23 Air and the Environment

Introduction

This chapter examines the sources of air pollutants and their effects. Issues associated with the problems caused by acid rain, the depletion of the ozone layer and global warming are also discussed. Through studying these topics and issues, students also learn about how chemistry can affect the environment.

Chapter Opener (page 366)

1. Begin the chapter by discussing the following questions. Precise answers are not needed at this stage.

   What are some of the pollutants produced by motor vehicles? How are they produced and how do they affect our health?

   Answer: Motor vehicles produce nitrogen oxides, carbon monoxide and unburnt hydrocarbons. Refer to Section 23.1 on pages 366 of the Textbook.

   What is acid rain? How is acid rain formed and what are some of its effects?

   Answer: Acid rain is any rainfall that has an acidity level beyond what is expected in non-polluting rainfall. Refer to Section 23.3 on pages 368–373 of the Textbook.

   What is global warming and how is it caused? What are the consequences of global warming?

   Answer: Refer to Section 23.6 on pages 378–380 of the Textbook.

2. Carry out an 'Inquiry Preview'.

Stimulation

Here are two ways to introduce this chapter:

1. If the lesson happens to be on a day when the air is hazy, get the class to look out of the windows at the atmosphere.
2. Show the class a picture of haze in Singapore to prompt discussion. The discussion could include questions on why unpolluted air is important to us, why hazy or polluted air is harmful and the origins of haze. (Students should be familiar with haze, which comes from neighbouring countries and is caused when jungles are burnt to clear land for agricultural purposes and dead vegetation is burnt from rice fields.)

Notes for Teachers

National Education: Problems caused by haze

Haze comes from neighbouring countries and because of Singapore's small size, easily affects the whole island. Since we are not able to stop haze from crossing over, we have to persuade other countries to prevent it. Ministers from the different ASEAN countries have come together to discuss this issue and work together to come up with solutions. Singapore, for example, provides Indonesia with satellite images of fire hot spots.

Discuss:

- The importance of preserving our physical environment.
- The effect of the haze on our ecosystem.
- The importance of cooperating with and helping neighbouring countries (fostering ties, strengthening bonds, gaining mutual benefits e.g. if the haze is cleared, then we also benefit by having cleaner air).

The harm and inconveniences caused by haze include:

- Breathing problems, particular for people with asthma.
- Interference with air traffic due to poor visibility; leads to delays or cancellation of flights.
- Tourism industry suffers when visitors stay away.

Learning Outcomes

After completing this chapter, the students should be able to:

- describe the volume composition of gases present in dry air
- name some common atmospheric pollutants
- state the sources of these pollutants from natural causes and from the burning of fuels, especially in vehicles, industry and power stations
- discuss some of the effects of these pollutants on health, including the poisonous nature of carbon monoxide
- describe the reactions involved and possible solutions to the problems arising from some air pollutants
- describe the role of nitrogen dioxide and sulfur dioxide in the formation of acid rain, its effects and how it can be controlled
- discuss the importance of the ozone layer and the problems involved with the depletion of ozone by reaction with CFCs
- describe the carbon cycle (including combustion, respiration and photosynthesis) and how it regulates the amount of carbon dioxide in the atmosphere
- state that carbon dioxide and methane are greenhouse gases and may contribute to global warming, give the sources of these gases and discuss possible consequences of an increase in global warming

ChemMystery (page 367)

This mystery deals with the issue of global warming, its causes, effects and implications. In introducing the mystery, show the class a map to locate the Maldives.

Will the Maldives turn into the next Atlantis?

Initial Investigation

1. The changes in global climate patterns (such as temperature, rain, or wind) that last for extended periods of time as a result of either natural processes or human activity. (Today, it often refers to the increase in surface temperature of the Earth caused by human activities.)
2. The water will come from the melting of land ice, primarily the glaciers in the Antarctic and Greenland. (But not Arctic ice, the melting of which does not affect sea levels.)
3. Coral reefs are underwater structures made from calcium carbonate produced by corals, which are small marine animals. They provide important habitats for marine life, such as algae, fish and sea birds.

Teaching pointers

23.1 What Affects the Quality of Our Air? (page 368)

1. Show the causes and effects of air pollution by explaining to students the domino effect of burning fuels.
2. You may want to illustrate the process with a 'cause and effect' mind map. The diagram will set the tone for the rest of the chapter.

23.2 What is the Composition of Air? (page 368)

1. Students are sometimes confused about the terms 'by volume' and 'by mass' when referring to composition. Ensure that the composition of air *by volume* is understood.
2. You may want to carry out an experiment, using the apparatus in Figure 23.3 on page 369 of the Textbook, to find the percentage of oxygen in the air. See 'Finding the percentage of oxygen in the air' on the next page.

Skills Practice (page 369)

1. Clouds consist of fine water droplets. They are formed by the condensation of water vapour from the evaporation of water in the sea.
2. Gases in the air which are elements: Oxygen, nitrogen and noble gases. Gases in the air which are compounds: Carbon dioxide and water.
3. The composition of air is described as 'by volume' and *not* 'by mass'. The approximate composition (by volume) of nitrogen and oxygen in dry air is 78% and 21% respectively. This means that every 100 cm^3 of air contains 78 cm^3 of nitrogen and 21 cm^3 of oxygen.
4. **(a)** The atmospheres of both planets contain argon and nitrogen. Both consist of three gases.
   (b) Nitrogen is the main gas on Earth whereas on Mars, it is carbon dioxide. Mars has no oxygen.

   Note: This comparison is based only on the information provided in Figure 23.4 on page 369 of the Textbook.
5. Clockwise from top left: oxygen, argon/neon, water, argon/neon, carbon dioxide. Nitrogen is in the centre.

Notes for Teachers

Discovery of gases in the air

When Aristotle said that air was an element, that idea that lasted for nearly 2000 years. But discoveries in the 17th to the 19th centuries showed that air is actually a mixture of gases, some of which are elements while others are compounds.

Here is a brief timeline of some of these discoveries:

1620: In Belgium, Jan Van Helmont (1579–1644) invented the word 'gas'. He also discovered the gas we now call *carbon dioxide*.

1772: Several people at about the same time discovered the gas we call *nitrogen*.

1774: In England, Joseph Priestley (1733–1804) discovered the gas we now call *oxygen*. He finds that the gas makes a lighted candle burn more brightly and that it relights a glowing splint.

1775: In France, Antoine Lavoisier (1743–1794) worked out the accurate percentages of oxygen and nitrogen in the air.

1890s: The English chemist, William Ramsey (1852–1916), discovered the noble gases in the air.

Finding the percentage of oxygen in the air

1. Set up the apparatus as shown in Figure 23.3 on page 369 of the Textbook. A small diameter silica glass tube is required. It is best that the copper is in the form of small granules produced from the reduction of copper(II) oxide pellets.
2. Record the total volume of air in both gas syringes.
3. Heat the copper powder strongly with a Bunsen burner. Pass the air back and forth over the hot copper until there is no further change in volume.
4. Allow the apparatus to cool to room temperature.
5. Record the total volume of gas left in the syringes.
6. Calculate the percentage of oxygen in the air.

Note: A result of less than 21% oxygen is likely because of water vapour in the air.

Teaching pointers

23.3 What is Air Pollution? (page 370)

Air pollutants

1. Air pollutants come from both natural sources and human activities. For some pollutants, such as carbon monoxide and hydrocarbons, greater amounts are produced from natural sources than from human activities. Pollutants from natural sources tend to be more evenly distributed throughout the Earth, whereas pollutants from human activities are concentrated around cities and industrial areas. Sulfur dioxide is the major man-made air pollutant. Man-made pollutants upset the natural ecological balance and cause pollutants to build up in the atmosphere, especially around large cities.
2. Rubbish incinerators are also a source of air pollutants. Singapore has four incinerators that are located at Ulu Pandan, Tuas, Senoko and Tuas South. Another incinerator is currently being built next to the Tuas South plant and will replace the one at Ulu Pandan. The following website has more information on local rubbish incineration:
http://www.recyclingpoint.com.sg/Education.htm
3. An additional 'Chemistry in Society' on air quality in Singapore is found at the end of the chapter. Air quality is measured by the Pollutant Standard Index (PSI), which is a general figure that combines levels of different pollutants. The pollutant that contributes most to the index may be different in different places. If, for example a PSI of 50 in one part of Singapore may be due to high levels of sulfur dioxide while in another part, the index of 50 may be due to high levels of particulates. See also the note below on this activity. Additional Exercise 2 on PSI readings, also found at the end of this chapter, can be used as well.

Acid rain

4. Acid rain is an important environmental issue associated with air pollution. Emphasise that acid rain results from sulfur dioxide and nitrogen dioxide but not carbon dioxide.
5. Recent research has shown that natural releases of sulfur dioxide from huge clusters of certain kinds of plankton in the sea also make a significant contribution towards the formation of acid rain.
6. Acid rain has little effect on us. Even swimming in water affected by acid rain is not harmful. However, the gases that cause acid rain are harmful to our health.
7. Most acid rain results from the burning of fossil fuels as energy sources. You may mention the use of alternative energy sources to fossil fuels. These include hydroelectric power, nuclear energy, wind energy, geothermal energy, solar energy and energy from biomass. Students may have met these forms of energy in their Lower Secondary science course. At present, only hydroelectric power and nuclear energy can provide enough energy to replace the electricity generated from fossil fuels.
8. An addition experiment is included at the end of this chapter to simulate the production of acid rain and its effects. This can be carried out as an optional teacher demonstration. In the experiment, distilled water may be used as source of unpolluted rain water. The worksheet can be photocopied and distributed to students to complete as the demonstration is carried out.

(page 371)

Mystery Clue

For sources of nitrogen oxides and methane, refer to pages 370–371 of the Textbook. Carbon dioxide is produced whenever fossil fuels (coal, oil and natural gas) are burnt. As the quantities of these gases in the atmosphere increases, the (average) temperature of the Earth will increase (refer to global warming in Section 23.6).

Ozone

9. 'Good' ozone can be contrasted with 'bad' ozone. The 'bad' ozone is that near ground level and which is harmful to health and the environment (see page 371 of the Textbook). 'Good' ozone is that in the stratosphere that protects the Earth from Ultraviolet (UV) radiation; it is this layer that is being destroyed.

10. Most of the damage to the ozone layer is due to human activities.

11. The following are useful visual aids where CFCs are or have been used:

- pieces of expanded polystyrene (foam)
- aerosol spray cans (no longer use CFCs)
- white correcting fluid for paper (ideally 'old' ones with CFC solvent and 'new' ones with hydrocarbon solvent)

12. To protect the ozone layer, the government has prohibited the import of CFCs since 1996. This is in accordance with international agreements on the use of ozone depleting materials.

13. Until 2006, the ozone hole in the Antarctica was growing every day. In 2005, its area, on average, was about 10 million square kilometres. Australia, which is partly under this ozone hole, faces a serious UV radiation problem. Rates of skin cancer are high, with an estimated two out of every three people in the country likely to develop skin cancer.

14. In 2006 it was announced that the size of the hole has started to decrease, suggesting that the international reduction in the use of CFCs is beginning to work.

15. An additional exercise on investigating ozone that involves a computer simulation is found at the end of this chapter. The worksheet can be photocopied and distributed to students.

Chemistry in **Society** (page 372)

Why is Carbon Monoxide Poisonous?

Exercise

1. The treatment of carbon monoxide poisoning involves the administration of high doses of oxygen. Hence regardless of the design, the Medipack should contain an oxygen mask (non-rebreather mask) and a suitably-sized canister of oxygen gas.

2. Students are not required to know the mechanics of a car engine. Answers that are based on increasing air flow (since carbon monoxide is a by-product of incomplete combustion) or creating engines that run on hydrogen (the gas contains no carbon and hence does not produce CO, CO_2, hydrocarbons and other pollutants) are acceptable.

Skills Practice (page 375)

1. Two pollutants are carbon monoxide and nitrogen oxides from vehicle exhausts.
2. Diesel fuel, used in vehicles, contains a little sulfur which results in pollution of the air by sulfur dioxide.
3. Carbon dioxide is present even in non-polluted rainfall, making it slightly acidic. Acid rain is any rainfall that has an acidity level beyond what is expected in non-polluted rainfall.
4. The emissions from power stations, factories and vehicles produce sulfur dioxide and nitrogen dioxide. These oxides react with air and rainwater to form acids. But because the government strictly controls such emissions, little local acid rain will be produced.

(page 374)

Mystery Clue

The effects of the ozone hole and global warming will be felt in many parts of the world and not just in those countries that contribute most to the problems. Thus the Maldives will be affected by rises in sea levels because of global warming even though they themselves contribute little to the problem.

Notes for Teachers

Sources of some air pollutants

Pollutant	Harmful effects	Estimated amount*	Natural sources	Estimated amount*
carbon monoxide (CO)	Burning of fossil fuels	700	Forest fires, biological processes	2100
nitrogen oxides (NO, NO_2)	Combustion at high temperatures, e.g. in vehicle engines	75	Bacterial action in soils, electrical storms (lightning)	160
sulfur dioxide (SO_2)	Burning of coal and oil, roasting of sulfide ores	200	Volcanoes	20
unburnt hydrocarbons	Sewage treatment, ammonia fertiliser	6	Biological decay	250
methane (CH_4)	Petroleum refining, sewage treatment	3	Volcanoes, biological decay in soil and water	85

*Mass produced per year around the world in millions of tonnes

Effects of sulfur dioxide

1. Volcanoes are believed to have had a great impact on the environment in the past. The biggest eruption in historic times was at Tambora in present-day Indonesia in 1815.
2. When a 20 kilometre-wide asteroid or comet hit the Earth 65 million years ago, it put so much sulfur dioxide into the atmosphere that the intense acid rain destroyed much of the Earth's vegetation for decades. This is one of the reasons why the impact was believed to have wiped out the dinosaurs; there was simply no food.

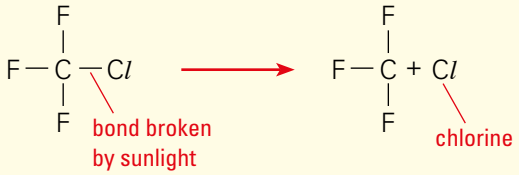
Air pollution measures in different countries

Country	Name	Pollutants calculated
Singapore	Pollution Standard Index	SO_2, NO_2, O_3, CO, PM10
Malaysia	Air Pollution Index	SO_2, NO_2, O_3, CO, PM10
Hong Kong	Air Pollution Index	SO_2, NO_2, O_3, CO, PM10
United States	Air Quality Index	SO_2, NO_2, O_3, CO, PM10, PM2.5
China	Air Pollution Index	SO_2, NO_2, PM10

Problems with CFCs

CFCs are good examples of chemicals that, when first introduced, seemed to be of great benefit to people without any apparent disadvantages. They are non-toxic and unreactive and so do not poison people, damage property or the land, as compared to SO_2 which causes acid rain. CFCs were used to make foam plastics. As CFCs do not burn and do not support combustion, they reduce the fire risks from burning plastics. The same applies to propellant for aerosol spray cans. There is no fire risk from the gas, unlike the hydrocarbon alternative. CFCs replaced poisonous ammonia as the coolant fluid in refrigerators as any leak is harmless. They were also used in air-conditioning units. CFCs were widely used as solvents to remove grease, for example, for computer chips.

When CFC molecules are released into the air, they remain 'forever' as they are unreactive. They will eventually, perhaps after 10 years or more, reach the upper atmosphere where they are decomposed by sunlight to produce chlorine atoms:



Each chlorine atom destroys up to 10 000 ozone molecules. This was discovered to be happening over Antarctica about 25 years ago. It seems that CFC molecules accumulate over Antarctica in the cold winter and then release their chlorine atoms as the air warms up. When the protective ozone is destroyed, high-energy UV solar radiation is able to reach the Earth where it damages vegetation and causes skin cancer (people living in countries near Antarctica are advised to wear hats outdoors).

The destruction of the ozone layer is no longer restricted to Antarctica. It is spreading and is a potential serious threat to animals and plants. Laboratory experiments have shown that high-energy UV radiation can greatly reduce the yield from food crops such as grain and rice.

International agreements are now restricting the use of CFCs. Many countries ban the use of CFCs in aerosol cans, refrigerators and foam plastics. Chlorine-free replacements are being introduced, such as hydrocarbons despite the fire risks. Even the use of CFC-type compounds in correcting fluids has been stopped. The solvent trichloroethane has been replaced with hydrocarbon solvents such as methylcyclohexane. You may want to show the class 'old' and 'new' bottles with the change in solvent (the new ones have a fire risk label). Unfortunately, the depletion of the ozone layer continues to increase despite the restrictions on CFC use.

This is happening mainly for two reasons:

- There is already a large 'pool' of CFC molecules in the air and it takes a long time for the CFC molecules to reach the upper atmosphere to be destroyed by sunlight.
- More CFC molecules are being added to the air from old refrigerators, foam plastics and used aerosol cans dumped in landfills. 'Empty' aerosol cans often still contain some gas, which will escape as the metal cans rust in the ground.

One way to deal with the second reason is to pay people to hand in old refrigerators so that the CFC can be recovered. It is possible that the depletion of the ozone layer will only start diminishing after 2030 or 2040. Ask the class to name some factors that may influence the date.

Some of the factors that may influence the date include:

- The actual amount of CFCs in the atmosphere.
- The amount of CFCs still trapped in landfills and how quickly it is released into the air.
- The effectiveness of the restrictions on the use of CFCs.
- The action taken by underdeveloped countries who have not agreed to restrict CFC use. They may start to manufacture and use large amounts of CFCs. Countries such as China and India are demanding compensation from rich countries for not using CFCs as they say that CFC restrictions harm their development.

IT Link

The following sites contain lots of information, including why the ozone hole is over Antarctica, how ozone is depleted and the effects of ozone depletion:

- http://www.theozonehole.com/
- http://www.atm.ch.cam.ac.uk/tour/part2.html

Teaching pointers

23.4 How Can We Reduce Air Pollution? (page 376)

1. Catalytic converters are used in vehicles with petrol engines. There are no similar converters for vehicles with diesel engines. Catalytic converters only work properly after a car has travelled a few kilometres; this is because the converter needs to be hot (about 300 °C) for the reactions to be fast enough. A converter contains 1–2 g of platinum and lasts for about 80 000 km until it has to be replaced as the platinum has worn away or stops working. As platinum is expensive, used converters are collected and the platinum is recycled.
2. Compressed natural gas (CNG) and liquefied petroleum gas (LPG) are sulfur-free though they tend to be more expensive than 'dirtier' alternatives.
3. The devices used in power stations to remove sulfur dioxide are called scrubbers. The process is called *scrubbing* or *flue gas desulfurisation*.
4. Pollutant gases in some coal-burning power stations are treated with ammonia gas. The ammonia reacts with the sulfur dioxide to form ammonium sulfate and with nitrogen dioxide to form ammonium nitrate. The process is expensive, but as both ammonium sulfate and ammonium nitrate are fertilisers, the sale of these products offsets the costs.
5. Three other ways of reducing pollutants in power stations are:
   (a) use of electrostatic precipitators
   (b) use of special burners
   (c) having high chimneys

Notes for Teachers

1. *Electrostatic precipitators*: In the burning of coal, many small unburnt particles (particulates) are formed. Electrostatic precipitators remove about 99% of these particulates as ash. The combustion gases pass through a high voltage electrical field. The particles become negatively charged and are attracted to the positive electrode and fall off into a collecting bin.
2. *Special burners*: The methods discussed in the textbook do not remove nitrogen oxides or carbon monoxide. Efficient burners, called NO_x burners, reduce the amount of nitrogen oxides formed and ensure that carbon dioxide instead of carbon monoxide is formed.
3. *High chimneys*: Increasing the height of chimneys can spread pollutants over a larger area but does not actually reduce the amounts of pollutants produced.

Skills Practice (page 378)

1. In the first reaction, carbon monoxide is oxidised (oxygen gained) while nitrogen monoxide is reduced (oxygen lost). In the second reaction, octane is oxidised (hydrogen lost) while oxygen gas is reduced (hydrogen gained).
2. **(a)** Mass of sulfur dioxide produced per hour = $0.2 \div 100 \times 1000$
   $= 2$ tonnes

   (b) $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$
   $CaO(s) + SO_2(s) \longrightarrow CaSO_3(s)$

   From the equations above, one mole of $CaCO_3$ ($M_r = 100$) forms one mole CaO which combines with one mole SO_2 ($M_r = 64$). Therefore, by proportion, 2 tonnes of SO_2 requires $(\frac{2}{64} \times 100)$ or 3.125 tonnes of $CaCO_3$.

Teaching pointers

23.5 What is the Carbon Cycle? (page 378)

1. The amount of carbon dioxide in the atmosphere is actually very small when compared to the main gases of nitrogen and oxygen. But this small amount still has a major effect of global warming. (Students often think the amount of carbon dioxide is quite large as it is so often mentioned in the media). It is current only 0.03% although it is believed to have been almost 10% 2000 million years ago.
2. The amount of carbon dioxide in the atmosphere has kept fairly constant over recent millennia as the carbon dioxide added to the air through respiration and decay of organic matter is balanced by that removed by photosynthesis (see Carbon Cycle on page 378 of the Textbook).

(page 378)

Mystery Clue

Carbon neutral means the amount of carbon dioxide that enters the atmosphere (e.g. by burning of fuels and respiration) is equal to the amount that is removed (mainly by photosynthesis).

23.6 What is Global Warming? (page 380)

1. There are about 30 different gases which are considered to be greenhouse gases.
2. It is only in the past 200 years that the amount of carbon dioxide in the atmosphere has started to increase again and it has increased by about 30% in the past 40 years. Human activities add about 20 000 million tonnes of carbon dioxide per year to the air, i.e. about 3 tonnes for each person on Earth.
3. Point out that global warming is complex and not fully understood. It is also a very contentious issue, with some scientists claiming that carbon dioxide may not be the cause of the rise in the temperature of the Earth. Therefore, take the opportunity to discuss the role of scientific method and debate in reaching conclusions. To help with this, additional material is provided at the end of this chapter:
   - **(a)** A 'Chemistry in Society' on Global Warming and the Environment.
   - **(b)** An additional exercise for a class debate on global warming, which could be carried out.

(page 381)

Mystery Clue

This could include an increase in average temperature, an increase in the number and severity of storms, and an increase in the number of mosquitoes and related diseases.

Skills Practice (page 382)

1. During photosynthesis, carbon dioxide is absorbed by plants and converted into starch.
2. **(a)** Global warming, which causes rising sea levels as water expands with rising temperatures.
   (b) Burn less fossil fuels.
   (c) There is no point in only reducing consumption of fossil fuels in your own country, as CO_2 from other countries will cross over into your airspace. CO_2 levels are the same in every country as the air spreads everywhere. This can only be stopped by international agreement between all countries.
   (d) There will be increased rainfall in Singapore due to global warming.
   (e) For example, the Maldives and the low-lying Pacific Islands.

   Note: Several small inhabited islands have now either completely or almost completely disappeared beneath rising seas and the people evacuated. These include the small Indian islands of Lohachara and Ghoramara in the Bay of Bengal and the Carteret Islands off Papua New Guinea.
3. Agriculture results in an increase in the amount of crops, more respiration, and more CO_2 entering the atmosphere. Deforestation results in a decrease in the number of forests, thus less CO_2 is being removed. Burning fuels results in the production of CO_2.
4. **(a)** Ways to reduce the greenhouse effect: Burn less fossil fuels, prevent deforestation (clearing and burning), replace all CFCs by other chemicals and use more electric vehicles.
   (b) All the above methods are being tried now.

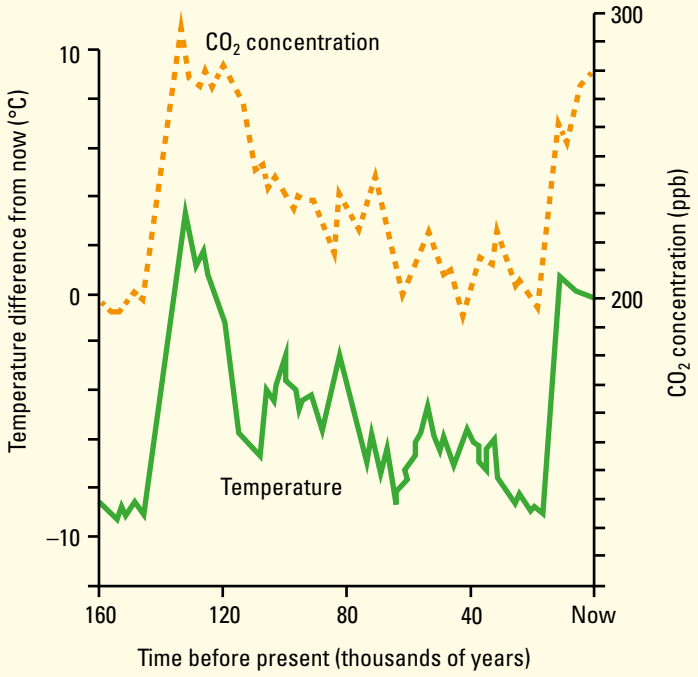
Notes for Teachers

Climate Change or Global Warming?

The term climate change is often used interchangeably with the term *global warming*, but the phrase 'climate change' is growing in preferred use to 'global warming' because it helps to convey the idea that there are other changes in addition to rising temperatures that affect the climate.

More information on greenhouse gases and global warming

- It is generally accepted that polluting gases in the atmosphere cause global warming. The main cause is due to CO_2. There is a very good correlation between air temperature and CO_2 concentration over the past 160 thousand years. This is deduced from the analysis of ice cores from Antarctica (see graph).



- Although other gases also cause global warming, CO_2 is responsible for at least 50% of it because compared to the other gases, there is so much of it in the atmosphere. Nitrous oxide, NO, is over 100 times more effective than carbon dioxide at trapping heat from the Sun but is responsible for only 6% of global warming since there is only so little in the atmosphere.

  The main 'greenhouse gases' are (in order of importance): Carbon dioxide, methane, CFCs, low-level ozone and nitrous oxide. Water vapour is also a greenhouse gas.
- It is difficult to predict future global temperature rises due to a number of factors. Ask students to suggest what these factors might be.

IT Link

The following website has more information on other changes in addition to rising temperatures that affect the climate:

http://www.epa.gov/climatechange/basicinfo.html

A useful website on climate change, global warming, the greenhouse effect and the relations between them:

http://www.epa.gov/climatechange/kids/basics/index.html

Good websites for global warming are:

- http://www.envirolink.org/
- http://tiki.oneworld.net/global_warming/climate_home.html?gclid=CM2NttOipakCFQrhbgodxw3Xtw

Click on 'Climate Change'. Using this website, ask students to find out about global warming before the discussion in class. Students should focus on the following:

- the definition of global warming
- the causes of global warming
- the harm caused by global warming
- what can be done to prevent global warming

Online games on global warming:

http://www.lickglobalwarming.org/game.cfm

(Students may play the games in 'Temperature Puzzle' and 'CO_2 Emission Puzzle' on this website.)

Factor	Possible effect on global warming
Amount of fossil fuels burnt (e.g. due to more vehicles on the roads)	If more fossil fuels are burnt, more CO_2 enters the atmosphere and the temperature will rise.
Fossil fuels replaced with non-carbon fuels (e.g. hydrogen) or alternative energy such as solar power	Temperature will fall as less CO_2 enters the atmosphere.
Amount of methane, N_2 and other greenhouse gases added to the atmosphere	If more of these gases enters the atmosphere (e.g. from rice fields and animals), the temperature will increase.
Amount of CO_2 absorbed by seawater	This depends on temperature and is difficult to predict.
Vegetation growth	Increasing temperature increases vegetation growth and this will lower temperature as more CO_2 is removed (the opposite will happen if land become desert).
Logging	Increased logging will result in fewer trees and perhaps an increase in temperature as less CO_2 is removed in photosynthesis.
Water vapour in the air and cloud cover	Effect is complicated.
Area of Earth covered by ice	Ice reflects sunlight so the temperature is lowered.

Most scientists and governments agree that the main factor causing temperature to rise is the amount of fossil fuels being burnt. As a result, many countries have agreed to reduce their consumption of fossil fuels or at least to prevent a further increase.

Consequences of global warming for Singapore

The effect of global warming is likely to vary around the world but in Singapore:

- Temperature will rise perhaps by 10 °C by 2050.
- There will be a higher amount of rainfall.
- There will be a risk of flooding of low-level land as sea level rises (sea levels might rise by 20 – 40 cm over the next 30 years and if the polar ice caps melt, sea levels will rise by 20 metres).

Students should realise Singapore's vulnerability due to its small size and lack of mountains (Bukit Timah is only 162 metres above sea level).

Ask students to suggest practical measures that Singaporeans can take to minimise future effects of global warming. Some possibilities are:

- To build sea walls to stop flooding of low-lying land.
- To increase the height of land reclaimed from the sea (an expensive process).
- To build more and better storm drains for the expected higher rainfall.

Ask students to suggest any possible advantages of global warming. One main advantage is increased fresh water supply due to increased rainfall.

Solving the Mystery (page 382)

Will the Maldives turn into the next Atlantis?

Infer
Climate change refers to any significant change in measures of climate, such as temperature, rainfall, or wind. Global warming is an increase in the temperature of the atmosphere near the Earth's surface, which can contribute to changes in global climate patterns. Both can result from natural factors or human activities.

Connect
The main task is to eliminate the burning of fossil fuels which are the major sources of carbon dioxide. They plan to use new renewable electricity with large wind turbines, rooftop solar panels, and a biomass plant burning coconut husks. The clean electricity would power homes, businesses and also vehicles. Cars and boats with petrol and diesel engines would be gradually replaced by electric versions. Refer to:
http://www.guardian.co.uk/environment/2009/mar/15/maldives-president-nasheed-carbon-neutral

Further Thought
The money raised from the 'green' tax on visitors would help the country fight climate change. This has been tried or proposed in a few other places but has never succeeded, mainly because of opposition from tour operators and hotel owners who fear that the taxes drive potential visitors away. Refer to:
http://www.guardian.co.uk/environment/blog/2009/jul/14/maldives-climate-eden-project

23 Chapter Review

Self-Management

Misconception Analysis (page 383)

1. **True** It is the pollutants that give air its colour and smell.

2. **True** In incomplete combustion, soot (carbon particles) can be formed. Hot carbon particles glow yellow and give the flame its colour.

3. **False** Carbon dioxide is not a harmful gas. It is present in the air that we breathe. However, carbon dioxide is a greenhouse gas and it contributes to global warming.

4. **True** As carbon monoxide prevents the blood from carrying oxygen, a person dies from a lack of oxygen, that is, by suffocation.

5. **False** Acid rain is too dilute to destroy our skin, though it may cause irritation.

6. **False** The ozone layer around the Earth absorbs harmful UV radiation from the Sun, preventing it from reaching the ground. If the ozone layer is thin, more UV radiation reaches the ground and can lead to an increase in skin cancer among people.

7. **True** This is mainly due to an increase in the amount of carbon dioxide from the burning of fuels in industries.

8. **False** Other gases, such as methane, also contribute to global warming although carbon dioxide is the major contributor.

Practice

Structured Questions (page 384)

1. (a) $H_2S(g) + 2H_2O(g) \longrightarrow 3H_2(g) + SO_2(g)$
   (b) Carbon dioxide and nitrogen
   (c) Carbon monoxide and sulfur dioxide are harmful to our health. Carbon monoxide causes breathing problems and can lead to death. Sulfur dioxide causes respiratory problems such as asthma attacks.
   (d) Sulfur dioxide

2. (a) (i) Sulfur dioxide/Nitrogen dioxide
   (ii) Burning of sulfur present in oil./High temperatures in the burners.
   (iii) Use sulfur-free natural gas/flue-gas desulfurisation/special burners.
   (b) (i) Methane, CH_4
   (ii) $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g/l)$
   (iii) Advantage: Natural gas is sulfur-free, thus it does not give rise to pollution. It can be piped to power stations which is more convenient than having to transport oil in ships.

3. (a) (i) Sulfur dioxide and nitrogen dioxide
   (ii) Sulfuric acid and nitric acid
   (b) Sources of sulfur dioxide and oxides of nitrogen: Burning of coal and oil in factories.

   Sources of oxides of nitrogen: Combustion at high temperatures in motor vehicles.

   Sulfur in coal and oil burns to form sulfur dioxide. Oxides of nitrogen are formed by the combination of nitrogen and oxygen from the air when fuels burn at high temperatures.
   (c) (i) Unpolluted rain water ranges between pH 5 – 6 as carbon dioxide in the air dissolves in rain water to form a weak acid — carbonic acid.
   (ii) Acid rain has an approximate pH of 4 or lower as sulfur dioxide and oxides of nitrogen dissolve in rain water to form strong acids — sulfuric acid and nitric acid respectively.
   (d) For example, acid rain kills fish and corrodes buildings and objects made of calcium carbonate.

4. (a) Ultraviolet (UV) radiation from the Sun.
   (b) (i) Chlorofluorocarbons (CFCs)
   (ii) For example, aerosol propellants, coolant liquids in refrigerators and air-conditioners.
   (c) (i) It could lead to skin cancers and causes damage to plants and crops.
   (ii) The ozone layer is the thinnest over Antarctica.

5. (a) The burning of (the carbon in) fossil fuels.
   (b) An increase in temperature of the Earth's atmosphere.
   (c) Global warming
   (d) For example, global warming will cause land ice to melt, resulting in sea levels to rise even further. It also causes big changes in global climate.

Free Response Questions (page 385)

1. Responses to this question may include the following points:
   - Most fuels are burnt in factories, power stations and vehicles.
   - Gases such as sulfur dioxide, oxides of nitrogen, carbon dioxide are formed.
   - Sulfur dioxide and oxides of nitrogen form acid rain, which harms the environment, e.g. kills fish in rivers and corrodes many buildings.
   - The increase in carbon dioxide as a result of the burning contributes to global warming.

2. Some of the possible methods that can be used are:
   - Fit catalytic converters to cars to reduce pollution from exhaust gases. This is only suitable for new vehicles.
   - Increase the number of non-polluting electric cars. However, this requires frequent recharging of the batteries.
   - Switch to compressed natural gas (CNG) instead of diesel in taxis and buses. It may take many years to replace old vehicles.
   - Increase inspections to ensure that vehicles do not emit smoke. This is a cheap method.
   - Reduce the number of vehicles on the roads, e.g. by increasing car taxes. This will not be a popular method.

   Recommendation: Any reasonable method or combination of methods. For example, increasing the inspections of vehicles and reducing the number of vehicles on the roads can be carried out immediately. Fitting catalytic converters to cars and switching to compressed natural gas (CNG) can be introduced gradually.

Extension (page 385)

1. **Poster on Air Pollution**
   This may be a suitable project for the more artistically able students. For other students, this could be an optional activity.

2. **Acid Rain**
   (a) Parthenon in Greece and Taj Mahal in India.
   (b) A bridge over the Ohio River in the United States collapsed in 1967, killing 47 people. The bridge had been corroded by acid rain.
   (c) (i) pH ~5
   (ii) pH ~6
   (iii) pH ~3.5

Additional

Chemistry in Society

Air Quality in Singapore

Singapore, like most big cities, can suffer from air pollution. Every day, pollutants produced by the burning of fuels in motor vehicles, factories and power stations enter the air. The air pollutants can be harmful to our health.

The National Environment Agency (NEA) monitors air pollution at 15 air monitoring stations in different parts of Singapore. The stations measure the concentrations of five key air pollutants. These are sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone and PM10 (particulate matter such as very fine smoke particles).

The concentrations of these pollutants are converted into a sub-index for each pollutant. A Pollutant Standard Index (PSI) for each region of Singapore is then determined by taking the highest value of the five air pollutants. The PSI gives an indication of the air quality as shown in the table below.

PSI value	PSI descriptor
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Vey unhealthy
Above 300	Hazardous

Every hour, the NEA reports the PSI readings on its website. The table below is a typical report of PSI readings for the five regions of Singapore.

Region	24-hour sub-index at 4 PM on 28 May 2012					PSI	Air quality descriptor	Responsible pollutant
	Sulfur dioxide	PM10	Ozone	Carbon monoxide	Nitrogen dioxide +			
North	14	28	18	10	–	28	Good	PM10
South	18	18	25	5	–	25	Good	Ozone
East	7	21	21	4	–	21	Good	PM10
West	42	25	21	6	–	42	Good	Sulfur dioxide
Central	7	17	11	8	–	17	Good	PM10
Overall Singapore	42	28	25	10	–	42	Good	Sulfur dioxide

+ The sub-index for nitrogen dioxide is reported only when the concentration exceeds 1130 $\mu g/m^3$

Additional

Chemistry in Society

Global Warming and Scientific Method

Is global warming a fact?
As you have learnt, scientific knowledge is never complete and science does not have the perfect truth. Scientists can even draw different conclusions from the same observations and data. This leads to a lot of discussion and debate among scientists.

One great debate involves global warming. Many scientists have concluded that excess greenhouse gases cause global warming. But others have a different view. Here are two of their reasons:

- As well as the warming effects, cooling effects are also taking place. For example, higher temperatures cause more water to evaporate into clouds. The clouds cool the Earth by shading it from sunlight.
- Although the average temperature of the Earth has increased in the last 200 years, the 19th century was quite cold and temperatures may just be returning to 'normal'.

Global warming is a very complex issue. Much of the information we have comes from computer models that estimate temperature changes. However, these estimates may not be exact. In addition, an observed temperature increase may be caused by something else. Some measurements suggest that variations in the energy output of the Sun cause temperature changes far more significant than those caused by greenhouse gases.

Additional Teaching Material

Additional Exercise 1: Investigating Ozone

Objective

- To investigate issues related to ozone

Key Competency

CIT: sound reasoning [*analysing*, *evaluating*]

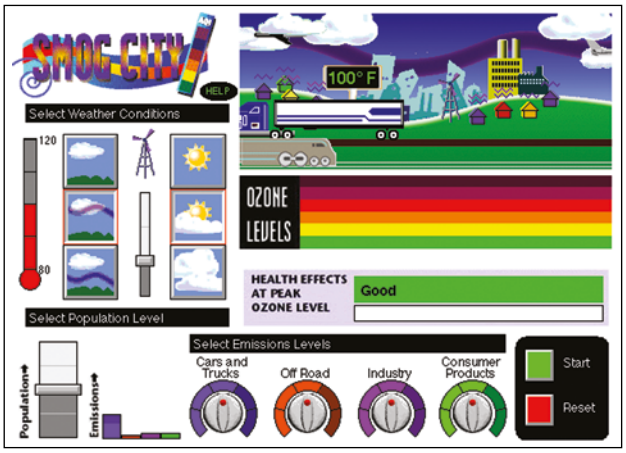
In this activity, students investigate issues related to ozone levels in the atmosphere. In Step 1, students are required to suggest how various factors will affect ozone levels. Students can do this using a computer simulation called 'Smog City' which can be downloaded at the following website: http://www.smogcity.com/

A worksheet for this simulation activity is provided at the end of this chapter. You can photocopy and distribute it to the class. You may carry out the activity during class time or set as homework to be done, either as a class assignment or for students' own interest.

Ozone does not come directly from factories and vehicles. It is produced when oxides of nitrogen and unburnt hydrocarbons from the vehicles react together in sunlight.

A number of factors affect the amount of ozone present in the atmosphere. These include the population, weather conditions (temperature, wind and cloud), and the amounts of pollutants emitted into the atmosphere (from vehicles, industries and consumer products).

In this activity, you will first carry out a computer simulation to investigate how these factors affect ozone levels. Then you will look at ozone levels in Singapore.



Investigating Ozone Worksheet — Factors Affecting Ozone Levels

1. For the simulation, go to the following website on 'Smog City' which can be downloaded: http://www.smogcity.com/

Open it and click 'Run Smog City'. The picture shown at the bottom will appear.

2. **(a)** Press the 'Reset' button. Then increase the population factor to the maximum. Press 'Start' and note how a large population affects ozone levels.

(b) Repeat for each of the following conditions: increase in temperature, strong winds, sunny skies and increased emissions of air pollutants.

(c) Complete the table.

Factor	Ozone levels (increase or decrease)
Larger population	
Higher temperatures	
More wind	
Sunny skies	
More emissions of air pollutants	

3. Look at one of the graphs in Step 2 of ozone level against time of the day.

(a) At about what time of the day are ozone levels at their peak?

(b) Suggest one or more reasons for this.

4. Press the 'Reset' button then select a high temperature and calm winds. Vary the emissions knobs. Press 'Start.'

(a) Discover which source contributes the most to ozone air pollution.

(b) Suggest the reason for this.

5. Alter the conditions to create a 'very unhealthy' level of ozone.

(a) What conditions did you create?

(b) What health advice is given when ozone levels reach this level?

Additional Teaching Material

Additional Exercise 2: PSI Readings in Singapore

Objective

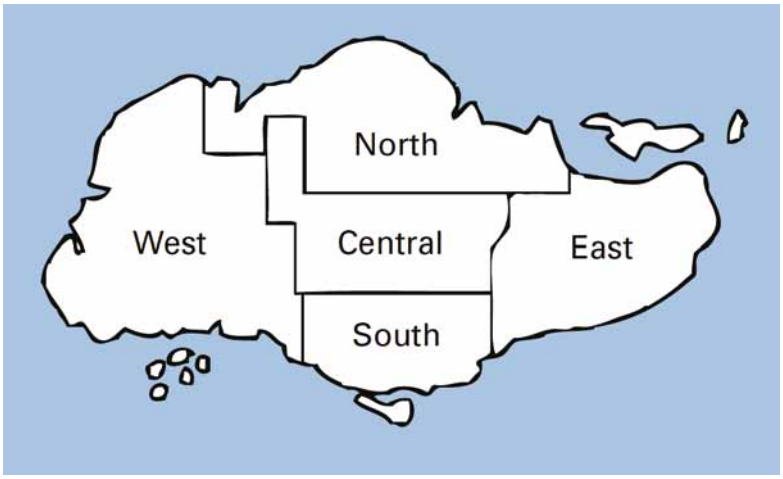
- To interpret air pollution readings in Singapore

Key Competency

CIT: sound reasoning [*analysing data*]

The National Environment Agency (NEA) monitors air pollution in five regions of Singapore. Air pollution levels are reported every hour on the NEA website: http://www.nea.gov.sg/psi/

The website gives the overall measurement of air pollution (the PSI) and measurements of five specific pollutants.



The map above shows the five regions of Singapore for which air pollution measurements are taken.

A. Interpreting PSI readings

The table gives a typical report of PSI readings for the five regions and for overall Singapore.

Region	24-hour sub-index at 4 PM on 28 May 2012					PSI	Air quality descriptor
	Sulfur dioxide	PM10	Ozone	Carbon monoxide	Nitrogen dioxide +		
North	7	46	34	7	-	46	Good
South	12	47	17	3	-	47	Good
East	5	47	23	2	-	47	Good
West	38	52	23	7	-	52	Moderate
Central	5	47	11	5	-	47	Good
Overall Singapore	38	52	34	7	-	52	Moderate

* Sub-index for nitrogen dioxide is reported only when the one-hour nitrogen dioxide concentration exceeds 1130mg/m^3

Questions

Use the table and the Internet to answer the following questions.

1. **(a)** What does 'PSI' stand for?

_____

(b) What is the range of values in the PSI?

_____

2. **(a)** What is PM10?

_____

(b) In which region of Singapore are PM10 levels highest?

_____

3. **(a)** What is the PSI for the Central region?

_____

(b) Which pollutant is responsible for this PSI? Explain.

_____

4. **(a)** What is the main cause of nitrogen dioxide in the air?

_____

(b) The levels of nitrogen dioxide in Singapore are often low. Suggest a reason for this.

_____

5. The PSI for some regions is described as 'good'.

(a) What is the PSI range of values for 'good'?

_____

(b) What, if any, health precautions need to be taken?

_____

B. Analysing PSI readings

1. Following changes in pollution levelsIn this activity, you will record pollution levels over a period of time to find out how they change with time.

To do this, choose **one** of the following:

- One of the five regions that interest you (e.g. the region near your home or your school)
- The pollutants whose measurements you will measure
- The period of time over which you will record (e.g. a week, month or longer)
- How frequent you will record the measurements (e.g. daily, weekly)
- When you will take the readings (e.g. if you record daily you will need to do it at the same time of the day to ensure a fair comparison can be made)

2. Use a computer to display the results in a chart or graph. Then attempt to analyse your results by answering the following questions.

(a) What variations occur in pollution levels over time? Suggest possible explanations.

(b) Are there any correlations between different pollutants? Suggest possible explanations for any correlations.

3. Optional Your teacher may ask you to make a presentation of your findings. This can take one (or more) of the following forms:

- A wall poster using pictures, graphs and words
- A written assignment (which will include graphs)
- A brief oral presentation to your class

Print and paste a copy of your chart or graph in the space below.

Additional Teaching Material

Additional Exercise 3: Global Warming — The Great Debate

Objective

- To appreciate that scientists can interpret the same data differently

Key Competencies

ICS: management of information [*collecting information*], communicating effectively [*writing a report*]

Scientists can draw different conclusions from the same observations and data. This leads to a lot of discussion and debate among scientists. One debate involves global warming. Many scientists have concluded that excess greenhouse gases cause global warming but others disagree. This activity is a research project on the two sides of this debate.

Collecting Information

1. Collect information on the two sides of this debate using library books, newspaper articles and the Internet.

Side A: This side says global warming is real and requires immediate attention and action.

Side B: This side says scientists have not proven that global warming is serious and action is not needed.

You may find the following websites useful:

- http://www.42explore.com/globewrm.htm
- http://library.thinkquest.org/27037/english/index.html [Click 'Global debate']
- http://www.studyworksonline.com/cda/explorations/main/0,,NAV2-79,00.html ????
- http://evworld.com/news.cfm?newsid=26846
- http://wwf.panda.org/about_our_earth/aboutcc/
- http://www.sepp.org/science-editorials.cfm?whichcat=Global%20Warming
- http://www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway/energy_resources/global_warmingrev2.shtml
- http://www.bbc.co.uk/schools/gcsebitesize/science/21c/radiation_life/_global_warmingrev3.shtml
- http://www.bbc.co.uk/schools/gcsebitesize/geography/climate_change/describing_climatic_trends_rev1.shtml

- http://www.bbc.co.uk/schools/gcsebitesize/geography/climate_change/greenhouse_effect_rev1.shtml

2. Record the information collected in the table.

Side A: Global warming is real	Side B: Global warming is not proven

3. Which side do you think has more evidence to support their views? Give your reasons.

_____

_____

_____

Follow-up Activities Optional

Writing a report

Write an essay with the title 'Global warming — real or unreal?' In your essay, outline the idea of global warming and its causes. Then discuss how scientists have different views as to whether global warming is real or unreal. You may also include your opinion as to whether global warming is real or unreal.

Additional Teaching Material

Additional Exercise 4: Pollution Game

Objective

- To correctly match a set of cards for a topic on pollution

Key Competencies

CIT: curiosity and creativity [*learning through games*]
ICS: coummunicating effectively

Game contents

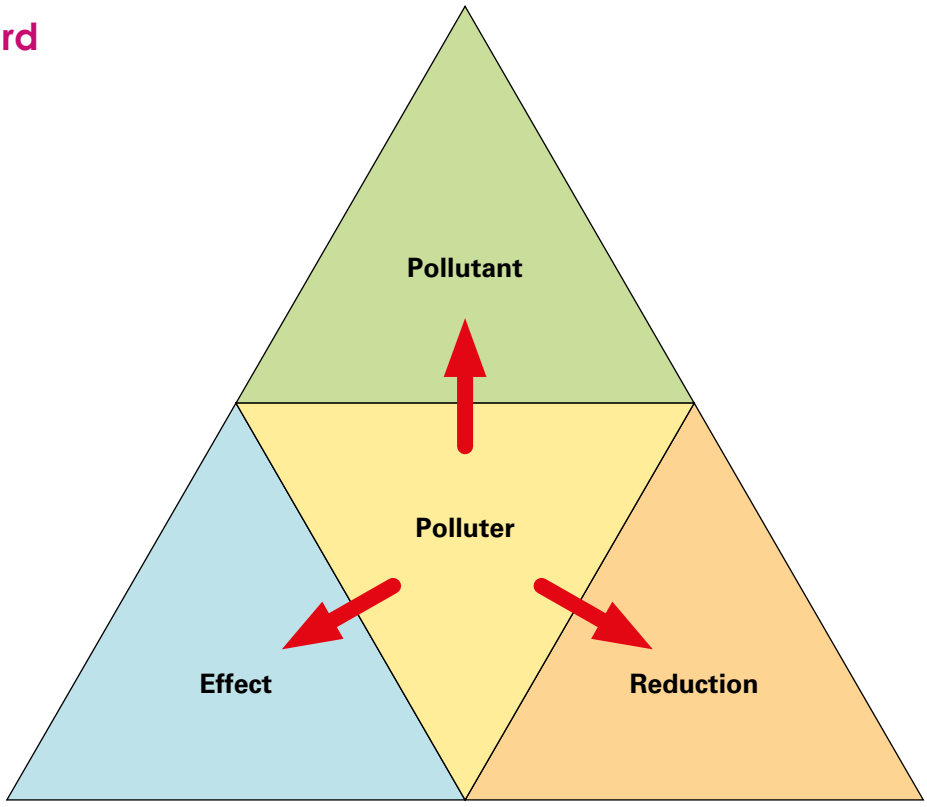
– 1 game board (shown below)
– 4 'Polluter' cards: Vehicle exhaust, Power station, Acid rain, Greenhouse gases
– 1 pack of cards consisting of 'Pollutant' cards, 'Effect' cards and 'Reduction' cards
(Your teacher will give you these cards.)

To play the game

1. Form groups of 2 to 4 players.
2. Each player chooses one of the 'Polluter' cards (either a free choice or at random). This card is placed in the centre of the game board.
3. Place the other cards; face down, on a table.
4. Decide who will play first.
5. Each player, in turn, turns up one card. If this card matches one of the spaces on the game board, the card is placed on that space. If not, the card is returned to the same place on the table, face down.
6. The winner is the first person to complete the game board correctly. The game may continue until the other players complete their boards.

Note: The teacher can decide if the cards on the game board are correct. If a player thinks another player has a wrong card, check with the teacher. If the card is wrong, it is immediately returned to the table.

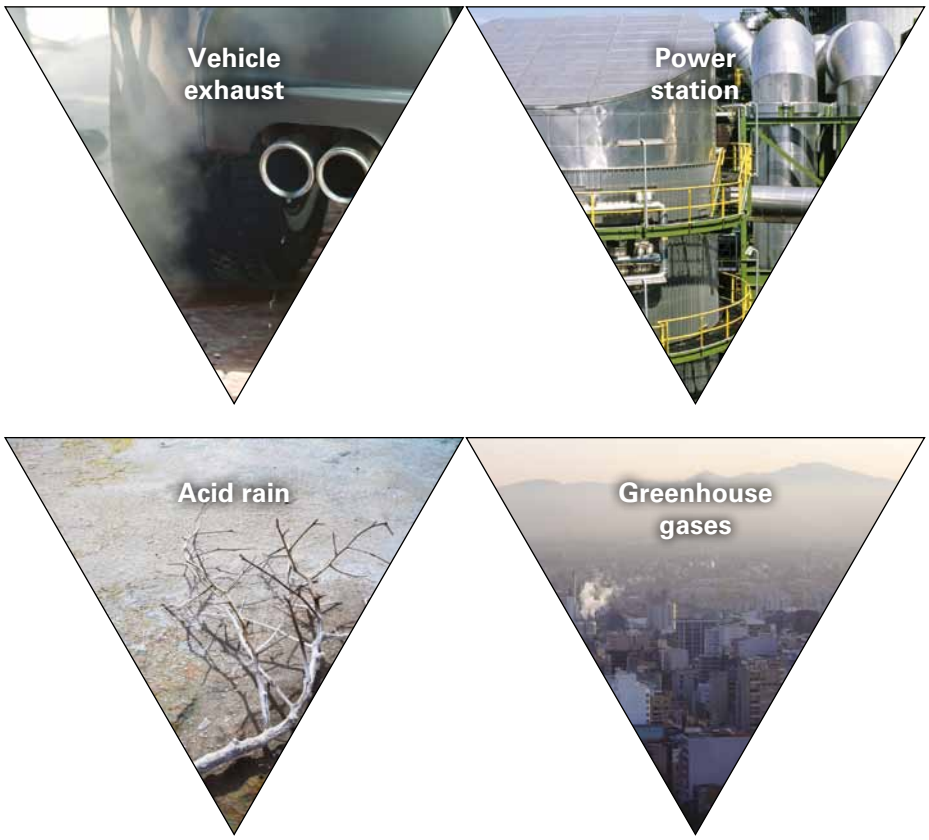
Game board



Cards for Pollution Game

All cards should be of the appropriate size to fit into the game board in the Theory Workbook for this activity.

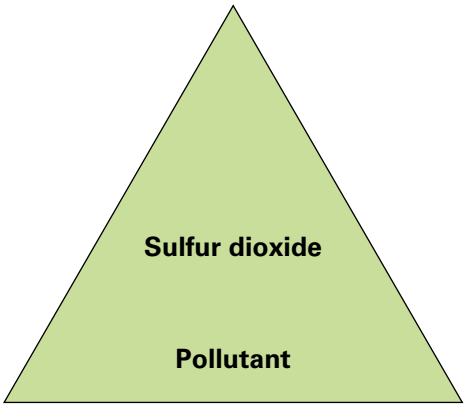
Polluter cards



Pollutant cards

There are 4 pollutant cards like this with text:

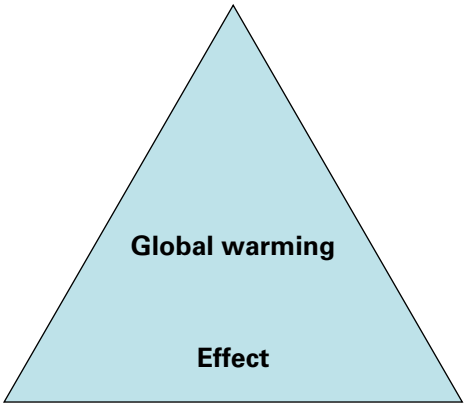
- Sulfur dioxide
- Carbon dioxide
- Carbon monoxide
- Dilute sulfuric and nitric acids



Effect cards

There are 4 effect cards like this with text:

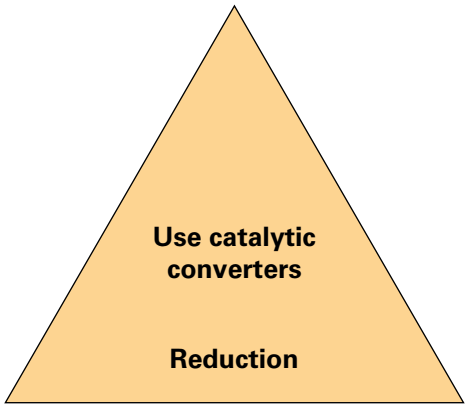
- Makes breathing difficult
- Prevents blood from carrying oxygen
- Global warming
- Damages trees and kills fish



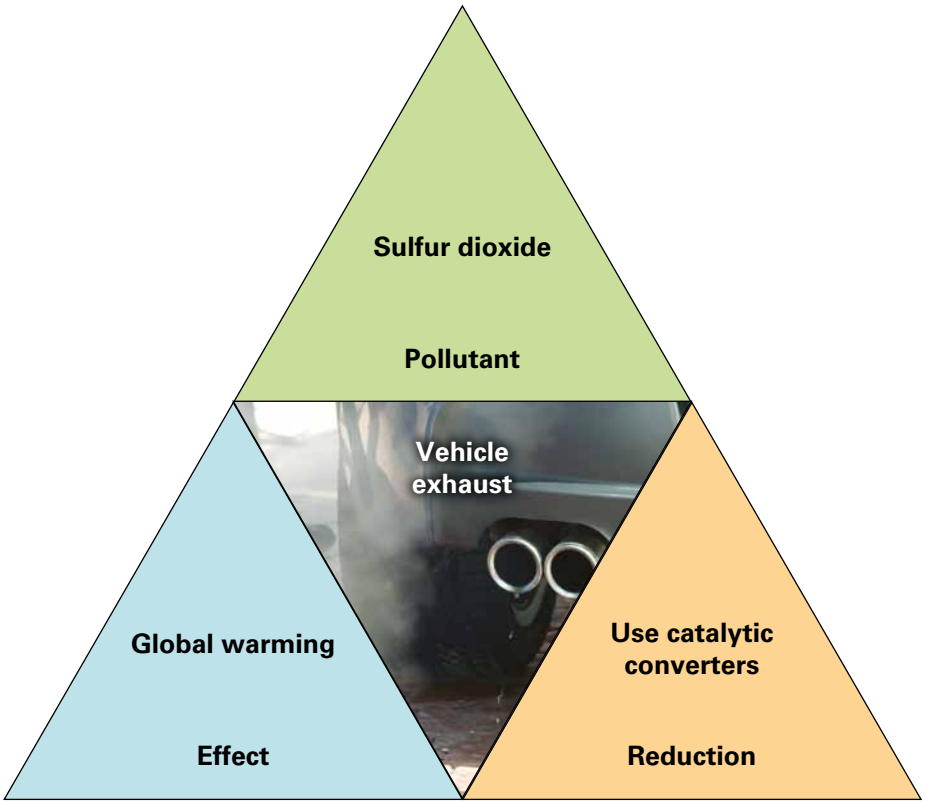
Reduction cards

There are 6 reduction cards like this with text:

- Burn low-sulfur fuels
- Use catalytic converters
- Add calcium carbonate to soil or water
- Use alternative energy sources
- Use natural gas
- Burn less fossil fuel



Here is an example of a matched set of cards:



Answers

Additional Exercise 1:

2. (c)

Factor	Ozone levels (increase or decrease)
Larger population	increase
Higher temperatures	increase
More wind	decrease
Sunny skies	increase
More emissions of air pollutants	increase

3. (a) Mid afternoon

(b) For example, the sun intensity and temperatures are at their maximum in mid afternoon./There are more vehicle emissions during the day.

4. (a) Cars and trucks contribute most to ozone air pollution.

(b) Motor vehicles produce nitrogen dioxide and unburnt hydrocarbons which are the two pollutants that form ozone.

5. (a) For example, a high temperature, little/no wind, sunny/a little cloud, medium/large population, medium/high emission levels.

(b) For example, people with respiratory diseases such as asthma, should avoid all prolonged outdoor activities.

Additional Exercise 2:

1. (a) Pollutants Standards Index

(b) From 0 to above 300

2. (a) Particulate matter of 10 microns or smaller in size such as very fine soot/smoke particles.

(b) The West Region

3. (a) PSI = 47

(b) The pollutant with the highest sub-index is taken as the PSI, in this case PM10.

4. (a) It is produced inside motor car engines.

(b) Cars are fitted with catalytic converters which remove most of the NO_2 produced in the engines.

5. (a) Up to 50

(b) Levels in this range cause no health problems for the general population.

Additional Exercise 3:

2.

Side A: Global warming is real	Side B: Global warming is not proven
E.g.: • Global warming is occurring faster that at any time in the past 10 000 years. • We have increased levels of carbon dioxide in our atmosphere by 30% in the past 100 years. • The average temperature of the Earth is 0.5 °C higher than now. • Increased temperatures will lead to rising sea levels, increased flooding, storms and more deserts. • Warmer temperatures will also increase the number of mosquitoes that cause malaria and other diseases. • Plants and animals that cannot adapt will become extinct.	E.g.: • Predictions of future temperature rise are based on computer models; these models might not be correct. • Observations now show no warming is occuring in most places. • Most warming is only in Siberia and parts of the USA. • A lot of carbon dioxide dissolves in seawater or is removed by photosynthesis. • Experiments show that a small warming of the Earth will lower sea level. • Whether the earth becomes warmer or cooler, there will be winners and losers.

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