# Chapter 2 Atmospheric Environment

## Size and composition of the atmosphere

The environment comprises the Earth's crust, the oceans and the atmosphere. The depth of the crust that affects us on a regular basis is between a few hundred and perhaps a thousand metres, and the oceans have a similar mass. But the atmosphere is much smaller – although it reaches to an effective height of about 10,000 metres, its density is a thousand times less than water. So it is equivalent to a layer of water on the Earth just 10 metres thick – less than 1% of the mass of the oceans or the Earth's crust. So it is easily polluted and, being composed of gas, any pollution is quickly dispersed into the whole.

The composition of the atmosphere today is 78% nitrogen, 20% oxygen and 1% argon with smaller amounts of carbon dioxide and water vapour. Oxygen and water are fiercely reactive but nitrogen, carbon dioxide and argon are less reactive or totally unreactive. Until two and a half billion years ago there was little atmospheric oxygen. Its concentration was increased by photosynthesis in early plant life powered by the Sun. This break-up of carbon dioxide into free oxygen and carboniferous plant life 'charged the battery' for all life processes. Oxygen remains a powerful chemical, not only when this battery is discharged in the burning of plant matter, fossilised or not, but also in related oxidative processes in living cells. These may be benign, as in the oxidation of sugars that provides the energy for living creatures; they may also be malign, as when oxidation disrupts cellular processes and leads to cancer. Fortunately life has evolved ways in which to protect itself against such oxygen damage that are effective most of the time. Coincidentally, these same protection mechanisms turn out to be equally effective against the damage caused by radiation, as we shall see later.

## Atmospheric change

The average surface temperature of the Earth is critically dependent on the composition of the atmosphere, and a small release of pollution can have a relatively large effect on the climate. The reason for this is explored in Chapter 4 in terms of the spectrum of thermal radiation absorbed and emitted by the Earth. Pollution released into the oceans would also have an environmental effect, but a much diluted one that would not impact directly on the temperature. In the case of the Earth's crust dangerous materials – suitably buried – can stay put for many millions of years. So care of the environment is concerned first and foremost with the atmosphere.

Since man started to employ fire and organised agriculture to raise his standard of living, he has released an increasing mass of contaminants into the atmosphere, although only recently has the extent of their effect been appreciated.

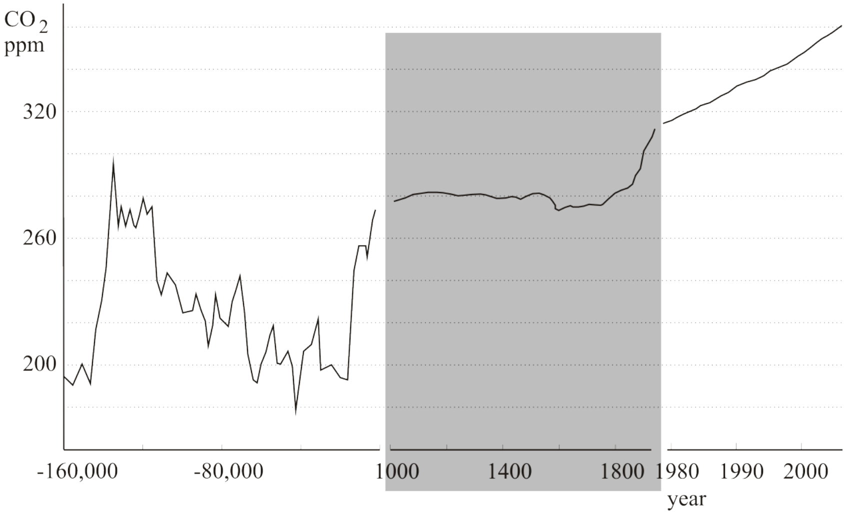


**Figure 1 The concentration of carbon dioxide in the atmosphere for three separate epochs. Left: prehistoric variation (measured from Antarctic ice cores). Centre: historic data (also from ice cores). Right: modern measurements (direct from the atmosphere).**

For example, the growth in the concentration of carbon dioxide in the atmosphere is shown in Figure 1. The left part of the diagram shows the concentration for most of the past 160,000 years, going up and down within the range 200–280 parts per million (ppm) and spanning various states of the world's ice sheets. The central part of the plot shows that it was fairly constant at 280 ppm from 1000 AD until the industrial revolution, with its rapid increase in population and pollution. Since then it has risen remorselessly as shown on the right – the latest data say that it has risen by 40 ppm in 25 years and currently stands at 360 ppm. Note the large change in timescale for the three parts of the plot.

A plot for methane would show a similar rapid increase. These effects come from the increased burning of fossil fuels and the destruction of forests, exacerbated by the rising world population of humans and animals. These gases are called greenhouse gases because they have the effect of causing a rise in the average world temperature, as explained in Chapter 4. The temperature change is expected to be self-reinforcing for several reasons whose relative importance is still uncertain.

Firstly, the water vapour in the atmosphere naturally increases as the air gets warmer, and, since water vapour is also a greenhouse gas (as explained later on page 39), it is expected to contribute a further rise in temperature.

Secondly, as the temperature rises the extent of the polar ice caps is reduced, and, without the reflection of the snow and ice, the surface of the Earth becomes darker to sunlight. The extra solar absorption in polar regions is responsible for another increase in the surface temperature.

Thirdly, as the temperature rises, plant material that was previously preserved and locked in the 'deep freeze' of the permafrost starts to rot and decompose, emitting further greenhouse gases, specifically methane.

Any increased incidence of forest fires accompanying the temperature rise releases yet more gases. As living plant life absorbs carbon dioxide and releases oxygen, any reduction in forestation is harmful on both counts. The re-absorption of carbon dioxide from the atmosphere by sea water and through plant growth is slow. In fact, on average, it takes about a hundred years for any carbon dioxide, once released, to be re-absorbed. So, even if all emissions were stopped immediately, climate change would continue for a century or so before possibly stabilising. If emissions continue, the climate will continue to change. The population that the world can support may be reduced and, as deserts expand, large migrations of people towards more temperate regions may be expected. To reduce greenhouse gas emission, other ways of providing sufficient energy and food for the world population must be found, and all available solutions pursued simultaneously.

Much energy can be saved with care and by investment in new technology, for example efficient power supplies and LEDs (light-emitting diodes). For the energy production itself, wind, tidal, solar, geothermal and hydroelectric sources provide electric power without gas emission. Each is appropriate to a particular kind of locality. Some are intermittent, some are expensive and many are limited in scale. Intermittent sources need to be coupled with energy storage, but there are no easy options there. Energy for transport also needs storage, but battery technology and hydrogen storage have significant limitations.

## Energy and agriculture

Increased populations with rising standards of living expect more fresh water and food. The shift from a basic, mainly vegetarian, diet to a regular meat-eating lifestyle requires more water. But the extra water consumption of ruminants and their added gas releases are both significant. Meanwhile many parts of the world suffer increased desertification and depletion of ground water supplies. Unlimited clean water can be obtained from sea water by the process of desalination but this requires significant amounts of energy.

Much food goes to waste though traditionally its deterioration may be reduced by refrigeration, but this also requires energy, both to power the refrigeration and to transport the refrigeration units. Alternatively food may be preserved by irradiation, a method that requires no ongoing energy supply but is little used. Food waste and an affluent diet increase the demand for more agricultural land, which leads in turn to further deforestation.

These observations motivate a re-examination of society's attitude towards radiation and the nuclear option, as the major source of energy for almost all purposes.

The word energy is used frequently in the following chapters and it might be helpful to explain what it means. Energy is measured in joules, and 100 joules of energy is what it takes to power a 100 watt light bulb for 1 second. Energy is conserved – that means it does not get lost – and it is inter-convertible between different forms, to some extent. Forms of energy include heat, sunlight, chemical, nuclear, electrical, hydro and many others.

In a waterfall the same quantity of energy may be carried by a large mass of water that drops a small height, or a smaller mass of water that drops through a larger height. But the difference can be important. There is a similar distinction between nuclear and fossil fuel energy sources. The same total energy may come from a small number of atoms each releasing a large energy, or a large number of atoms (or molecules) releasing a small energy. The former is what happens in a nuclear power station and the latter in a fossil fuel one. Usually in the following chapters the word energy will refer to the energy per atom. It should be understood that many, many atoms may deliver much energy, but the amount of fuel required and the waste generated for each joule produced increases if the energy per atom is small.

This energy per atom is five million times smaller for fossil fuel than for nuclear, as explained in footnote 6 on page 29. So, for the same amount of electricity, the amount of fossil fuel required (with its waste) is five million times the amount of nuclear fuel (with its waste). This is the crux of the story.

# Chapter 3 The Atomic Nucleus

*His enormous head bristled with red hair; between his shoulders was an enormous hump…*
*The feet were huge; the hands monstrous. Yet with all that deformity was a certain fearsome appearance of vigour, agility and courage…*
*'It's Quasimodo, the bell ringer. Let all pregnant women beware!' cried the students.*
*'…Oh that hideous ape! ... As wicked as he is ugly …it's the devil.'*
*The women hid their faces.*

Victor Hugo, writer (1802–1885)

## Powerful and beneficial

In his novel, *The Hunchback of Notre Dame*, Victor Hugo introduces the central figure with these words. While the citizens of mediaeval Paris are repelled by his ugliness and afraid of his strength, no one cares to discover his true nature. As the story unfolds, Quasimodo reveals a natural gentleness and kindness towards Esmeralda, the beautiful gypsy girl, who is condemned to death on the gallows. The people's fear prevents them from appreciating him until he uses his strength in the attempt to save Esmeralda's life.

Such is the public image of radiation. Like Quasimodo, it is seen as ugly, strong and dangerous. Like him it engenders an almost universal reaction of fear and rejection. Many do not want to be near anything to do with radiation or even to understand such things. This is unfortunate, because the human race has survived through the power of thought and understanding. The suspension of that power is not good news for the future.

The following descriptive but scientifically robust account shows how radiation and the atomic nucleus fit into the natural physical world.