Chapter 7: Greenhouse gases and particulate matter

Debates on the anthropogenic greenhouse effect and climate change mostly involve carbon dioxide – CO₂. But there are many other substances that play a role in the greenhouse effect and, while carbon dioxide is the most significant of these at present, it will not necessarily remain so.

Section 7.2 mentions methane (CH₄), a gas that could possibly play a large role in the greenhouse issue. Then there are also halogenated hydrocarbons, including CFC’s, which are identified in sections 1.3 and 6.4 as degrading the ozone layer, although that is not their only crime: they also play a part in the greenhouse effect.

Ozone itself – O₃ – is likewise a contributor to climate change, but in a very complex way. The ozone in the stratosphere – the ozone layer – blocks ultraviolet (UV) radiation, preventing it from reaching the lower troposphere and the earth. This means that the stratospheric ozone lowers the temperature. Because CFC’s and other substances have degraded the ozone layer, the stratosphere absorbs less UV and has resultantly cooled slightly in the last few decades, while the temperature closer to earth has risen for the same reason – a greater amount of UV is getting through. The tropospheric ozone that is located at a lower level consequently acts like a greenhouse gas and contributes to rising temperatures.

Nitrous oxide (N₂O) also plays a significant role in respect of the greenhouse effect.

Water vapour

And then there is water vapour, which is a major greenhouse gas, although its exact role in climate change is difficult to assess. Firstly, human beings do not have a particularly large direct influence on the amount of water vapour in the atmosphere. But they do have an indirect one, and this is large. In our changing climate, the evaporation of water is increasing dramatically in some parts of the world as a result of issues like higher temperatures, irrigation for agriculture and the larger surface areas created by dams. But in other regions this process is decreasing, thanks to droughts and desertification. Changing winds (caused by El Niño and other phenomena) and currents, as discussed in chapter 7, also affect the evaporation levels.

Water vapour also influences climate change in another way – cloud formation. On the one hand, clouds trap infrared radiation emitted by the earth (this is a well-known phenomenon: cloudless nights are cooler ones), while on the other, clouds deflect sunlight, contributing to the earth’s albedo (another well-known phenomenon: cloudless days are hotter days). There is still much debate about whether cloud cover has increased or decreased on average in recent years, and hence little is known as yet about its influence on climate change. What is however clear is that complex feedback loops are involved, both positive and negative ones.

Concrete data

The table below contains some data on the most significant greenhouse gasses. The table can be downloaded as a spreadsheet named ‘Greenhouse gases.xls’ from the website of the book. The spreadsheet contains further information, including links to websites from which the data in the table was derived.
Global warming potential

Amongst other headings, the table includes one by the name of ‘Global Warming Potential’, often abbreviated to GWP. Global warming potential is the measure by which a given gas plays a role in the greenhouse effect. In more accurate terms, the GWP is the measure of how much one kilogram of a greenhouse gas contributes to the greenhouse effect.

The GWP of CO$_2$ is set at 1, making the GWP a relative measure. The fact that the GWP of methane is 23 means that its role in the greenhouse effect is (per kilogram) 23 times greater than that of CO$_2$. Another way of putting it is that the GWP is expressed in carbon dioxide equivalents (CDE).

The GWP not only takes into account the annual contribution made by a gas, but also its persistence in the atmosphere, which is determined by the speed at which the gas is broken down. If gas A and gas B should, per unit of time and kilogram, play an equally large role in the greenhouse effect, but if gas B remains in the atmosphere ten times longer than gas A, then the GWP of gas B is ten times as large.

The total contribution (the radiative forcing) of a gas to the greenhouse effect, which is shown in figure 7.4 in the book, is determined by a number of factors:

- The quantity of gas present in the atmosphere
- The duration for which the gas is present in the atmosphere
- The altitude at which the gas is present
- The wavelength range (the ‘colour’) at which the gas absorbs radiation
Whether other gases also absorb radiation at that wavelength range

**Particulate matter**

Another factor that influences climate change is the amount of particulate matter. Particulate matter is made up of tiny particles - *aerosols*, including soot, plant and animal fibres and volcanic ash. Other aerosols are created by these particles through chemical reactions in the atmosphere. Aerosols also come into being as a result of desertification, with the wind and weather eroding the barren earth, blowing microscopic sand grains into the air.

Particulate matter plays a complicated role when it comes to influencing the temperature of the earth. The particles are light-absorbing and consequently contribute to the rise in global temperatures, but they also reflect a portion of the sunlight and so play a role in increasing the albedo, which moderates the temperature increase. This is what is known as *negative radiative forcing*. You can see this negative value in the aforementioned spreadsheet - the extended version of the above table - that you can download. The figure is a relatively uncertain one, as it is the sum total of the radiative forcing of many different types of particulate matter. The dark-coloured soot particles, for example, have positive forcing, while the biggest negative contribution is derived from the sulphuric particles.

Moreover, the aerosols also have an indirect radiative forcing because the presence of particles in the atmosphere plays a role in cloud formation. The extent of this effect as well as the form it adopts is difficult to ascertain, in part because of large regional differences.

All in all, what is a given is that the presence of particulate matter has, on balance, a moderating effect on climate change. One could conclude that it is great that the concentration of particulate matter in the atmosphere is on the rise, thanks to human activities – the primary ones being traffic, industry and agriculture. But there is unfortunately also a flipside, which involves the health effects.

Smog is a form of air pollution that involves a mixture of aerosols and ozone (O₃) or sulphur dioxide (SO₂) at high levels of concentration in the air, particularly in urban and industrial areas. (Although smog can contain ozone, this has nothing to do with the ‘hole in the ozone layer’.)

The larger particles (the so-called PM₁₀) have a diameter of ten micrometers or less (a micrometer being one-thousandth of a millimetre), and are the least hazardous. It is the smallest particles (PM₂.₅), measuring 2.₅ micrometers or less across, that cause the most damage. They are able to permeate into every part of the lungs and cause cardiovascular diseases, bronchitis and asthma.

Consequently, particulate matter is a bigger killer than alcohol or drug abuse. In the USA, estimates vary between 22,000 and 52,000 deaths annually (Mokdad et al, 2004), while the annual number of deaths in Europe amounts to 200,000. Aside from this, the annual economic loss amounts to billions of dollars pounds and euros, thanks to sick leave and medical costs.
In many countries, strict limitations have been put on the allowed concentration of particulate matter in the atmosphere. Nevertheless, nonattainment is common. As an example, a map for the USA is shown, followed by a more detailed map of the state of California (source for both: EPA, 2011).
Questions
- Which is more important: the health of people, or the climate of the planet?
- In other words: should we be happy with high concentrations of particulate matter, if this reduces climate change?
- Or should we try to lower PM concentrations, as people are dying from it?

Literature