Chapter 13

Climate change – learning from the stratospheric ozone challenge

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Mario Molina studied physical chemistry and obtained his PhD at the University of California, Berkeley. In 1974, well before the first measurements of the Antarctic ozone hole, he co-authored a paper that described how chlorofluorocarbon (CFC) gases, widely used in industry at that time, destroy the atmospheric ozone layer. In 1995, Molina was honoured with the Nobel Prize in Chemistry for his work on ozone depletion. As Professor of Chemistry and of Earth, Atmospheric and Planetary Sciences at the Massachusetts Institute of Technology, Molina continued his research on man-made changes of atmospheric chemistry. In 2004 he joined the faculty at the University of California in San Diego.

Note: This chapter is a commentary on chapter 12.

The most recent findings on climate change provide clear evidence that 'human activities, especially the combustion of fossil fuels, are influencing the climate in ways that threaten the well-being and continued development of human society' (Richardson *et al.,* 2009). At the same time, Pachauri (this volume) states that climate change 'poses a daunting challenge, but, if acted upon quickly and effectively, one that promises a more inclusive and less vulnerable planet for the global population as a whole'. We have, thus, an opportunity that we must not miss.

Although we know about the potentially disastrous consequences of destabilizing the climate, many people, organizations, and nations are still not responding adequately to the urgent call for action, and insist that more evidence is needed to warrant a global response. Such thinking is similar to that of a patient who asks for virtual certainty that a tumour is indeed malignant before agreeing to have it removed. Yet, most patients would surely agree to have surgery even if the probability of malignancy were merely ten or twenty percent. A similar attitude is still common when considering action on climate change. But we know that the risk of inaction, although difficult to quantify, is very significant, and we do not need more scientific evidence to conclude that drastic action is necessary.

If we continue to delay action we will miss a unique opportunity to make our world a more just and healthy place for all. It is time to remember that we have cooperated on solving global problems before, most notably the problem of ozone depletion in the stratosphere. It might be helpful to look back at previous successes and mistakes to increase the likelihood that our efforts to avoid climate destabilization will be successful.

Stratospheric ozone – a short history

Ozone is found mainly in the stratosphere – the second layer of our atmosphere, at a height of about 10–50 km. An ozone molecule contains three atoms of oxygen instead of the two found in normal oxygen molecules; it is formed at high altitudes through the action of short-wavelength solar radiation on oxygen molecules. Stratospheric ozone has made it possible for life to evolve on our planet; it acts like a sunscreen, absorbing most of the harmful ultraviolet radiation that destroys the DNA molecule, which is essential for life as we know it.

In 1974, we discovered that chlorofluorocarbons (CFCs) – then commonly used in refrigeration and as propellants for spray cans – can have a detrimental effect on ozone (Molina and Rowland, 1974). In the stratosphere, CFCs decompose by the action of short wavelength solar radiation splitting off chlorine atoms, which in turn start chain reactions that break down ozone. We concluded that CFCs could cause a depletion of the ozone layer, potentially affecting human health and the environment.

Our theory was eventually confirmed by atmospheric observations, laboratory measurements and modelling studies. In 1985 the Antarctic ozone 'hole' was discovered (Farman *et al.,* 1985); in the middle of the stratosphere above Antarctica more than 95% of the ozone disappeared in the spring months, and subsequent measurements confirmed that the disappearance was caused by the CFCs. These discoveries initiated a political process that culminated in a multilateral agreement to phase out practically all substances that are responsible for stratospheric ozone depletion. This treaty, the Montreal Protocol, came into full force four years later, in January 1989, and has been amended several times since then. It can be regarded as one of the best examples of effective global collaboration on behalf of humanity and the environment; the amount of CFCs in the atmosphere has started to decline, and although the ozone hole still forms every year over Antarctica, the rest of the ozone layer has started to show signs of recovery from a less severe, but still noticeable thinning.

It turns out that the CFCs that affect stratospheric ozone are also powerful greenhouse gases, and thus the Montreal Protocol has also led to significant climate change mitigation. So far, it has been considerably more effective than the Kyoto Protocol, the treaty that was developed in 1997 to regulate greenhouse gases, and that is currently being reassessed (Velders *et al.,* 2007). Most of the compounds now replacing ozone depleting substances are hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs); some of these chemicals are also strong greenhouse gases (Velders *et al.,* 2009), and for this reason recent amendments to the Montreal Protocol are now aimed at accelerating their phase-out.

An example for global action: Montreal versus Kyoto treaties

The current global problem caused by greenhouse gas emissions has many similarities to the stratospheric ozone problem. In both cases it is crucial to exchange 'business as usual' for collaboration between nations as one global community. But the quick and effective implementation of the Montreal Protocol to protect the ozone layer stands in stark contrast to the Kyoto Protocol. Even though climate change is well documented by a large numbers of scientific studies, the Kyoto Treaty has not been successful on a global scale; global society has yet to find a way to agree on effective actions on climate change. Several important differences between the problems of ozone depletion and climate change are discussed below. They at least partially explain why the Montreal Protocol is more effective than the Kyoto Protocol. Recognizing these differences might enable us to find more effective solutions to climate change.

The science behind ozone depletion is very well established. Reproducible scientific data involving atmospheric observations, laboratory measurements and modelling studies clearly show that the chemical processes that are initiated by CFCs in the stratosphere result in the depletion of ozone. The basic science of climate change is also relatively straightforward; increased concentrations of greenhouse gases warm the surface of the planet. However, the Earth's climate system is quite complicated, and there are many feedbacks which affect the overall functioning of this system. The changes are gradual and occur in a dynamic and complex system; furthermore, at first sight these changes appear to be natural, and hence there is more room for scepticism.

CFCs are clearly of human origin, and do not exist naturally in our atmosphere. In contrast, carbon dioxide and methane, which are the main gases responsible for the greenhouse effect, have predominantly natural sources and play an important role in producing the benign climate that has facilitated the development of human civilization in the past 12 000 or so years. In fact, greenhouse gases make life on Earth possible; the average surface temperature of our planet would be about -15 °C without these gases, when in fact it is +15 °C as a consequence of the 'natural' greenhouse effect. The problem is that human activities are adding large amounts of these 'natural' gases to the atmosphere, causing an enhanced anthropogenic greenhouse effect that is significantly affecting the natural climate.

The extent of change necessary to phase out CFCs was relatively small and relatively easy to monitor. This is probably the most important difference to the climate change issue. The ozone-depleting chemicals were used mainly as refrigerants, solvents and as propellants for spray cans, and could be replaced with other compounds, most with very similar qualities. The Montreal Protocol called for a complete phase-out of the production of ozone-depleting chemicals, which has already been largely accomplished. Most people never even noticed the changes, as the required transition affected only a few industries.

In contrast, climate change is caused mainly by activities related to the production and consumption of fossil fuel energy, which has so far been essential for the functioning of our industrialized society. Effective action therefore requires a major transformation, not only involving a few industries, but affecting a great number of activities of society. Furthermore, the unwanted side-effects from these activities involve the generation of compounds that are naturally emitted to the environment; it is much harder to monitor not only who is responsible for the unwanted emissions but also if they are actually changing. Furthermore, it is not easy to establish the appropriate baseline to decide if the emissions in question are decreasing or increasing. It is harder still to monitor changes in the greenhouse gas emissions related to deforestation, agricultural and land-use practices, which contribute about one third of the total emissions responsible for climate change.

It is thus not surprising that efforts to mitigate climate change have been slow and difficult to implement compared to those of the Montreal Protocol. Today, action will only be effective if there is large-scale collaboration between politicians, industry and civil society, and between most nations. It is important to communicate the urgency of the problem to all these groups. It is also important to understand that its solution involves costs, but these are clearly smaller than the costs associated with inaction, as shown by recent economic studies. It is therefore essential not only to base any solutions on the best science available, but also to clearly communicate the short- and long-term benefits and challenges of the suggested solutions.

Opportunities to act

Because effective climate action is more urgent than the scientific community had anticipated only a few years ago, it is imperative for society to find an effective way to move forward in an effort that will define the future of modern societies. Unfortunately, there is no 'silver bullet'; however, there are technologies currently available that could be implemented in the near future and would result in a significant reduction of greenhouse gas emissions at a relatively modest cost, namely a few percent of global GDP (Stern, 2006; Paltsev *et al.,* 2009; Stern and Garbett-Shiels, this volume). Some of these technologies involve significantly increasing the efficiency with which energy is consumed in a variety of sectors (industry, transportation, housing, etc.); some others involve the use of renewable energy sources (such as solar, wind and biomass); and yet others involve sequestering and capturing the carbon dioxide emitted in power plants consuming coal, oil or biomass.

The role of developing nations in mitigating climate change

So far, developing nations have not been the major contributors to anthropogenic global climate change, but they are bearing the brunt of its effects (see Pachauri, this volume). This has led to the common perception that developing nations are the victims of unjust and ineffective policies, and that the industrialized nations have the responsibility to solve the problem they created. Along these lines, any changes to be carried out by the developing world to address the climate change issue would have to be paid for by the industrialized countries.

At the same time – and rightly so – developing nations are striving to achieve the same standard of living as the industrialized world, implying similar levels of energy consumption. The problem is that so far their economic growth is being achieved along the same path the industrialized countries followed in the past. Industrialized nations are thus reluctant to transfer the funds requested by developing nations as they believe that these funds might not be properly employed to significantly reduce the growth of greenhouse gas emissions.

As understandable as these attitudes might be, they do not help solve the problem.

There are not enough natural resources on our planet, and the atmosphere is not large enough to absorb the unwanted by-products of human activities without consequences. Clearly, economic development cannot continue along the same path it has followed in the past, and something has to change quite drastically. Developed nations have to understand, and most of them do, that for reasons of justice they must contribute to the solution of the problem by transferring economic resources and technology to developing nations. In fact, an important precedent was set by the Montreal Protocol: the creation of the 'Multilateral Fund'. This fund was instrumental in addressing the stratospheric ozone question by providing resources to developing nations to achieve a smooth transition to a CFC-free society. At the same time, developing nations have to realize that they can and must aim for a different system, one not heavily tied to the consumption of energy and the combustion of fossil fuels. They also have to acknowledge that these changes are very significant and should not occur only to the extent implied by a transfer of funds from developed nations. The climate change problem is truly global; all nations stand to benefit from an effective international treaty, and all nations stand to lose if no agreement is reached.

An example of a developing country with a positive attitude is Mexico; this country has already made a commitment to follow a low-carbon economic growth plan and to halve its greenhouse gas emissions by the year 2050. Furthermore, Mexico is proposing the establishment of a 'Green Fund' with contributions from both developed and developing countries to facilitate the global transition to low-carbon economies. Some of the proposed changes in Mexico will merely require new government regulations – for example, those that lead to more efficient energy use – while others will require economic assistance from abroad. The point is, however, that Mexico is already embarking on this new economic growth path with the expectation that a global agreement will be reached, that this new path will improve its competitiveness in the global economy, and that it will also end up facilitating the eradication of poverty. Fortunately, it appears that other nations, such as China and India, are also developing and beginning to implement similar plans. In the end, it is this type of positive attitude that might lead to a successful global treaty. The main problems that are currently being experienced in international negotiations result from excessive demands from some industrialized countries for 'binding commitments' by all developing nations, or excessive demands by some developing nations for economic contributions as a condition for change. Here again, the Montreal Protocol stands out as an example which demonstrates that an effective international agreement can indeed be negotiated.

Air pollution and climate change

Air pollution continues to be a serious problem, particularly in many developing countries. The public health impacts of poor air quality are well documented, and thus the economic and quality-of-life benefits to society of air pollution controls provide ample justification for their implementation. Furthermore, it turns out that many of the measures required to address air pollution also provide important benefits in relation to climate change.

The most common components of air pollution include atmospheric ozone and aerosols. Although ozone is most abundant in the stratosphere, the lowest layer of the atmosphere, the troposphere, also contains ozone of natural origin. The concentration of this 'tropospheric ozone' has increased in recent years as a consequence of human activities, mainly the burning of fossil fuels and biomass. At high temperatures characteristic of a combustion process, small amounts of oxygen and nitrogen (the most abundant compounds in air) combine to form nitric oxide, which, together with carbon monoxide and unburned gaseous organic compounds, undergo a series of chemical reactions in the presence of sunlight to generate ozone. As a consequence of its detrimental health effects, ozone levels are controlled in many cities, but barely so in the background troposphere, where it acts as a powerful greenhouse gas. Thus, reducing emissions of ozone precursors (nitrogen oxides and gaseous organic compounds) leads not only to improved air quality, but also contributes to climate change mitigation.

Atmospheric aerosols are solid and/or liquid airborne particles. A large fraction of man-made aerosols come in the form of smoke from burning tropical forests, biomass, and fossil fuels. Black carbon is a component of smoke, and is generated in part by diesel engines not fitted with modern emission control devices. It turns out that black carbon emissions have not only serious public health impacts, but also contribute very significantly to climate change (Ramanathan and Carmichael, 2008). On the other hand, a major component of atmospheric aerosols of human origin comes in the form of sulphates, created by the burning of coal and oil. In contrast to black carbon, sulphate aerosols are white and reflect or scatter incoming solar radiation, and thus lead to climate cooling, compensating to some extent for the anthropogenic greenhouse effect. In fact, the true impact of greenhouse gases has been masked to some extent by this type of aerosol (Ramanathan and Feng, 2008). Nevertheless, air quality considerations alone justify the need to reduce emissions of these white aerosols, even if that means that stricter controls of greenhouse gases and black carbon will be required to properly reduce the climate change risk.

The role of ethics in mitigating climate change

Even though we are moving dangerously close to reaching tipping points with nearly irreversible consequences for the Earth's climate system (Lenton *et al.,* 2008), the world as a whole is still debating what, if any, changes are needed to address the climate change crisis. Clearly, science and knowledge alone are not enough to move people to action. In addition to scientific communication, experts need to help decision-makers in society to truly understand what climate change is all about.

Global environmental problems have been caused so far predominantly by developed countries, which are home to about one fourth of the global population. The enormous challenge now facing society is to enable the economic development of the rest of the global population, so that they too can enjoy a satisfactory standard of living, without, however, degrading the natural environment. Our generation has the responsibility to address the climate change problem in such a way as to ensure that future generations have access to environment and natural resources suitable for the continued improvement of their economic well-being. Solving the climate change and air quality dilemmas is thus not just well justified from a purely economic point of view, but ethical considerations imply that it is a truly imperative endeavour for our generation.

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