^{2+} held by the soil particles, which are essential for plant growth. These nutrients leach out and are lost in the drainage water. Nitrate (NO^{3-}) ions from nitric acid are not a major problem because they are taken up by plant roots and used as a nitrogen source, but sulphate (SO^{4-}) ions move freely through the soil solution carrying H^+ ions with them into surrounding water systems. Acid rain therefore has the effect of removing plant nutrients from the soil, but plants are affected in more direct ways as well. The leaves of evergreen plants, particularly coniferous trees, are protected by a waxy layer (cuticle) which is eroded by acid rain. Over a period, nutrients are also lost from the leaves causing a die back of the crown of the tree.

Acid rain can have even more drastic effects on lakes and waterways. The exoskeletons of crayfish and shrimp become soft and susceptible to fungal attack at pH levels below 5.5, and no fish survive at levels below 4.5. In studies on Scandinavian lakes the loss of brown trout and salmon was linked to two different consequences of acid rain. One was the denaturation of an enzyme, essential to the hatching of eggs. The other was the leaching of Al^{3+} ions into lakes from the surrounding soil which caused the secretion of large amounts of mucus by the fish gills. As a result gas exchange and osmoregulation became impaired and the fish died.

CHECKPOINT SUMMARY

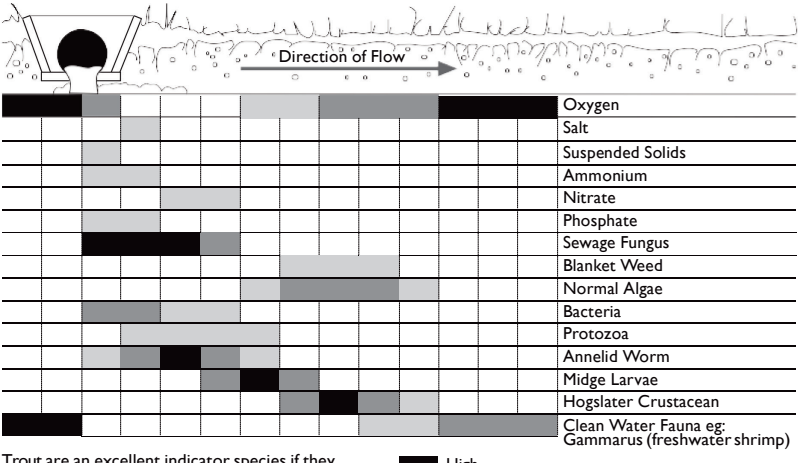
- Increasing population pressure and economic demands lead to deforestation. Removal of tree cover on poor soils can lead to the collapse of the entire ecosystem and the formation of deserts (desertification)
- Under less extreme conditions deforestation can lead to isolation of small patches of woodland which are insufficient to support the original forest communities with their rich biodiversity
- If the cleared areas are used for crop production there is a dramatic drop in the biodiversity and hence stability of communities, and massive monocultures are prone to pest attack
- Atmospheric pollution as a result of the combustion of fossil fuels results in acid rain (sulphuric and nitric acids), and greenhouse gases (e.g. carbon dioxide) which absorb solar radiation and lead to a warming of the atmosphere.

Organic pollution and eutrophication

Farmyard waste in the form of manure and silage liquid, and untreated domestic sewage contains large amounts of organic matter which can cause serious pollution problems if allowed to enter rivers and lakes. This material provides food for a multitude of anaerobic microorganisms in aquatic ecosystems and as these organisms complete the process of decomposition, they use up valuable oxygen supplies. Aquatic organisms may be classified according to their oxygen need; those with the greatest need are **indicator species** for the cleanest water, that is their presence indicates water unpolluted by organic matter.

The direct link between organic pollution and oxygen availability is the basis of a test for water purity called the **BOD** (Biological Oxygen Demand) test. BOD is the amount of oxygen required by microbes to decompose the organic matter present in a water sample. Water samples are collected in glass bottles and an initial measurement of their oxygen content is taken using an oxygen meter. The samples are incubated in the dark at 20°C for 5 days and then the oxygen content is re-measured. The difference between the two readings gives the BOD (in mg O_2 dm^{-3}). It varies from 0 - 12 in clean rivers to 250 in untreated sewage.

The decomposition of organic matter releases inorganic nutrients into water systems which can be just as damaging to the environment (ref. 3.4). The presence of excess nutrients initiates a process called **eutrophication** (from the Greek words *eu* - well, *trophe* - fed) 'Well fed' algal populations can undergo rapid population 'explosions' into algal 'blooms' on the surface of the water, blocking light penetration and providing a further source of organic material at the end of the growing season. Fertilisers (3.5) and farmyard wastes are the main sources of inorganic nutrients, but even treated sewage can contain large quantities of phosphates from detergents.



Trout are an excellent indicator species if they survive then the water is fit for almost anything

European legislation for air and water purity

Anti-pollution measures to safeguard air and water purity tend to be long term, expensive, and unpopular with the commercial sectors. It is hardly surprising, therefore, that few national governments concern themselves seriously with environmental issues. Political pressure and national sentiments are generated more when the environmental threat crosses national boundaries. The European Community legislation focusses its attention mainly on the transboundary (international) pollution of air and water through international conventions and agreements, but it also translates these agreements into specific Directives which become binding on the member states, some examples of which are given below.

Water protection and management

International agreements and **conventions** exist with regard to the conservation of marine and coastal waters, and the major European rivers. These include currently, for example, a convention for the protection of the marine environment of the north eastern Atlantic, protocol concerning specially protected areas and biodiversity in the Mediterranean, and conventions of the International Commission for the protection of the rivers Elbe and Oder.

International agreements of this kind define areas of common interest but have less immediate effect than the **Council Directives** which tend to be much more specific, and thus easier to define and enforce, for example; regulations regarding minimum levels of drinking water purity from ground and surface sources, prohibitions on the discharge of hydrocarbons from boats, nitrates from agricultural land and mercury from chlor-alkali industries.

Council Directives must be adopted as law by member states after a given time, typically 18 months after the formulation of the legislation by the EC. It is then up to the Department of the Environment or equivalent bodies to enforce them in the individual European countries.

Monitoring of atmospheric pollution

As for air quality, European legislation may be divided into two broad categories: conventions and agreements about transboundary pollution and Council Directives to specify limits and controls within the member states. The major transboundary issues are sulphur dioxide and nitrous oxide emissions and their long range effects; the control of greenhouse gases; and the depletion of the ozone layer. Some Council Directives are aimed at the major industries, for example, testing and monitoring emissions of carbon dioxide, carbon monoxide, suspended particles, sulphur dioxide and oxides of nitrogen from chemical works and power plants; controlling the release of chlorofluorocarbons from foamplastics and refrigerant industries. Others have had a direct effect on daily life, for example, Directives about lead in motor fuels and the monitoring of pollutants from diesel engines for use in vehicles.

European legislation is not exactly watertight. The conventions have limited force because they are simply international agreements, and the Council Directives suffer from the time lag between formulation and adoption. If a member state 'breaks the rules' it can take a very

CHECKPOINT SUMMARY

- **Water pollution** results from the release of the many toxic waste products of man into the water system
- Acid rain acidifies water and destroys aquatic ecosystems
- Raw human and animal sewage has a high organic content and its oxidation by aerobic microorganisms depletes water of its oxygen
- Run-off of excess nitrates and phosphates from artificial fertilizers in the soil cause eutrophication of the water which can trigger excess algal growth (algal blooms), which can deplete other essential nutrients, leading to death of the algae, their aerobic decomposition, and depletion of oxygen in the water
- Depletion of oxygen in aquatic ecosystems leads to the death of aerobic organisms and the collapse of the ecosystem into anaerobic conditions, which cannot be simply reversed by oxygenation
- European legislation exists to control air and water quality.