Bio Factsheet

Number 15

The Greenhouse Effect

Many people regard global warming or the greenhouse effect as the most serious environmental threat to our present way of life on earth.

Put simply, the greenhouse effect is the natural "trapping in" of heat by some of the gases in the atmosphere. Figure 1 shows the key points of the greenhouse effect.

EXAM HINT - *Candidates often confuse the greenhouse effect with ozone depletion. Although they have some common causes, their mechanisms and effects are very different.*

Some of the greenhouse gases, for example, carbon dioxide, occur naturally in the atmosphere, whilst others such as the chlorofluorocarbons (CFCs) are entirely man-made. Regardless of their origin, such gases warm the lower atmosphere by trapping outgoing longwave radiation in a manner similar to that of glass in a greenhouse, hence the term greenhouse effect.

It is important to realise that the greenhouse effect is a **natural**, essential process. Without it, the average temperature on earth would be about -17°C and life would be impossible.

However, over the last hundred years human activities have resulted in rising concentrations of all the greenhouse gases. This has led to an increased or **"enhanced" greenhouse effect** and this in turn seems to have led to an increase in average global temperature.

It is the possible implications of this extra heating effect that are causing so much concern.

We simply do not know how much the temperature will continue to rise and what effect any changes will have on local, regional and world climate. Which areas will benefit and which will suffer, and how, is still largely unknown. The temperature will not rise everywhere equally; in fact some areas will probably become cooler (because of this, most of the scientific literature now uses the term "global climate change" rather than global warming). The effects of possible changes will be discussed shortly, but first we need to look at the greenhouse gases in a little more detail.

Typical exam questions

1. Describe the trend shown in Fig 2.
(1 mark)

2. Suggest why the concentration of CO_2 fluctuates within any one year.
(2 marks)

Why is carbon dioxide so important?

In discussions of the greenhouse effect, attention is almost invariably focused on rising CO_2 levels. This is not because it is an unusually powerful greenhouse gas - indeed, gases such as methane are thirty times more powerful weight for weight - but because of its sheer abundance (Table 1). As a consequence, its effects outweigh those of all the other greenhouse gases combined. Historically, high carbon dioxide concentrations have always coincided with inter-glacial periods and low concentrations with ice ages.

Figure 2. shows how carbon dioxide concentrations have increased recently.

Figure 2: Mean Monthly CO_2 concentrations at Mauna Loa

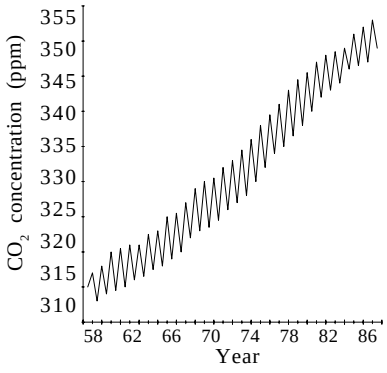


Figure 1: The Greenhouse Effect

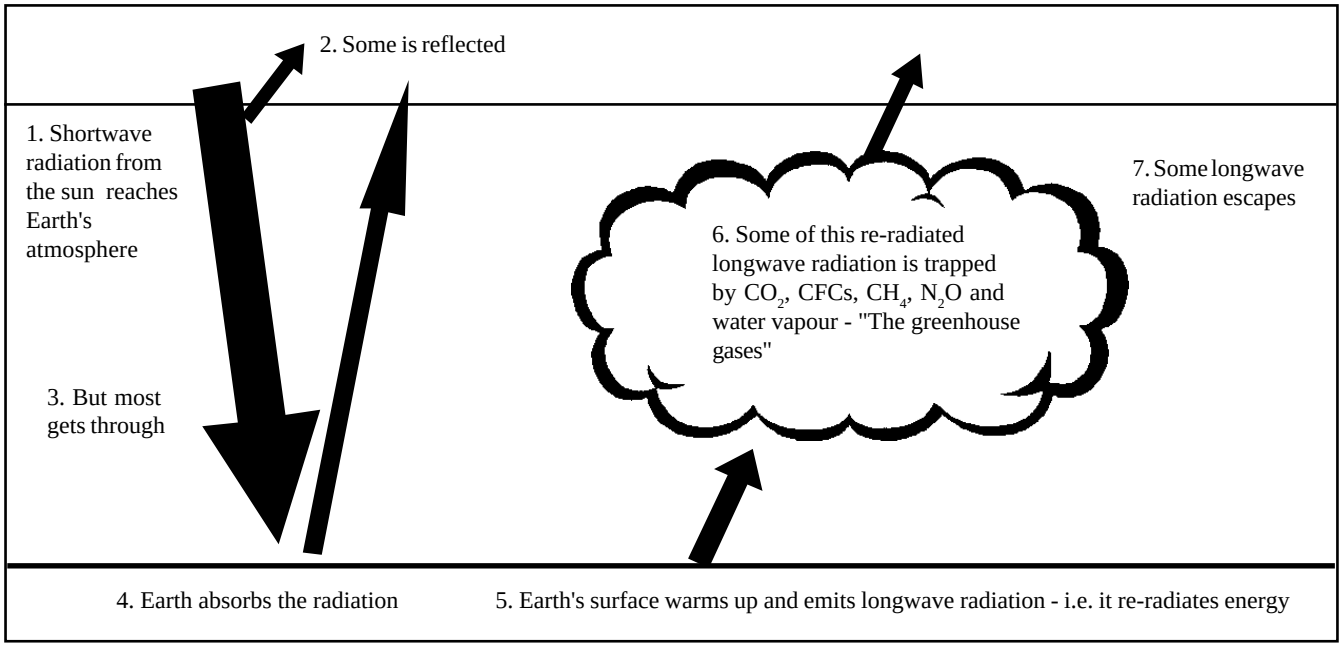
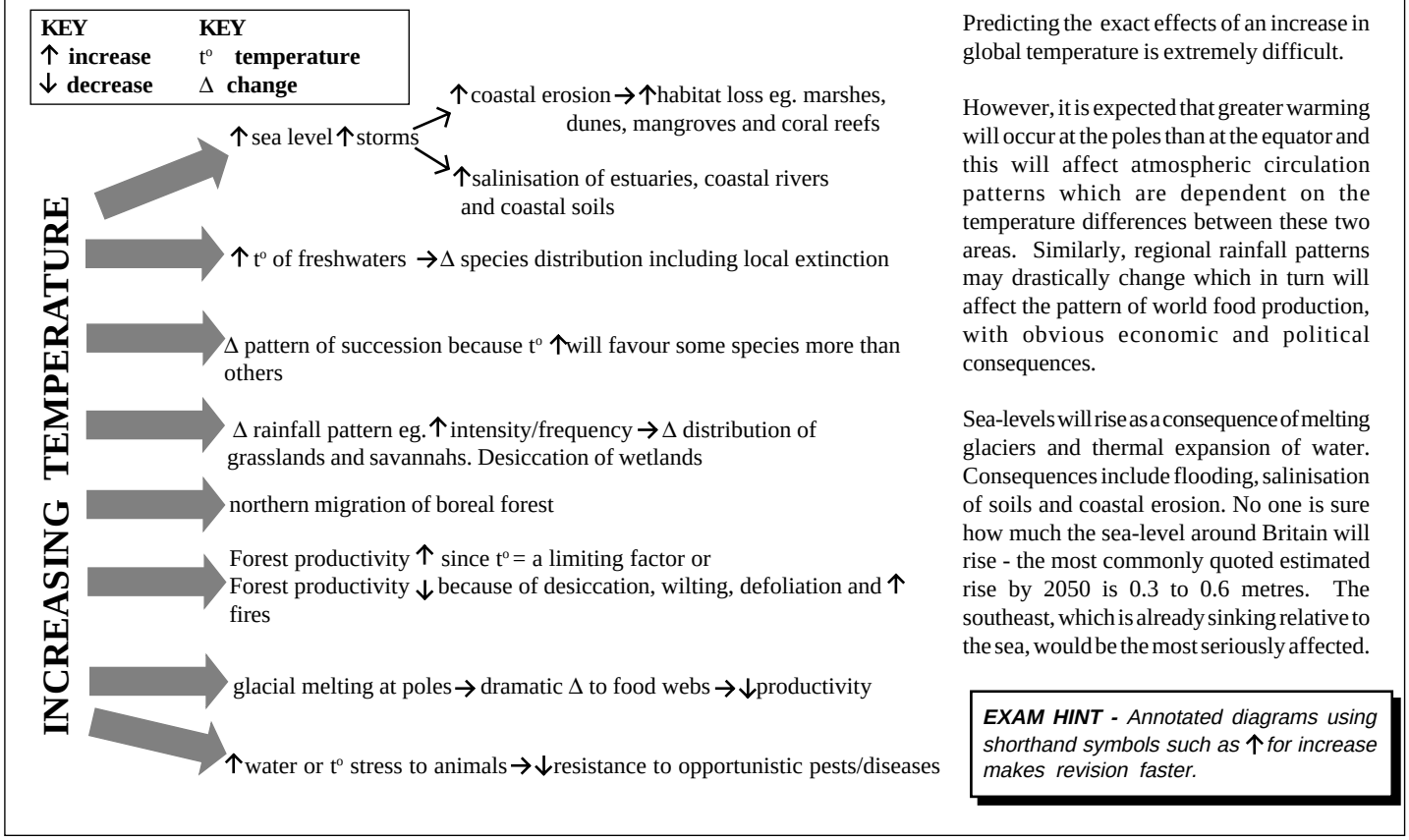


Table 1: The major greenhouse gases (excluding water vapour*)

** The concentration of water vapour, which has the greatest greenhouse effect, is not significantly affected by human activity*

Gas	Conc (ppm)	Average residence time (yrs)	Sources	Reason for increase
CO_2	360	100	Combustion of fossil fuels Respiration	a) Growing world energy demand leading to increased fossil fuel combustion b) Destruction of vegetation - eg. rainforests - leading to i) decline in global photosynthesis ii) increased CO_2 in atmosphere due to burning of cleared vegetation
CH_4	1.7	10	a) Anaerobic bacteria in marshes and in guts of ruminants b) Decomposition of organic material c) Leakage from gas pipes and coal mines	a) Increase in ruminant population b) Increase in area given over to landfill c) Increase in area given over to rice paddy
N_2O	0.3	130	a) Combustion of fossil fuels b) Denitrifying bacteria acting on nitrates and nitrites	a) Increased use of fossil fuels b) Increased use of nitrate fertilisers c) Increased cultivation of soil
O_3	0.01-0.05	(variable)	Reaction product of car exhaust pollutants (nitrous oxides, hydrocarbons) and sunlight	Increased use of fossil fuels for transport
CFCs	0.003	55-116	Coolants, propellants and expanders	Increased use of aerosols, refrigerators etc. (although following the Montreal Protocol, CFCs are now banned in developed countries)

Figure 3: Possible Biological and Ecological Consequences of Increasing Temperature



Predicting the exact effects of an increase in global temperature is extremely difficult.

However, it is expected that greater warming will occur at the poles than at the equator and this will affect atmospheric circulation patterns which are dependent on the temperature differences between these two areas. Similarly, regional rainfall patterns may drastically change which in turn will affect the pattern of world food production, with obvious economic and political consequences.

Sea-levels will rise as a consequence of melting glaciers and thermal expansion of water. Consequences include flooding, salinisation of soils and coastal erosion. No one is sure how much the sea-level around Britain will rise - the most commonly quoted estimated rise by 2050 is 0.3 to 0.6 metres. The southeast, which is already sinking relative to the sea, would be the most seriously affected.

***EXAM HINT** - Annotated diagrams using shorthand symbols such as ↑ for increase makes revision faster.*

This figure is meant only to indicate the complexity of possible changes; some areas will certainly become cooler.

What Can Be Done?

Strategies to reduce the emissions or levels of the greenhouse gases have mainly targeted carbon dioxide. These include:

1. Reducing the consumption of fossil fuels by increasing the fuel efficiency of buildings and vehicles. Improvements to the latter would also reduce N_2O emissions.

2. Switching fuel from coal to oil and gas which release less carbon dioxide upon consumption.

3. Switching from fossil fuels to renewable energy sources such as solar, geothermal, wind, wave, tidal and hydro-electric.

4. Preventing destruction of the tropical rainforests, simultaneously removing a problem and providing a solution.

However, as mentioned earlier, because the other greenhouse gases absorb different infra-red wavelengths to carbon dioxide, reductions in this gas alone are unlikely to be sufficient.

CFC emissions have already been reduced as a result of the Montreal Protocol in 1989 and subsequent amendments. Alternatives to CFCs are now widely available.

Any measures which reduced vehicle use or pollution would simultaneously help to reduce emissions of carbon dioxide, nitrous oxide and levels of tropospheric ozone. Worldwide however, the trend is in the wrong direction, with one new car joining the roads every second. In Britain, road transport is responsible for 18% of carbon dioxide emissions,45% of nitrous oxide emissions and 30% of all hydrocarbon emissions.

Negative and Positive Feedback

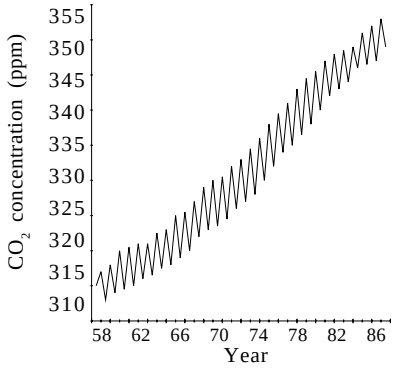
Negative feedback is an important principle of homeostasis - if a system begins to move out of equilibrium, negative feedback will initiate processes which tend to bring the system back into equilibrium. In terms of the greenhouse effect, one possible negative feedback may be that with increasing temperature there will be an increase in evaporation which will lead to increased cloudiness through condensation of the water vapour. This could reduce the amount of solar radiation which actually reaches the earth's surface, causing a cooling effect.

Positive feedback may also be involved - the world's oceans are important sinks for carbon dioxide but as their temperature rises, their ability to absorb the gas will decrease and therefore more carbon dioxide will be left in the atmosphere, further raising the temperature.

Practice questions

1. Define the term 'greenhouse effect'.
(3 marks)

2. The Figure shows atmospheric concentrations of carbon dioxide at Mauna Loa observatory in Hawaii



(a) i) Describe the trend shown.
(1 mark)

ii)In the Northern Hemisphere, winter concentrations of carbon dioxide are usually higher than summer concentrations. Suggest a possible explanation for this.
(2 marks)

3. Suggest 4 different ways in which the enhanced greenhouse effect may affect the carbon cycle.
(4 marks)

Answers

Semicolons indicate marking points.

1. Heating of the atmosphere;
Longwave radiation trapped;
By CO_2, CFCs, N_2O, CH_4, water vapour;

2. a) i) Increasing CO_2 concentration;

ii) Reduced photosynthesis/ Less carbon dioxide absorbed;
Deciduous trees are leafless/ temperature limiting;
or Greater fossil fuel combustion;
Releases carbon dioxide;

3. Increased rate of photosynthesis/respiration/ weathering/decomposition;
As temperature may be a limiting factor;
Ref. to enzymes;
So atmospheric concentration may change;
May increase size of long term sink if phytoplankton form sediments;
Decreased solution leading to increased atmospheric concentration;

Bibliography

Barnola JM, Raynaud D, Lorius C, Korotkevitch YS (1987): Vostok ice core provides 160,000 year record of atmospheric carbon dioxide. Nature 329, 408-414

Nilsson A (1992) Greenhouse Earth John Wiley

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