Teachers' Support
Transport and Air

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Atmosphere, Air and Pollution

What is the atmosphere?

The gases surrounding the earth make up the atmosphere. It is many hundreds of kilometres thick and is composed of four layers, these resulting from the properties of the air within. Details of the names, thickness and temperature of each layer may be seen in Figure 2.

It is the troposphere, the lowest level of the atmosphere, which is the most important when we consider regional and local air pollution problems. Ozone depletion and the enhanced greenhouse effect are global air pollution problems that affect the atmosphere. The greenhouse effect is a result of an overall heat gain by the atmosphere as a whole. Ozone depletion occurs in the second level of the atmosphere, the stratosphere.

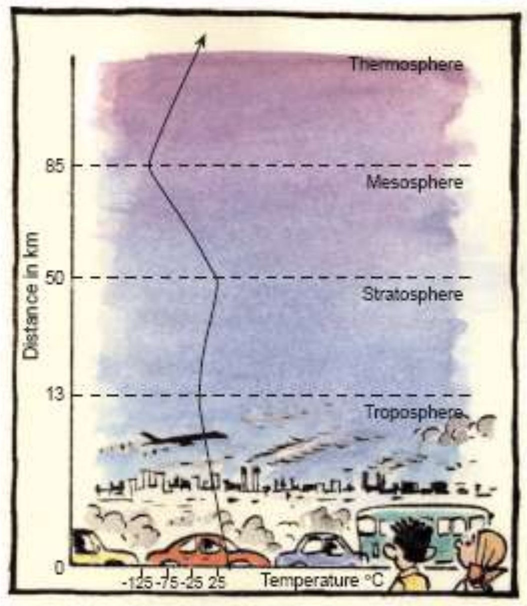

Figure 2. The layers of the atmosphere. (The distance axis is not to scale).

What is the air?
The air is the substance around us which we breathe in and out of our lungs. At the earth's surface, air consists of

- 78% nitrogen (N2),
- 21% oxygen (02),
- less than 1% of argon (Ar),
- a very small amount (0.03%) of carbon dioxide (CO2),
- traces of other gases such as methane (CH4) and oxides of nitrogen (NOx).
- Water vapour is present in air in varying amounts. (In Perth this can vary from 0.3% on cold days to 1.0% on hot days.)

The air also contains tiny particles such as dust, sea salt, volcanic ash and soot which are small enough to float in the air for a long time.

Air has been a part of the planet's systems longer than life, although its composition has varied due to changing geological and atmospheric conditions.

What is air pollution?
Air pollution occurs when the air contains gases, dust, fumes or odour in amounts that could be harmful to the health or comfort of humans and animals or could cause damage to plants or materials. The substances that cause air pollution are called pollutants.

Before the industrial revolution, nature's own air-conditioning managed to keep the air fairly clean. Wind mixed the gases and spread them out, rain washed the dust and other easily dissolved substances to the ground, and plants absorbed carbon dioxide and replaced it with oxygen. In the post-industrial revolution years, considerably more pollution has been added to the air by industrial, commercial and domestic sources.

As these sources are usually found in or near Australian cities, the gases that are produced are usually concentrated in the air around them. It is when these concentrated gases exceed safe limits that we have a pollution problem. Nature can no longer manage air pollution without our help.

Pollutants which are pumped into our atmosphere and are polluting in their own right are called primary pollutants. Some examples are carbon monoxide from car exhausts and sulphur dioxide from the combustion of coal. Further pollution can arise if primary pollutants in the atmosphere undergo chemical reactions. These are called derived or secondary pollutants. An excellent example is photochemical smog.

Area sources refer to widespread, low-level sources of pollution. For example, there are a large number of homes in Perth. Individually, each home contributes only a little pollution, but in total all homes make a significant contribution. Other examples of area sources include fires, light industry, service stations, road works, gardens and horticultural properties.

The impact of petrol vehicles
Fossil fuel combustion, particularly by motor vehicles, has been identified as the largest single contributor to air pollution.

When considering Perth's air, it is the vehicles which are used for transport that are responsible for almost all of the carbon monoxide pollution and around half of the hydrocarbons and oxides of nitrogen.

The pollution put out by petrol vehicles comes from two sources. The first group are the exhaust emissions and these include carbon monoxide, oxides of nitrogen, hydrocarbons and particulates.

The second type of pollution from cars is called evaporative emissions. Evaporative emissions are vapours of fuel which are released into the atmosphere, without being burnt. Fuel vapour can be seen coming out of the car's petrol tank when you fill up at the service station. Fuel vapour emissions can be reduced if we avoid spilling petrol and overfilling our cars. Properly fitting fuel caps stop further leakage of fuel vapours. It may also be possible to reduce fuel vapour emissions if fuel formulations with a lower volatility level were made available to the general public.

In 1975, all new cars sold in Australia were required to be fitted with basic anti-pollution equipment. These cars were designed to run on leaded petrol. Since January 1986 all new cars have been built with catalytic converters and have been designed to run on unleaded petrol.

If a car is well tuned and maintained it is likely to emit between 9-25% less pollution into the atmosphere than a similar poorly maintained vehicle. In addition a well maintained car is between 1.5% and 5.0% more fuel efficient.

Cars which have been altered, and no longer conform to the original specifications, tend to put out considerably more pollution into the air. Such modifications include non-standard cylinder heads, pistons, valves, camshafts, fuel systems or exhausts.

The impact of diesel vehicles
Eighty-eight per cent of the heavy duty vehicles and five per cent of the light vehicles on our roads use diesel. While a diesel vehicle will emit less hydrocarbons and carbon monoxide than a similar sized petrol vehicle, it will give off more oxides of nitrogen and fine particles. Most of the particles are tiny (less than 0.01mm in size) and these can cause or exacerbate respiratory disorders. In addition, they contribute to haze and as a result the particles can soil our environment.

What are the major air pollution problems for Perth?
1. Photochemical smog

Photochemical smog is considered to be one of the most significant pollution problems facing many cities of the world and Perth is no exception. Cities which are particularly at risk have periods of time when there is an abundance of sunlight, moderate winds and high temperatures. In Perth, photochemical smog tends to occur in late spring, during summer and early in autumn.

Photochemical smog, which may be invisible to the naked eye, is characterised by high concentrations of ground level ozone. Ozone is formed when oxides of nitrogen and reactive organic compounds, react together for a few hours under the influence of sunlight and high temperatures.

Studies show that motor vehicles are the major contributor to Perth's photochemical smog. Industry and area sources also make significant contributions.

Perth typically has 9 to 17 days per year when ozone levels exceed the World Health Organisation goal of 80 parts per billion (ppb). High ozone levels have been measured from Rockingham in the south to Two Rocks in the north, Rottnest to the west and Rolling Green to the east.

When at low concentrations ozone is colourless and odourless, but at higher concentrations it has a pungent odour and is bluish in colour. Ozone impacts upon the healthy and the fit as well as the more susceptible members of the population. These include the very young, elderly and those with respiratory or cardiovascular problems.

Studies have found that our lung function may be reduced if we exercise while ozone levels are elevated. When ozone levels are increased to around 100 parts per billion there is an increased incidence of eye, nose and throat irritations. Ozone causes damage to all parts of our respiratory tracts, particularly the cells which are involved in gas exchange. This may lead to people experiencing the symptoms of chest tightness and wheezing.

At levels of 120 parts per billion, ozone can cause changes in our airways which will increase our sensitivity to allergens such as pollen. There is further evidence that elevated ozone levels can trigger asthma attacks and increase our susceptibility to infection.

When at elevated concentrations, ozone can damage the leaves of plants and reduce their ability to photosynthesise. This will lead to reduced growth rates and yields. At current levels the impact of ozone on plant life within Western Australia is not well understood, however, it has been estimated that photochemically produced ozone has lead to a five to 10 per cent decline in crop yields in the United States of America. It is also possible that plants become more susceptible to disease and less tolerant to cold temperatures. Genetic information within the seeds may also be altered.

Ozone also damages susceptible materials such as rubber, plastics, concrete, stone, cloth, dyes and paint work.

What can we do about smog?

Should emissions and the consequent photochemical smog concentrations increase by small amounts in the Perth region, it is expected that the number of days when ozone levels are above acceptable standards will increase considerably. We are in the fortunate position of being able to reduce our photochemical smog emissions before the problem gets out of hand.

There are many things which we can do to reduce the amount and frequency of photochemical smog events in Perth. We must reduce our contributions of oxides of nitrogen and reactive organic compounds to the atmosphere. This can be achieved by using alternative modes of transport and leaving the car at home.

Other cities have had considerable success at reducing their level of photochemical smog. An excellent example is San Francisco which in 1969 had 65 days over 120 parts per billion. Through regulatory and community action this was reduced to one day by 1994.

What causes a smog event for Perth?

Perth's worst photochemical smog days, are between late spring and early autumn, when there is a weak low pressure trough situated very close to the coast. Under these conditions, pollution created by the morning peak hour traffic is blown out to sea by north easterly winds. Here the pollution sits and if the temperature is warm enough, the smog reactions proceed rapidly. The smog is then returned over the metropolitan area with the sea breeze. The process is illustrated in Figure 17.

Photochemical smog may also be experienced if bushfire smoke is blown across the metropolitan region.

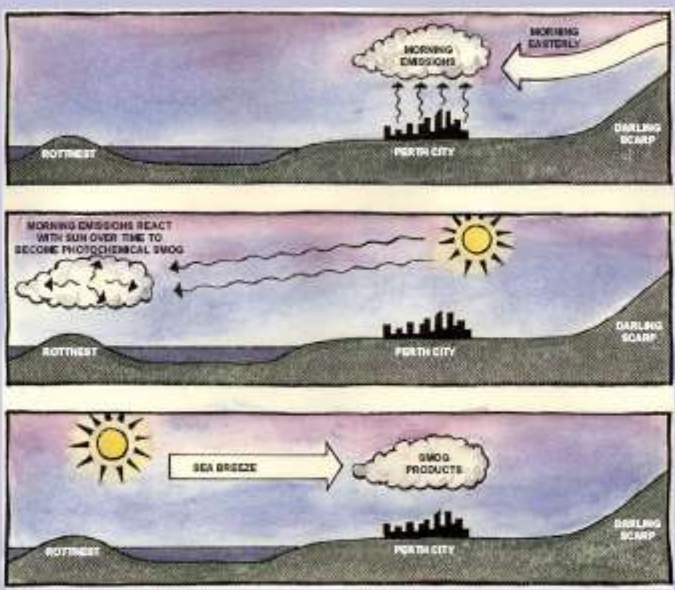

Figure 17. Formation of photochemical smog over Perth.

2. Haze

Haze is the name given to the collections of tiny particles from wood smoke and vehicle exhausts which make our skies look brown. Haze is most likely to be observed on cold, calm winter mornings.

The haze particles are so tiny that between 15,000 and 50,000 particles can be lined up side by side along a line one centimetre long. Fine particle matter is sampled at the city centre and four metropolitan sites. Some areas have been found to have similar levels to those recorded in Sydney and Melbourne.

Haze levels tend to be highest in winter and lowest in summer. The largest source of haze forming particles in winter is smoke from domestic wood heaters. The burning of green wastes, forests, and paddocks contribute to haze formation at other times of the year, particularly autumn and spring. Particles emitted from exhausts, particularly of diesel engines, also make significant contributions to haze.

Pollutants present in the atmosphere can react together and produce additional fine particle matter. The smallest source of fine particle matter is naturally occurring dust and sea salts.

Haze is worst on days of temperature inversions. How do temperature inversions form?
On cool, clear, calm nights the ground and the air next to the ground cool down. As the air cools, it becomes heavier and, as a result, the air does not mix with the warmer lighter air above.

How is this relevant to Haze?
Haze is particularly evident on days of temperature inversions. The fine particle matter gets trapped in the layer of cold air close to the ground. With the temperature inversion preventing vertical dilution and little horizontal dilution occurring because of light winds, the continued production of particles (fires burning, exhaust emissions) causes the particles to accumulate in the air. The particles scatter the sunlight, making the sky in the direction of the sun appear bright, while away from the sun the sky looks brown

Any material floating about in the air can be breathed in to our bodies. The larger particles are trapped by the fine hairs inside our noses and windpipes. These are passed from our bodies when we blow our nose or cough. Because of their smaller size, fine particle matter is inhaled deep into our lungs. While some of the particles are exhaled, a fraction are retained and these can have serious impacts on our health.

The people most at risk are the very young, the elderly, or people with lung or heart diseases. Fine particles are known to exacerbate problems experienced by bronchitis, emphysema and asthma sufferers. There is also evidence that fine particle matter can lead to premature deaths. The main group at risk are elderly people who suffer from chronic respiratory problems. We should also be aware that fine particle matter may also contain harmful chemicals which can damage our lungs, or even worse, cause cancer.

When airborne particles finally settle they add a film of “dirt” to the natural and physical environment.

3. Carbon monoxide
Carbon monoxide, a colourless, odourless, highly toxic gas, is one of the most common and widely distributed air pollutants. It arises from the incomplete burning of materials, industrial processes and biological decay.

Carbon monoxide comes from many sources. The group referred to as “area sources” is diverse. It includes our homes and gardens, schools and office blocks, shops and service stations. Of particular interest to us is our own homes.

One of the most significant individual sources of carbon monoxide is cigarette smoke. Scientific research indicates that smokers, and passive smokers, are exposed to up to four times more carbon monoxide than people in a smoke-free environment.

People who are exercising are more prone to carbon monoxide poisoning than people at rest. Low level of carbon monoxide pollution can lead to a reduction in our ability to carry out exercise. As the concentration of carbon monoxide within our blood increases, our ability to receive information about our environment decreases. We become less able to concentrate and experience headaches.

Short term exposure to very high carbon monoxide levels can prove fatal. Carbon monoxide enters the bloodstream and considerably reduces our body’s capacity to get oxygen to the cells. As our heart compensates and sends more blood to each cell, it is put under considerable strain. If vital organs such as the brain are starved of oxygen, some of the cells will die and brain damage can occur.

The health threat of carbon monoxide poisoning is greatest for people who suffer from cardiovascular disease. In some of the world's large cities it has been found that there is a correlation between carbon monoxide levels in the air and the admissions of elderly people to hospital with congestive heart failure.

Since 1990, carbon monoxide levels in Perth have been closely monitored in the central business district because of the high concentrations of motor vehicles found there. The carbon monoxide level within the air we breathe is currently believed to be within safe limits. With our population increasing and the expected increase in the number of kilometres travelled per person in vehicles, it has been predicted, despite improved emission controls, carbon monoxide levels will rise in the future.

4. Oxides of Nitrogen

The most common oxides of nitrogen in the atmosphere are nitric oxide and nitrogen dioxide. Nitric oxide is a colourless, odourless gas while nitrogen dioxide is an orange-brown gas with a stinging smell.

The largest man-made source of the oxides of nitrogen is the combustion of fossil fuels. Our motor vehicles which are responsible for 51 per cent of the emissions. Industry contributes approximately 44 per cent of the oxides of nitrogen emissions to Perth's air. Examples of such industries include power generation and the production of nitric acid. The remaining contributions of nitrogen oxides come from area sources, including our homes and workplaces. The use of gas appliances for heating and cooking and the smoking of cigarettes both lead to an increase in the oxides of nitrogen within indoor environments.

As previously described, oxides of nitrogen are one of the two groups of pollutants responsible for the formation of photochemical smog. In addition, oxides of nitrogen can have significant impacts on health. While nitric oxide is a relatively safe gas, it is converted to nitrogen dioxide in the atmosphere. At levels above 300 parts per billion, nitrogen dioxide can affect our respiratory systems and increase our susceptibility to infection. This is a real problem for new babies, older people, or for those people with problems such as bronchitis and asthma. There is evidence that nitrogen dioxide can trigger asthma attacks in known sufferers. If we are exposed to high levels of nitrogen dioxide for long periods of time, it is possible that cells on the interior surfaces of our lungs may be irreversibly changed. With this, our lung function is reduced.

Nitrogen dioxide is also known to prematurely age materials such as paint, metals, rubber, fabric, leather, paper and building materials. In addition the oxides of nitrogen can react with water and form weak solutions of nitric acid and this can contribute to a phenomenon known as wet acid deposition.

Nitrogen dioxide levels in Perth rarely exceed the West Australian standard of 150 parts per billion on average in any one hour.

5. Air toxics

One hundred and eighty nine air toxic substances have been identified by the United States Environmental Protection Agency. The list of air toxics includes benzene, 1,3 butadiene and the polycyclic aromatic hydrocarbons.

Benzene, 1,3 butadiene and polycyclic aromatic hydrocarbons are emitted from internal combustion engines including motor vehicles. Diesel vehicles are known to emit particularly high concentrations of polycyclic aromatic hydrocarbons. It is therefore not surprising to learn that the levels of air toxics will be higher near busy roads.

While cars are the major source of air toxics for people with limited exposure to cigarette smoke, this is not always the case for smokers and their associated sidestream smokers.

Benzene is readily released into the atmosphere in fuel vapour. This occurs if our vehicle has a leaky fuel cap and as we fill up at the petrol station. Smoke produced by incomplete combustion of wood and fossil fuels is another source of air toxic substances.

Is there an indoor air pollution problem?
Indoor air quality is important. A good indoor climate reduces illness. It also helps us to feel more comfortable so we are able to work more efficiently. It may come as a surprise to learn that the quality of air indoors is often poorer than that outdoors. It is therefore important that we understand the impact of indoor air quality on our health. It is particularly important to consider the impact of indoor air pollution when we learn that the majority of people spend between 85 and 95 per cent of their time indoors and that elderly, sick and very young people spend nearly all of their time indoors.

The use of synthetic building materials, household products, gas for cooking and a variety of fuels for heating can lead to pollutants being at excessively high levels indoors. Carpets have also been identified as being a major source of indoor air pollution. This problem is exacerbated by building design and room partitioning which does not allow a good flow of fresh air.

Smoking of cigarettes in indoor and enclosed areas is a considerable health risk for all people using the area. As a result, smoking has been banned in all government offices, and public areas in Western Australia.

There are a number of substances which have been recognised as indoor pollutants. To maintain good air quality within indoor spaces we must minimise the number of pollution sources and encourage the movement of plenty of fresh air into our homes.

What are the economic costs of air pollution?
Air pollution has a real health cost. Various attempts have been made to convert this to a dollar value.

A number of broad assumptions have been made in an effort to quantify the costs. In 1994, a study was completed by the Brisbane City Council to find the health cost of air pollution. The study was considered to be particularly relevant for the people of Perth as Brisbane has a similarly sized population and levels of air pollution. Given that those carrying out the study estimated a human life to be worth $5 million, the cost of fine particle matter pollution was calculated as being between $230 million and $415 million per year. This translates to between 46 and 83 premature deaths per year. In addition, the authors costed illness caused by fine particle matter and ozone at between $23 million and $45 million per year.

Another study, the Victorian Transport Externalities Study, attempted to estimate the cost of air toxics and ozone on the health of Melbourne's population. The population of Melbourne is two and a half times larger than Perth. As a result of Melbourne having more traffic, more air toxics are emitted into the atmosphere. During 1990, the estimated cost of cancer caused by air toxics to the Melbourne population was calculated as between $26 and $45.2 million. Melbourne tends to have more days than Perth when ozone levels exceed the one hourly World Health Organisation's goal of 80 parts per billion. In a 12 month period spanning 1992 and 1993, Melbourne had 13 days exceeding 80 parts per billion of ozone in one hour. The cost associated with premature deaths, asthma attacks and the reduced activity of people, as a result of ozone-related illness, was given an average estimate of $2.5 million dollars.

The two studies considered three aspects of air pollution. No consideration was given to the health costs of carbon monoxide, nitrogen dioxide, sulphur dioxide or lead by the studies. Even though we are mindful that there were a number of assumptions made by the researchers, it is evident that there are significant health costs associated with air pollution.

To get the total picture of the cost of air pollution we must look beyond human health and consider environmental costs. What is the cost of damage to plants, animals and ecosystems as a whole? What value is placed on the premature deterioration of monuments and buildings or other pollution sensitive materials such as rubber, plastics, cloth and paint work?

At this stage, specific estimates for these costs have not been calculated. It is important however, that we keep in mind that these are important components as we consider the overall cost of air pollution and pollution reduction.

What can we do to reduce our air pollution?
To improve the quality of the air we breathe we must think about our individual contribution to pollution.

Each of us add to the air pollution in some way or another.

If we all make an effort and reduce our contribution to air pollution, this will make a big difference to the air we breathe. In the following pages some suggestions are made as to how we can reduce air pollution from private vehicles, our homes and gardens, through recreation and by working together as a community.

Now is the time to act
If we make comparisons between Perth and other cities of the world we may conclude that Perth's air pollution is not that bad. While this is good, we must not relax. At this point in time we have the opportunity to prevent Perth becoming seriously polluted.

Our population is growing and our use of private vehicles is showing an increasing trend. If no change is made more toxic emissions will be pumped into the air. Some of these will cause immediate affects for us and our environment, while others will show their effects at later stages.
Scientists have identified that only a small increase in emissions of reactive organic compounds and oxides of nitrogen will lead to a considerable increase in the number of days when ozone levels exceed what are currently considered to be acceptable limits.

Air pollution has its costs. It affects the health and quality of life of people, animals and plants. Buildings, monuments and artworks are damaged by a variety of pollutants. By reducing our air pollution emissions, we are contributing to a cleaner
and healthier environment.

Further References:
http://www.greenenergytv.com/browse/Educate.aspx#1472379756 (good website and cartoon re carbon footprints)