Effects on human health

The effects of DDT on human health are disputed and conflicting. For example, some studies have shown that:

- farmers exposed to DDT occupationally had an increased incidence of asthma and/or diabetes;
- some people exposed to DDT had a higher risk of liver-, breast-, and/or pancreatic-cancer;
- DDT exposure is a risk factor for early pregnancy loss, premature birth and/or low birth weight;
- a 2007 study found increased infertility among South African men from communities where DDT is used to combat malaria.

Use of DDT against malaria

Malaria remains a major public health challenge in many parts of the world. The WHO estimates that there are 250 million cases every year, resulting in almost 1 million deaths. About 90 per cent of these deaths occur in Africa. In 2006, only 13 countries were still using DDT.

Nevertheless, the WHO is 'very much concerned with health consequences from use of DDT' and it has reaffirmed its commitment to eventually phase it out. In South America, malaria cases increased after countries stopped using DDT. In Ecuador between 1993 and 1995, the use of DDT increased and there was a 61 per cent reduction in malaria rates.

To learn more about the use and impacts of DDT, go to www.pearsonhotlinks.com, insert the express code 2630P and click on activity 5.9.

Some donor governments and agencies have refused to fund DDT spraying, or made aid contingent on not using DDT. Use of DDT in Mozambique was stopped because 80 per cent of the country's health budget came from donor funds, and donors refused to allow the use of DDT.

Examiner's hint:
Discuss – Make a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.

EXERCISES

1. Outline the processes of pollution.
2. Outline strategies for reducing the impacts of pollution.
3. Discuss the human factors that affect the approaches to pollution management.
4. Describe the variations in the level of DDT along a food chain.
5. Outline the main uses (past and present) of DDT.
6. Comment on the risks of using DDT.

5.4 Eutrophication

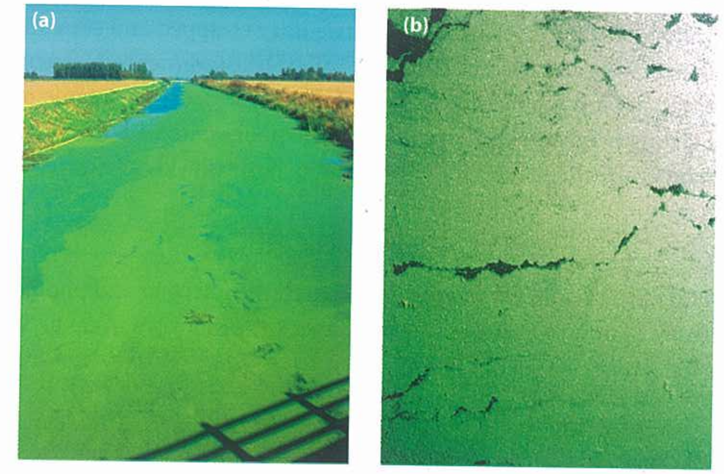
Assessment statements

5.4.1 Outline the processes of eutrophication.
5.4.2 Evaluate the impacts of eutrophication.
5.4.3 Describe and evaluate pollution management strategies with respect to eutrophication.

Eutrophication refers to the nutrient enrichment of streams, pond and groundwater. It is caused when increased levels of nitrogen or phosphorus are carried into water bodies. It can cause algal blooms, oxygen starvation and eventually the decline of biodiversity in aquatic ecosystems.

Processes of eutrophication

In eutrophication, increased amounts of nitrogen and/or phosphorus are carried in streams, lakes and groundwater causing nutrient enrichment. This leads to an increase in algal blooms as plants respond to the increased nutrient availability. This is an example of positive feedback (Chapter 1, page 7).



(**a**) Overgrowth of algae due to eutrophication, Cambridgeshire, UK. (**b**) Close-up of surface algal bloom due to eutrophication.

However, the increase in algae and plankton shade the water below, cutting off the light supply for submerged plants. The prolific growth of algae and cyanobacteria, especially in autumn as a result of increased levels of nutrients in the water and higher temperatures, results in **anoxia** (oxygen starvation in the water). The increased plant biomass and decomposition – which lead to a build up of dead organic matter – also lead to changes in species composition.

Some of these changes are the direct result of eutrophication (e.g. stimulation of algal growth in water bodies) while others are indirect (e.g. changes in the diversity of fish species due to reduced oxygen concentration). Eutrophication is very much a dynamic system – as levels of nitrates and phosphorus in streams and groundwater change, there is a corresponding change in species composition.

Algae and cyanobacteria are tiny organisms occurring in fresh water and saltwater. Algae belong to the eukaryotes – single celled or multi-cell organisms whose cells contain a nucleus. The cyanobacteria belong to the prokaryotes – single-cell organisms without a membrane-bound nucleus. The cyanobacteria used to be called 'blue–green algae' (a term you may still come across) but they have been reclassified as bacteria. The first members of the cyanobacteria to be discovered were indeed blue–green in colour, but since then, new members of the group have been found that are not this distinctive colour.

A number of changes may occur as a result of eutrophication.

- Turbidity (murkiness) increases, reducing the amount of light reaching submerged plants.
- Rate of deposition of sediment increases, due to increased vegetation cover reducing the speed of water, decreasing the lifespan of lakes.
- Net primary productivity is usually higher compared with unpolluted water and may be seen by extensive algal or bacterial blooms.
- Dissolved oxygen in water decreases, as organisms decomposing the increased biomass consume oxygen.
- Diversity of primary producers changes and finally decreases; the dominant species change. Initially, the number of primary producers increases and may become more diverse. However, as eutrophication proceeds, early algal blooms give way to cyanobacteria.
- Fish populations are adversely affected by reduced oxygen availability, and the fish community becomes dominated by surface-dwelling coarse fish, such as pike and perch.

In freshwater aquatic systems, a major effect of eutrophication is the loss of the submerged **macrophytes** (aquatic plants). Macrophytes are thought to disappear because they lose their energy supply (sunlight penetrating the water). Due to eutrophication, sunlight is intercepted by the increased biomass of phytoplankton exploiting the high nutrient conditions. In principle, the submerged macrophytes could also benefit from increased nutrient availability, but they have no opportunity to do so because they are shaded by the free-floating microscopic organisms.

Eutrophication involves:

- increase in nitrates and phosphates in water
- rapid growth of algae
- light blocked from submerged aquatic plants
- accumulation of dead organic matter
- increased activity of decomposers
- increased removal of oxygen by decomposers
- reduced oxygen kills fish and other organisms.

Natural eutrophication

The process of primary succession (Chapter 2, page 65; Chapter 4, page 185) is associated with gradual eutrophication as nutrients are trapped and stored by vegetation, both as living tissue and organic matter in soil or lake sediments. Nutrient enrichment occurs through addition of sediment, rainfall and the decay of organic matter and waste products. Starting from an oligotrophic (nutrient-poor) state with low productivity, a typical temperate lake increases in productivity fairly quickly as nutrients accumulate.

Anthropogenic eutrophication

Human activities worldwide have caused the nitrogen and phosphorus content of many rivers to double and, in some countries, local increases of up to 50 times have been recorded.

Phosphorus

Phosphorus is a rare element in the Earth's crust. Unlike nitrogen, there is no reservoir of gaseous phosphorus compounds available in the atmosphere. In natural systems, phosphorus is more likely to be a growth-limiting nutrient than nitrogen.

In addition, domestic detergents are a major source of phosphates in sewage effluents. Estimates of the relative contribution of domestic detergents to phosphorus build-up in Britain's watercourses vary between 20 per cent and 60 per cent. As phosphorus increases in a freshwater ecosystem, the amount of plankton increases and the amount of freshwater plants decreases.

About three-quarters of the world's production of phosphorus (167 Mt in 2008) comes from the USA, China, Morocco and Russia.

The mining of phosphate-rich rocks has increased the mobilization of phosphorus. A total of $12 \times 10^{12}\ \mathrm{g\,P\,yr^{-1}}$ are mined from rock deposits. This is six times the rate at which phosphorus is locked up in ocean sediments from which the rocks are formed.

Nitrogen

Nearly 80 per cent of the atmosphere is nitrogen. In addition, air pollution has increased rates of nitrogen deposition. The main anthropogenic source is a mix of nitrogen oxides (NO_x), mainly nitrogen monoxide (NO), released during the combustion of fossil fuels in vehicles and power plants. Despite its abundance, nitrogen is more likely to be the limiting nutrient in terrestrial ecosystems (as opposed to aquatic ones), where soils can typically retain phosphorus while nitrogen is leached away.

Nutrients applied to farmland through fertilizers may spread to the wider environment by:

- drainage water percolating through the soil, leaching soluble plant nutrients
- washing of excreta, applied to the land as fertilizer, into watercourses
- erosion of surface soils or the movement of fine soil particles into subsoil drainage systems.

In Europe, large quantities of slurry from intensively reared and housed livestock is spread on the fields. Animal excreta are very rich in both nitrogen and phosphorus and, therefore, their application to land can contribute to problems from polluted run-off.

To learn more about the World Resources Institute assessment of eutrophication in coastal areas, go to www.pearsonhotlinks.com, insert the express code 2630P and click on activity 5.10.

Evaluating the impact of eutrophication

There are three main reasons why the high concentrations of nitrogen in rivers and groundwater are a problem. First, nitrogen compounds can cause undesirable effects in the aquatic ecosystems, especially excessive growth of algae. Second, the loss of fertilizer is an economic loss to the farmer. Third, high nitrate concentrations in drinking water may affect human health.

CASE STUDY

Eutrophication of Lake Erie

Natural eutrophication normally takes thousands of years to progress. In contrast, anthropogenic or cultural eutrophication is very rapid. During the 1960s, Lake Erie (on the USA–Canada border) was experiencing rapid anthropogenic eutrophication and was the subject of much concern and research.

Eutrophication of Lake Erie caused algal and cyanobacterial blooms which caused changes in water quality. The increase in cyanobacteria at the expense of water plants led to a decline in biodiversity. With fewer types of primary producer, there were fewer types of consumer, and so the overall ecosystem biodiversity decreased. Cyanobacteria are unpalatable to zooplankton, thus their expansion proceeds rapidly. The cyanobacterial blooms led to oxygen depletion and the death of fish. In addition, algal and bacterial species can cause the death of fish by clogging their gills and causing asphyxiation. Many indigenous fish disappeared and were replaced by species that could tolerate the eutrophic conditions. Low oxygen levels caused by the respiration of the increased lake phytomass killed invertebrates and fish. Increased levels of bacteria reduced water velocity and light levels, causing increased turbidity in the water and increased sedimentation. The death of macrophytes on the lake floor increased the build up of dead organic matter in the thickening lake sediments. Rotting, bacterial masses covered beaches and shorelines.

Researchers at the University of Manitoba set up the Experimental Lakes Area (ELA) in 1968 to investigate the causes and impacts of eutrophication in Lake Erie. Between June 1969 and May 1976, it was the main focus of experimental studies at the ELA.

Aerial view of lake 227 in 1994. The bright green colour is caused by cyanobacteria stimulated by the experimental addition of phosphorus for the 26th consecutive year. Lake 305 in the background is unfertilized with phosphorus.

Over a number of years, seven different lakes (ELA lakes 227, 304, 302, 261, 226, 303, and 230) were treated in different ways. Lakes 227 and 226 were especially important in showing the effect of phosphorus in eutrophication. Studies of gas exchange and internal mixing in lake 227 during the early 1970s clearly demonstrated that algae in lakes were able to obtain sufficient carbon dioxide, via diffusion from the atmosphere to the lake water, to support eutrophic blooms. 'Blue–green algae' (now called cyanobacteria) were found to be able to fix nitrogen that had diffused naturally into the lake from the air, making nitrogen available for supporting growth.

ELA lake 226 was the site of a very successful experiment. The lake was divided into two relatively equal parts using a plastic divider curtain. Carbon and nitrogen were added to one half of the lake, while carbon, nitrogen and phosphorus were added to the other half of the lake. For eight years, the side receiving phosphorus developed eutrophic cyanobacterial blooms, while the side receiving only carbon and nitrogen did not. The experiment suggested that in this case phosphorus was the key nutrient. A multi-billion dollar phosphate control programme was soon instituted within the St. Lawrence Great Lakes Basin. Legislation to control phosphates in sewage, and to remove phosphates from laundry detergents, was part of this programme.

Case study continued

Algae may be a nuisance but they do not produce substances toxic to humans or animals. Cyanobacteria, on the other hand, produce substances that are extremely toxic causing serious illness and death if ingested. This is why cyanobacteria are a very worrying problem in water sources or reservoirs used for leisure facilities.

- Use split applications to obtain the best match of nitrogen supply and demand by the crop and to reduce risk of nitrogen loss by leaching.
  – For cereals: main application in March–April, after a small early application in February.
  – For grass: small applications monthly throughout the growing season to match the requirement of plants, and especially after cutting, reduces risk of loss.
- Do not apply nitrogen next to headlands (areas at the edges of fields where tractors turn round) when the field is by a stream or lake.
- Do not apply nitrogen just before heavy rain is forecast (assuming that forecasts are accurate).
- Use less nitrogen if the previous year was dry because less will have been less lost. This is difficult to assess precisely.
- Do not plough up grass as this releases nitrogen.
- Use steep slopes for permanent pasture grass or woodland; use flat land above slopes for arable crops. This minimizes the greater risk of wash from steep land.
- Incorporate straw – straw decay uses nitrogen, with up to 13 per cent less nitrogen lost – it also locks up phosphorus.
- Direct drilling and minimal cultivation reduces nitrogen loss by up to a half. Less disturbance means less conversion of nitrogen to nitrate but straw has to be burnt.

Regulating and reducing the nutrient source

CASE STUDY

Effluent diversion at Lake Washington, USA

In some circumstances it may be possible to divert sewage effluent away from a water body. This was achieved at Lake Washington, near Seattle, USA. In 1955, Lake Washington was affected by cyanobacteria. The lake was receiving sewage effluent from about 70 000 people. The sewerage system was redesigned to divert effluent away from the lake to the nearby sea inlet of Puget Sound.

ENVIRONMENTAL PHILOSOPHIES

Different users and organizations view eutrophication in different ways – farmers claim to need to use fertilizers to improve food supply; chemical companies argue they produce fertilizers to meet demand from farmers; water companies seek money from the government and the consumer to make eutrophic water safe to drink; the consumers see rising water bills and potential health impacts of eutrophication.

Phosphate stripping

Up to 45 per cent of total phosphorus loadings to freshwater in the UK comes from sewage treatment works. This input can be reduced by 90 per cent or more by carrying out phosphate stripping. The effluent is run into a tank and dosed with a precipitant, which combines with phosphate in solution to create a solid, which then settles out and can be removed.

Domestic campaigns

Public campaigns in Australia have encouraged people to:

- use zero- or low-phosphorus detergents
- wash only full loads in washing machines
- wash vehicles on porous surfaces away from drains or gutters
- reduce use of fertilizers on lawns and gardens
- compost garden and food waste
- collect and bury pet faeces.

Clean-up strategies

Once nutrients are in an ecosystem, it is much harder and more expensive to remove them than it would have been to tackle the eutrophication at source.

The main clean-up methods available are:

- precipitation (e.g. treatment with a solution of aluminium or ferrous salt to precipitate phosphates)
- removal of nutrient-enriched sediments, for example by mud pumping
- removal of biomass (e.g. harvesting of common reed) and using it for thatching or fuel.

Removal of fish can allow primary consumer species to recover and control algal growth. Once water quality has improved, fish can be re-introduced.

Mechanical removal of plants from aquatic systems is a common method for mitigating the effects of eutrophication. Efforts may be focussed on removal of unwanted aquatic plants (e.g. water hyacinth) that tend to colonize eutrophic water. Each tonne of wet biomass harvested removes about 3 kilograms of nitrogen and 0.2 kilograms of phosphorus from the system. Alternatively, plants may be introduced deliberately to mop-up excess nutrients.

Managing eutrophication using barley bales. The bales of barley straw are just visible (brown) beneath the water surface at the right-hand edge of the lake.

Prevention of eutrophication at source compared with treating its effects (or reversing the process) has the following advantages.

- Technical feasibility – In some situations prevention at source may be achieved by diverting a polluted watercourse away from the sensitive ecosystem, while removal of nutrients from a system by techniques such as mud-pumping is more of a technical challenge.
- Cost – Nutrient stripping at source using a precipitant is relatively cheap and simple to implement. Biomass stripping of affected water is labour-intensive and therefore expensive.
- Products – Constructed wetlands may be managed to provide economic products such as fuel, compost or thatching material more easily than trying to use the biomass stripped from a less managed system.

W To learn more about experiments related to eutrophication, go to www.pearsonhotlinks.com, insert the express code 2630P and click on activity 5.11.

EXERCISES

1 Outline the processes of eutrophication.

2 Evaluate the impacts of eutrophication.

3 Describe and evaluate pollution management strategies with respect to eutrophication.

4 Outline the effects of eutrophication on natural and human environments.

5 'It is easier and more cost-effective to control the causes of eutrophication rather than to deal with the symptoms (results) of eutrophication.' Critically examine this statement.

Examiner's hint:
Evaluate – make an appraisal by weighing up the strengths and limitations.