Editorial

Carbon dioxide, the unseen pollutant

Anthony Seaton
Emeritus Professor, Aberdeen University and Honorary Senior Consultant, Institute of Occupational Medicine, Edinburgh, Scotland, UK

"My name is Ozymandias, king of kings.
Look on my works, ye mighty, and despair!
Nothing beside remains. Round the decay
Of that colossal wreck, boundless and bare
The lone and level sands stretch far away."
PB Shelley

When William Harvey went to study in Padova, he took the first steps in what was to become a revolution in science. The dissection skills and enquiring mind he took home to England led him to the discovery of the circulation of the blood and the story of the generation of the fetus (1). The natural philosophers who followed him in Oxford, Willis, Boyle, Hooke and Wren, founded the Royal Society and started the scientific evolution of chemistry and physics from philosophy (2). In 1660 Boyle and Hooke showed how combustion as well as animal life depended on air and Mayou in 1667 showed that only a part of air was necessary for this. It can be said that Boyle was the originator of chemistry, but a century was to pass before this subject became allied to medicine. William Cullen, professor of medicine in Glasgow, introduced it first into university teaching and his pupil and successor, Joseph Black, in 1754 first made a gas chemically, by heating magnesium carbonate, noting the weight loss and finding that the gas evolved, carbon dioxide, did not support combustion. In turn, his pupil, Daniel Rutherford identified nitrogen in 1772.

By 1775 oxygen had been discovered, first by the Swede Carl Scheele then by Joseph Priestley, and Antoine Lavoisier in Paris showed how man consumed oxygen, which he named, and released carbon dioxide. The first half of the carbon cycle had been discovered. There was then a gap of over 50 years until the German, Justus von Liebig, showed that plants take up carbon dioxide and release oxygen. He also showed the role of nitrogen in plant metabolism and introduced the use of artificial fertilizers. The cycle was complete.

In 1798, the English cleric and philosopher, Thomas Malthus, wrote his Essay on Population, pointing out the interdependence of population and the means of subsistence, and the consequences if subsistence failed (3). As he wrote, the industrial and agricultural revolutions were beginning, based on the use of machinery, powered first by man and horses, then by water, and then by coal. Populations expanded exponentially, permitted by increases in productivity and food supply. From a slowly rising world population of about 400 million in Malthus' time it rose over the next 200 years to more than 6 billion. This is the ever-increasing population that expects the earth's resources to supply enough for an ever-increasing standard of living.

The first shadow cast on man's expectations came in 1824 from the French mathematician, Jean-Baptiste Fourier, who calculated that the earth's atmosphere is responsible for trapping some of the sun's radiant heat in our planet and showed that glass had this "Greenhouse Effect". In 1860 Tyndall showed that this effect was a consequence of absorption of reflected radiation by the compound gases carbon dioxide, water vapour and hydrocarbons. However, when the Swede, Svante Arrhenius, in 1896 calculated that a rise of 5°C would follow a doubling of atmospheric carbon dioxide, this was thought of as beneficial by increasing agriculture and preventing another ice age (4).

Perhaps our eyes were taken off this issue in the 1940s to 1980s by the more immediate problem of particulate and gaseous air pollution from coal burning in cities, reaching a climax in the great London smog of 1952 that was associated with many thousands of excess deaths from heart and lung disease. Efforts to control this pollution in western Europe were very successful and even the exponential increase in use of motor vehicles failed to stop the decline in pollution levels. But the unseen pollutant, carbon dioxide, continued to climb unnoticed. A warning had been sounded in 1938 by the engineer Guy Callender, who first recognised that the capacity of the oceans to absorb carbon dioxide was limited to the surface layers, leading to possible saturation (5). This theme was taken up in the 1950s by Roger Revelle and Hans Seuss in USA, who confirmed the theory and instituted an atmospheric station on Manua Loa in Hawaii (6). This station has produced a time-series of measurements up to the present day, showing rises of carbon dioxide from 310 to 390 ppm over 40 years. Over this period, the Green movement has drawn attention to reduction of the other important sink for carbon, the earth's vegetation and especially its forests. It is now recognised that rising temperatures have adverse effects on two fragile but vital ecosystems in particular, tropical rainforests and oceanic algae, both of which are critically important in removing carbon from the atmosphere.

These rises in carbon dioxide relate to global temperature change. Reliable temperature measurements date back to the 1850s and show a steady rise from about 1920 to 1945 with a plateau up to 1980 and a rapid rise thereafter. Modelling by the UK Tyndall centre has shown that the shape of this graph is most likely to represent a period of reduction of rise after the war as a consequence of particulate pollution restricting the incoming solar radiation, an effect now neutralised by anti-pollution regulation in the developed world (7). Scientists have developed methods for examining atmospheric gases and temperatures in ancient times by analysing the gases and isotopes present in tiny bubbles trapped in ice cores drilled from glaciers in mountains and the polar regions. Two observations in particular give cause for anxiety. First, ice core measurements of carbon dioxide over 400,000 years have shown regular fluctuations between about 180 and 270 ppm, the nadirs coinciding with ice ages related to changes in the earth's axis. As the last peak appeared to be approaching, levels have continued to climb and are now 390 ppm (8). Certainly it looks as though Arrhenius was right in suggesting that rises in carbon dioxide would prevent the next ice age! Secondly, geologists, examining fossil leaves laid down in Antarctic rock at the time of the Pliocene period, 3 million years ago, when man first emerged in Africa, the polar regions were free of ice in the summers and Antarctica was vegetated, have estimated from the density of stomata in the leaves that this was the last time that carbon dioxide levels were similar to today's (9). It does seem likely that rises in global temperature and carbon dioxide are causatively linked to man's exploitation of fossil fuels.

At some point, temperature rise becomes irreversible, since the atmospheric system includes a number of positive feed-back mechanisms. As temperature rises, ice melts and less radiation is reflected back into space, permafrost melts and releases trapped methane (which is rising with carbon dioxide and is even more potent a greenhouse gas), forests and algae die off, and glacial loss increases through cracking. It has been suggested that this tipping point may be reached with a further 2°C rise, although this prediction is subject to some uncertainty. Whether this is so or not, if current trends in carbon dioxide emissions continue, that point could be reached within a few decades. The consequences of climate change are already apparent; rising sea levels, greater winter weather turbulence (recent events in New Orleans and Myanmar bear witness to the human disasters this implies), flooding and its converse, failure of water supplies and agriculture, displacement of impoverished people, warfare, starvation and migration. Migration north is now an established biological fact leading to changes in distribution of disease vectors and extinction of northern species that have nowhere further to go. Migration of the human species from Africa northwards is part of this and is already changing patterns of disease in Europe. Of course, climate change is not solely responsible for every one, but it plays an important contributing role in all.

We have two choices. We can either hope all the science is wrong and do nothing, or we can take serious steps to reduce our carbon emissions. It has been calculated that each of us in the developed world is responsible for about 3-6 tonnes of carbon each year. In order for climate change to stabilise, we need to reduce this to about 1 tonne, allowing for some increase in the rather low per capita output in the developing world (10). While all individuals can and should make their contribution, international agreements are necessary and firm action by governments to persuade us that a continually rising standard of living is neither consistent with achieving tolerable conditions for our children and grandchildren nor indeed necessary for a contented life. But we cannot expect governments to take action unless we are prepared as individuals to show the way. As in times of war, sacrifices will be necessary. Past great civilisations, the Mayans, Incas, Egyptians, Greeks and Romans all collapsed. Now however, the threat is not confined to one race of people but is global. Our advantages are that we can foresee it and have powerful technological tools to help us prevent its worst effects if we act wisely.

References

1. Keynes G. The life of William Harvey. Clarendon Press, Oxford, 1978
2. Zimmer C. Soul made flesh. The discovery of the brain and how it changed the world. Heinemann, Oxford, 2004.
3. Malthus TR. An essay on the principle of population (1798). Oxford University Press, Oxford, 1999.
4. Houghton J. Global warming. The complete briefing, 3rd edition. University Press, Cambridge, 2004.
5. Fleming JR. The Callendar effect: the life and work of Guy Stewart Callendar (1898-1964). American Meteorological Society, 2007.
6. Revelle R, Seuss H. Carbon dioxide exchange between atmosphere and ocean and the question of an increase of atmospheric CO2 during the past decades. *Tellus* 1957; 9: 18-27.
7. International Panel on Climate Change. 4th Assessment Report; synthesis report, chapter 2.4. http://www.ipcc.ch/ipccreports/ar4-syr.htm
8. Petit JR, Jouzel J, Raynaud D et al. Atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* 1999; 399: 429-36.
9. International Panel on Climate Change. Climate change 2001: the scientific basis. http://www.grida.no/climate/ipcc_tar/wg1/index.htm
10. Pearce F. The last generation. Eden Project Books, London, 2006.