An Environmental Rationale for Retention of Endangered Chemicals

Donald J. Wuebbles and James M. Calm

Some of the chemicals being phased out to protect the stratospheric ozone layer offer offsetting benefits, such as the potential to reduce global warming. Addressing these two environmental issues separately jeopardizes desirable and, in some cases, essential options for one effect based on lesser—or even inconsequential—impacts on the other.

Most of the chemicals responsible for ozone depletion also are greenhouse gases. The perhalogenated substances, such as bromofluorocarbons (BFCs), bromochlorofluorocarbons (BCFCs), and chlorofluorocarbons (CFCs), tend to be severe offenders for both the depletion of ozone and global warming. The need for their regulation is unambiguous. Likewise, the perfluorocarbons (PFCs) have long atmospheric lifetimes, are potent greenhouse gases, and also warrant restriction.

A landmark international treaty, the Montreal Protocol (*1*), regulates the production and release of compounds containing bromine and chlorine to protect stratospheric ozone. The Framework Convention on Climate Change addresses measures to reduce future warming from release of greenhouse gases. A treaty or binding accord is under negotiation, and international adoption is expected in December 1997 in Kyoto.

There are other classes of industrially important chemicals that fall into the gray area. Some hydrochlorofluorocarbons (HCFCs)—and conceptually some hydrobromocarbons (HBCs) and halogenated chemicals containing iodine—have very short atmospheric lifetimes. They decompose almost entirely before reaching the tropopause. Most of the liberated bromine and chlorine reacts with other gases and is rained out. Nevertheless, these short-lived chemicals still are regulated as ozone depleters.

D. J. Wuebbles is director of the Environmental Council and a professor in the Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, Urbana, IL 61801–3070, USA. E-mail: wuebbles@atmos.uiuc.edu. J. M. Calm is an engineering consultant in Great Falls, VA 22066–3003, USA.

The potency to destroy stratospheric ozone is quantified as the ozone depletion potential (ODP) (*2*). The corresponding indicator for effectiveness as a greenhouse gas is the global warming potential (GWP) (*3*). Both measures depend in part on a chemical's atmospheric lifetime, but they gauge separate effects for which direct comparison of consequences is not possible.

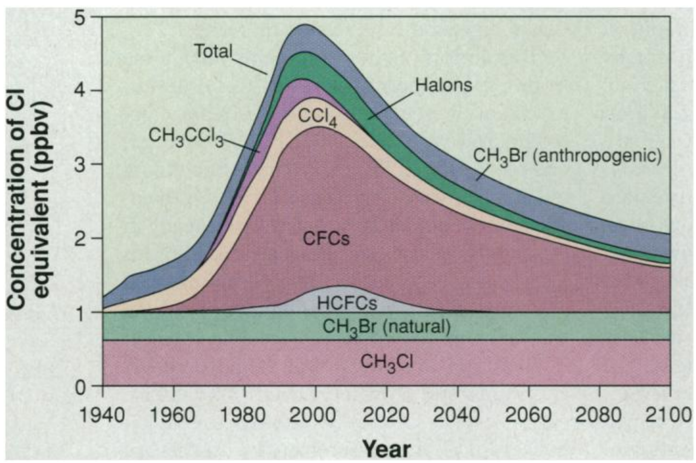

Fig. 1. Scenario 1: Ozone-depleting chemicals in the atmosphere, past and projected.

Also, neither metric considers the likelihood of emission—or, more precisely, the potential for containment—during use. Indeed, scientific assessments of impacts on stratospheric ozone and climate change generally assume that production is tantamount to emission (*4*).

Selective and controlled containment of chemicals now scheduled for phaseout because of their ODP could offer overriding environmental advantages. For example, use of HCFC-123 (2,2-dichloro-1,1,1-trifluoroethane) in closed systems would have a negligible impact on the ozone layer (*5*), but such use reduces greenhouse gas emissions significantly (*6*). HCFC-123 is used mainly as a refrigerant to replace CFC-11 (trichlorofluoromethane) in large chillers for air-conditioning and process refrigeration. Much smaller amounts are used as fire suppressants, intermediates to make other chemicals, and precision solvents. Negligible amounts—perhaps a metric ton per year worldwide—are used in refrigerant blends for special purposes in small closed systems. HCFC-123 has not replaced CFC-11 for foam-blowing and aerosol applications. For HCFC-123, the ODP is 0.014, the GWP (100-year integration) is 90, and the atmospheric lifetime is 1.4 years. These values are 97 to 99% lower—that is, more favorable—than those for CFC-11.

The key attraction of HCFC-123 as a refrigerant is its high thermodynamic efficiency. It offers a 3 to 5% advantage over alternatives in theoretical cycle limits and a 9 to 20% performance advantage for the best available chillers (*6*). High efficiency translates into reduced emissions of carbon dioxide and other greenhouse gases from associated energy use, which, in net impact, dwarf those from incidental releases of the refrigerant itself (*7*). High efficiency also reduces fuel and other resource requirements.

Not-in-kind technologies do not appear able to solve both the ozone and warming problems. Absorption refrigeration uses refrigerants and absorbents with zero ODP and negligibly low GWP, but this technology significantly increases global warming because its efficiency is lower (*7*). Other approaches and hoped-for refrigerants have not surfaced, despite enormous R&D investments. Moreover, construction growth in Asia and the Pacific Rim—locations with high cooling loads—is escalating rapidly. Hoped-for solutions will not meet required schedules, even if found.

We analyzed six scenarios to assess the chlorine and bromine loading (CBL) of HCFC-123 (*5*). CBL is a measure of the halogen content of the atmosphere and a key indicator of changes in ozone (*4*). The first scenario corresponds to the base case with data taken from the most recent international assessment (*4*) (Fig. 1). The second deletes HCFC-123 emissions from that study. Scenarios 3 through 6 sequentially add calculated HCFC-123 releases for four cases of HCFC-123 use as a refrigerant in chillers. They examine the probable and worst-case releases for the scheduled phaseout and for continued use. The analyses incorporate new, time-based projections for refrigerant emissions, from manufacturing through retirement.

HCFC-123 use produces a negligible effect on CBL and therefore on ozone (Fig. 2). The probable impact (scenario 3) is approximately 0.002% of the total (scenario 1). This minuscule level increases to less than 0.006% for a combination of sensitivity tests that far exceed plausible emissions for the worst case (scenario 4). Scenarios 5 and 6 suggest that a revision to the Montreal Protocol to allow continued use of HCFC-123 in closed refrigeration systems would have negligible effects—0.002 to 0.007%—on chlorine loading. These tiny fractions are considerably lower than the CBL variability from natural sources. Furthermore, most of the impact from HCFC-123 use will trail the peak from other compounds by more than a decade. The contribution to stratospheric chlorine from HCFC-123 emissions is almost nonexistent at the overall peak (see Fig. 1).

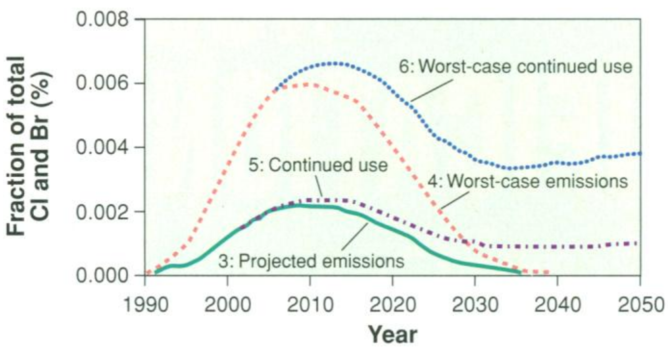

Fig. 2. Projected HCFC-123 levels in the atmosphere. Results from scenarios 3 to 6, relative to total CBL from scenario 1.

Similar conclusions are expected for HCFC-124 (2-chloro-1,1,1,2-tetrafluoroethane), used as a blend component for transition refrigerants and medical sterilant gases, but alternatives have been identified for these uses. Even compounds such as halons 1011 (bromochloromethane) and 3001 (1-bromopropane) would have inconsequential impacts on ozone, despite their bromine contents, because their atmospheric lifetimes are very short and their applications are limited. The ODPs for HCFC-124, halon 1011, and halon 3001 are 0.03, 0.12, and 0.006, and the atmospheric lifetimes are 6.1, 0.2, and 0.03 years, respectively (*4*, *8*).

The severe consequences of ozone depletion are being averted through the Montreal Protocol. The chlorine loading peak is imminent and may actually have passed, and the ozone layer then will begin to recover (*4*). The outlook for global warming and the severity of its consequences are far more threatening. Even if releases of all other greenhouse gases stopped, carbon dioxide emissions from energy use still would increase in concert with economic improvement in developing countries and with population growth. Because the net impact of carbon dioxide overshadows the combined effects of all other anthropogenic greenhouse gases, improvements in efficiency and reductions in energy demand are crucial.

It is probable that HCHC-123 and several other CFC replacements would have survived phaseout, had the global warming regulations been implemented before the ones for ozone. With keener awareness of the more limited options to reduce global warming (*6*), the framers of the Montreal Protocol might have been more cautious in rejecting chemicals with minimal impacts and offsetting benefits. Although speculative, this reasoning suggests that a more scientific approach is needed to determine environmental acceptability or restriction.

The findings concerning HCFC-123 raise four policy issues. First, use of single-measure ODP controls places excessive emphasis on the process rather than the objectives. Phaseout serves no purpose for compounds that have indiscernible impact on ozone as determined from their very low ODPs and minimal emissions. Second, the premise of the current Montreal Protocol, that production is tantamount to emission, warrants reconsideration. Beneficial chemicals with short atmospheric lifetimes are being retired although their containment and recovery, even with slight losses, would suffice. Third, phaseout of compounds based on GWPs will not resolve global warming concerns unless related emissions of greenhouse gases, from associated energy use, also are addressed. Chemicals that combine short atmospheric lifetimes with the potential for energy savings, as shown for HCFC-123, offer benefits that outweigh the consequences of very low ODP and GWP. And fourth, because new global environmental concerns may, and probably will, be identified in the future, careless elimination of options can be more harmful than beneficial.

References

1. *Montreal Protocol on Substances That Deplete the Ozone Layer* (United Nations, New York, 1987); *Handbook for the Montreal Protocol on Substances That Deplete the Ozone Layer* (United Nations Environment Programme, Nairobi, Kenya, 1996).
2. D. J. Wuebbles, *The Relative Efficiency of a Number of Halocarbons for Destroying Stratospheric Ozone, UCID-18924* (Lawrence Livermore National Laboratory, Livermore, CA, 1981); *J. Geophys. Res.* **88**, 1433 (1983).
3. *Climate Change 1995—Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge Univ. Press, Cambridge, 1996).
4. *Scientific Assessment of Ozone Depletion: 1994* (Report 37, Global Ozone Research and Monitoring Project, World Meteorological Organization, Geneva, Switzerland, 1995).
5. J. M. Calm, D. J. Wuebbles, A. Jain, in preparation.
6. J. M. Calm and D. A. Didion, in *Refrigerants for the 21st Century* (American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA, 1997), pp. 6–19.
7. J. M. Calm, *Comparative Global Warming Impacts of Electric Vapor-Compression and Direct-Fired Absorption Equipment* (Report TR-103297, Electric Power Research Institute, Palo Alto, CA, 1993).
8. D. J. Wuebbles, A. K. Jain, K. O. Patten, *Atmos. Environ.*, in press.