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Keeping Pandora's Box Shut: A Critical Assessment of the Montreal Protocol on Substances That Deplete the Ozone Layer

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KEEPING PANDORA'S BOX SHUT: A CRITICAL ASSESSMENT OF THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER

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I. INTRODUCTION

The recent entry into force of the Montreal Protocol on Substances That Deplete the Ozone Layer[1] ("Montreal Protocol" or "Protocol") marks an historic turning point in mankind's incipient efforts to protect the stratospheric ozone layer. The Protocol, which has won at least guarded praise from even its most skeptical critics,[2] calls for scheduled reductions in the use of several

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1. Montreal Protocol on Substances That Deplete the Ozone Layer, Sept. 16, 1987, 26 I.L.M. 1541.

2. *See, e.g.*, Doniger, *Politics of the Ozone Layer*, 4 ISSUES IN SCI. & TECH. 86-92 (1988) (The Montreal Protocol is "a major half-step forward toward protecting the stratospheric

chlorofluorocarbon (CFC) and bromine (halon) compounds. As one of the principal United States negotiators of the agreement observed, the Montreal Protocol represents the first time that the world community committed itself to imposing controls on an important industrial sector before actual damages to human health and ecology were registered.[3]

Almost immediately following the United States' ratification of the Protocol,[4] however, continuing scientific research into the problem of ozone depletion in various regions of the world has provided disturbing new evidence that depletion is already more advanced and threatening than had earlier been predicted.

The aim of this article is to assess the Montreal Protocol in light of evolving scientific understanding. After a brief description of the causes and effects of ozone depletion in Part Two, Part Three will summarize the major provisions of the Protocol itself. Part Four will then examine aspects of the ever-growing body of scientific studies the results of which have been reported since the Protocol was signed by twenty-four nations in September, 1987. Finally, Part Five will consider whether the emission reductions called for in the Montreal Protocol are adequate, in view of recent data, and whether these reductions are the most prudent course for the world community to follow to curb the release of ozone destroying chemicals.

II. THE CAUSES AND IMPACTS OF OZONE LAYER DEPLETION

It has now been fifteen years since two scientists, Mario J. Molina and Sherwood Rowland, first postulated that released CFCs would be harmful to the ozone layer which shields the earth's surface from damaging ultraviolet radiation.[5] Although it is

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ozone layer . . . . By conventional diplomatic standards, the Montreal accord is a significant accomplishment."); Stafford, *"Swan Song": Lawmaker Retires*, ENVTL. POL'Y ALERT, Oct. 19, 1988, at 9 (Special Report) ("The Montreal Protocol . . . is a good beginning and it is a hopeful note. But it falls short of what is needed.") (statement of Sen. Robert T. Stafford).

3. Benedick, *A Landmark Global Treaty at Montreal*, 2 TRANSBOUNDARY RESOURCES REP. 3 (1988).

4. By a vote of 83 to 0, the United States Senate voted to approve ratification of the Montreal Protocol on March 14, 1987. The United States became the second nation, after Mexico, to take this step. *See* Shabecoff, *Treaty on Ozone is Backed*, N.Y. Times, Mar. 15, 1988, at C2, col. 6; Rosewicz, *U.S. Ratifies Treaty to Curb Chemical Depleting Ozone Layer in Atmosphere*, Wall St. J., Mar. 15, 1988, at 8, col. 1.

5. *See* Molina & Rowland, *Stratospheric Sink for Chlorofluoromethanes: Chlorine*

now widely accepted that CFCs and other compounds do, in fact, deplete the ozone layer, the specific photochemical process by which this depletion occurs is still not completely understood.[6] Nevertheless, the scientific community *has* learned a great deal concerning ozone depletion in the last decade and a half.

It is now generally understood, for example, that ozone is constantly created, destroyed and recreated in the upper part of the atmosphere (*i.e.*, the stratosphere) by numerous photochemical reactions. The human release of CFCs, halons and other gases tends to alter the balance of these natural creative and destructive processes. Because CFCs are particularly stable compounds, they do not break up in the lower atmosphere (*i.e.*, the troposphere).[7] Instead, they gradually migrate to the stratosphere where, in the presence of ultraviolet radiation, they are broken down, releasing chlorine. This free-floating chlorine acts as a catalyst which destroys ozone without being consumed.[8]

This destructive process has significant implications for human health and has important impacts on plants, aquatic organisms and man-made materials. There is now evidence that the increased ultraviolet radiation which results from ozone loss,[9] actually induces certain types of skin cancer, suppresses the human immune system and causes cataracts.[10] Many varieties of terres-

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Atom-Catalyzed Destruction of Ozone, 1974 NATURE 910-12.

6. *See* NAT'L AERONAUTICS & SPACE ADMIN., ANTARCTIC OZONE: INITIAL FINDINGS FROM PUNTA ARENAS, CHILE 8-9 (1988) [hereinafter ANTARCTIC OZONE]; *see also* Browne, *New Ozone Threat, Scientists Fear Layer is Eroding at North Pole*, N.Y. Times, Oct. 11, 1988, at C1, col. 1.

7. In the view of one scientist, even if current CFC emissions were frozen at current levels, CFC concentrations in the atmosphere would continue to increase for more than a century. Hoffman, *The Importance of Knowing Sooner*, in I EFFECTS OF CHANGES IN STRATOSPHERIC OZONE AND GLOBAL CLIMATE 53 (1986) [hereinafter STRATOSPHERIC OZONE].

8. As two scientists have described the process:

> A chlorine (Cl) atom reacts with ozone (O_3) to form ClO and O_2. The ClO later reacts with another O_3, to form two molecules of O_2 which releases the chlorine atom. Thus two molecules of ozone are converted to three molecules of ordinary oxygen and the chlorine is once again free to start the process. A single chlorine atom can destroy thousands of ozone molecules. Eventually, it returns to the troposphere, where it is rained out as hydrochloric acid.

Titus & Seidel, *Overview of the Effects of Changing the Atmosphere*, in STRATOSPHERIC OZONE, *id.* at 4.

9. According to one carefully constructed journalistic account, every 1% loss of stratospheric ozone allows roughly 2% more ultraviolet light to reach the surface of the earth. *See* Glick, *Even with Action Today, Ozone Loss Will Increase*, N.Y. Times, Mar. 20, 1988, at A1, A17, col. 1.

10. *See* Emmett, *Health Effects of Ultraviolet Radiation*, in STRATOSPHERIC OZONE, *supra* note 7, at 129; Waxler, *Ozone Depletion and Ocular Risks from Ultraviolet Radia-*

trial and aquatic plants are also affected by increases in ultraviolet radiation which result from ozone depletion. These plants include such important crops as peas, beans, squash, melons and cabbage.[11] Further, many species of phytoplankton, which provide food for nearly all fish,[12] are also at risk. What is more, ultraviolet radiation reaching the earth's surface following stratospheric ozone destruction contributes, along with other forms of air pollution, to property damage such as fading paint, yellowing of window glazing and chalking of polymer automobile roofs.[13]

III. Summary of the Montreal Protocol

The Montreal Protocol was signed on September 16, 1987 by representatives of nearly every nation that produces or consumes ozone-depleting chemicals. These nations agreed that the Protocol would enter into force on January 1, 1989, provided by that date it was ratified by at least eleven signatory states "representing at least two-thirds of the 1986 estimated global consumption of the controlled substances."[14]

The Montreal Protocol consists, in the main, of three types of provisions: 1) controls on the production and consumption of ozone-depleting chemicals, 2) arrangements for the administration and enforcement of control requirements, and 3) measures to promote regular, periodic assessments of the Protocol's control provisions.

At the heart of the Montreal Protocol are its requirements re-

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tion, in Stratospheric Ozone, *supra* note 7, at 147.

11. Teramura, *Overview of Our Current State of Knowledge of UV Effects on Plants*, in Stratospheric Ozone, *supra* note 7, at 165.

12. Worrest, *The Effect of Solar UV-B Radiation on Aquatic Systems: An Overview*, in Stratospheric Ozone, *supra* note 7, at 175.

13. Titus & Seidel, *supra* note 8, at 7.

14. Montreal Protocol, *supra* note 1, art. 16, para. 1. The Montreal Protocol did, in fact, enter into force on the first day of 1989. By January 25, 1989, the Protocol had been ratified (or otherwise formally approved) by 27 states, including Mexico, United States, Norway, Sweden, Canada, New Zealand, Spain, Egypt, Uganda, Japan, Luxembourg, Portugal, Nigeria, Kenya, Union of Soviet Socialist Republics, Denmark, Federal Republic of Germany, Greece, Italy, United Kingdom, Netherlands, Finland, France, Switzerland, Malta, Belgium, Singapore, the European Economic Community and the Byelorussian and Ukrainian Soviet Socialist Republics. In addition, the treaty had been signed, but not yet ratified by 17 nations: Ghana, Panama, Senegal, Togo, Venezuela, Morocco, Israel, Australia, Chile, Argentina, Maldives, Austria, Indonesia, Burkina Faso, Congo, Thailand and the Philippines. Telephone Interview with Hanna Pavlik, Secretary, Treaty Section, U.N. (Jan. 25, 1989).

garding control of compounds which destroy the earth's ozone shield. As an interim measure, the Protocol requires a freeze, at 1986 levels, on annual consumption of five fluorocarbon compounds (CFC-11, 12, 113, 114, and 115), beginning in the seventh month after the Protocol enters into force.[15] It also calls for a similar freeze on consumption of halons-1221, 1301, and 2402, beginning three years from that date.[16] As an added measure, the treaty requires scheduled, long term reductions in the annual consumption of chlorofluorocarbons—to the extent of twenty percent by 1994 and fifty percent by 1999.[17]

In order to maintain a sufficient supply of CFC and halon-based products[18] for developing countries—and to respond to supply shortages and/or achieve economic efficiency in some of the more industrialized nations—the Protocol provides certain specific exceptions to the general limitations it imposes on CFC and halon consumption. For example, it provides that any party to the treaty that produced less than twenty-five kilotons of ozone-depleting substances in 1986 may, "for purposes of industrial rationalization," transfer to, or receive from, any other party, production of those substances in excess of the Protocol's general production levels, so long as the "total combined calculated levels of production of the parties concerned" does not exceed the production limits that would otherwise apply to those parties under the Protocol.[19] Significantly, the treaty contains a provision which would allow the Soviet Union to include in its 1986 base year level the expanded production foreseen in its five year plan.[20] The Protocol also allows the European Economic Community (EEC) to jointly fulfill its consumption requirements so long as all twelve EEC members sign and ratify the Protocol.[21]

Further, the agreement contains a number of provisions regarding the implementation of control requirements. It mandates a

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15. Montreal Protocol, *supra* note 1, art. 2, para. 1.

16. *Id.* para. 2.

17. *Id.* paras. 3-4.

18. CFCs have a wide variety of commercial uses. They are employed, among other things, as refrigerants, solvents for cleaning electronic components, and are used in the manufacture of flexible and rigid polyurethane foams. Halons are also used in fire extinguishers and other products. *See* Shabecoff, *Industry Acts to Curb Peril in Ozone Loss*, N.Y. Times, Mar. 21, 1988, at A1, col. 1.

19. Montreal Protocol, *supra* note 1, art. 2, para. 5. *See also id.* art. 5 (certain developing countries permitted to delay compliance with control requirements for 10 years).

20. *Id.* art. 2, para. 6.

21. *Id.* para. 8.

procedure for calculating "production," "consumption" and "imports and exports,"[22] prohibits the importation of ozone-depleting substances from states not parties to the treaty,[23] and bans the export of these substances to non-party states beginning on January 1, 1993.[24] The Protocol requires participating nations to "discourage" the export of technology for producing and utilizing controlled substances to non-participating states[25] and mandates that treaty participants "refrain from providing new subsidies, aid, credits, guarantees or insurance programmes" for the export of such technology to non-signatory nations.[26] Another requirement is annual reports by each party disclosing their production, imports and exports of ozone-depleting compounds,[27] as well as international cooperation in promoting research, development, and information exchanges regarding control techniques.[28]

Finally, the Montreal Protocol allows periodic reassessment of the appropriateness of its control requirements. It provides that, beginning in 1990, and at least every four years thereafter, "the parties shall assess the control measures provided for in Article 2 on the basis of available scientific, environmental, technical and economic information."[29] It also requires the parties to hold meetings at "regular intervals"[30] to review implementation of the Protocol, assess the control measures and consider and adopt any amendments which they deem appropriate.[31] The Protocol mandates that "extraordinary meetings of the parties shall be held at such times as may be deemed necessary by a meeting of the parties, or at the written request of any party, provided that, within six months of such a request being communicated to them by the secretariat, it is supported by at least one third of the parties."[32]

22. *Id.* art. 3.
23. *Id.* art. 4, para. 1.
24. *Id.* para. 2.
25. *Id.* para. 5.
26. *Id.* para. 6.
27. *Id.* art. 7, para. 2.
28. *Id.* art. 9.
29. *Id.* art. 6. In addition, the Protocol requires that, at least one year before each such assessment, the parties shall convene "appropriate panels of experts" who shall meet and report their conclusions to the parties. *Id.*
30. *Id.* art. 11, para. 1.
31. *Id.* para. 4.
32. *Id.* para. 1.

IV. Some Critical Developments Since the Signing of the Montreal Protocol

Since the Montreal Protocol was entered into, the world scientific community has conducted intensive research into the nature and effects of ozone depletion, and the likely impact of the treaty's control measures. This ongoing research[33] has yielded some significant, yet troubling conclusions.

In August and September 1987, the United States National Aeronautics and Space Administration (NASA), in cooperation with a number of other organizations and governmental agencies,[34] conducted a research campaign to study a decrease in springtime Antarctic ozone which scientists have observed since the late 1970s. This campaign, based in Puntas Arenas, Chile, conducted twenty-five aircraft flights over Antarctica at high and medium altitudes. It succeeded in finding clear evidence of a link between stratospheric ozone depletion and the presence of chlorine and bromine in the upper atmosphere. It also concluded that the Antarctic ozone hole was expanding, as compared with its size in previous years. This campaign further found that this expansion was a result of *both* chemical and meteorological mechanisms, the precise nature of which are still unknown.[35]

Not long after the Puntas Arenas study, on March 15, 1988, a group of more than one hundred of the world's most distinguished atmospheric scientists issued the *Executive Summary of the Ozone Trends Panel Report*.[36] This summary followed a comprehensive, eighteen month review of ground-based and satellite data concerning ozone layer depletion, as well as the results of the Puntas Arenas study and other scientific campaigns to the Antarctic. The report concluded that "there has been a large, sudden and unexpected decrease in the abundance of springtime

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33. In May 1988, for example, a number of scientific papers were presented at an "Ozone Trends Conference" in Snowmass, Colorado. Similarly, in October 1988, the U.N. Environment Program in the Hague, Netherlands organized a scientific conference on ozone depletion. Furthermore, in January 1989, more than 100 scientists operating from Ellsmere Island, Canada and Stavanger, Norway began to conduct a major study of the chemistry of the stratosphere above the Arctic. *See* Browne, *supra* note 6, at 19, 24.

34. Cooperating entities included the United States National Oceanic and Atmospheric Administration, the United States National Science Foundation, the United States Chemical Manufacturers Association, and the British Meteorological Organization.

35. *See* Antarctic Ozone, *supra* note 6.

36. Nat'l Aeronautics & Space Admin., Executive Summary of the Ozone Trends Panel Report (1988) [hereinafter NASA].

Antarctic ozone over the past decade"[37] and "the weight of the evidence strongly indicates that man-made chlorine species are primarily responsible for the observed decrease in ozone within the polar vortex."[38]

The Ozone Trends Panel (or "Panel") also found that "there is undisputed observational evidence that the atmospheric concentrations of a number of the gases that are important in controlling atmospheric ozone and climate are increasing at a rapid rate on a global scale because of human activities."[39] The Panel's analysis of data compiled between 1969 and 1986 by ground-based "Dobson instruments,"[40] showed that even after taking into account the effects of natural geophysical variability, "measurable decreases" occurred in the annual average of total column ozone in the Northern Hemisphere. These decreases averaged 1.7 percent to 3.0 percent per year, at latitudes between thirty degrees and sixty degrees.[41] According to the Panel, the decreases may be due "to the increased atmospheric abundance of trace gases, primarily CFCs."[42]

Another very significant post-Protocol study of ozone layer depletion was a report by two United States scientists, John S. Hoffman and Michael J. Gibbs.[43] Their work related various future levels of chlorine and bromine emissions to projected ozone losses. Using this approach, they estimated potential atmospheric changes which could occur under various scenarios, including complete implementation of the Montreal Protocol in its present form. Hoffman and Gibbs found that, based upon the reductions required in the Protocol (even assuming substantial global participation), chlorine and bromine levels will "increase substantially" from current levels.[44] In fact, by the year 2075, assuming 100 percent global participation in the Protocol, chlorine abundance is projected to grow

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37. *Id.* § 2.0, ¶ 12.

38. *Id.* ¶ 17.

39. *Id.* § 3.0. These gases include CFCs, halons, nitrous oxide, methane, carbon tetrachloride, and methyl chloroform.

40. Dobson instruments are ground-based instruments designed to measure atmospheric ozone concentrations on a uniform scale of measure.

41. NASA, *supra* note 36, § 2.0, ¶ 3. According to the Executive Summary of the Ozone Trends Panel Report, "Dobson data are not adequate to determine total column ozone changes in the tropics, sub-tropics, or the Southern Hemisphere outside Antarctica." *Id.*

42. *Id.* ¶ 4.

43. J. HOFFMAN & M. GIBBS, FUTURE CONCENTRATIONS OF STRATOSPHERIC CHLORINE AND BROMINE (U.S. Environmental Protection Agency Series No. 400/1-88/005, Aug. 1988) [hereinafter HOFFMAN & GIBBS].

44. *Id.* at 2.

by a factor of three from current levels.[45] Moreover, atmospheric bromine levels are expected to grow as well under the current Montreal Protocol, even if there is almost universal compliance with that treaty's requirements.[46]

Moreover, Hoffman and Gibbs concluded that any reductions which are made in the emission of fully-halogenated compounds, above and beyond those required by the Protocol, have the potential to "substantially" reduce future chlorine and bromine concentrations in the upper atmosphere.[47] The extent of these reductions, however, will depend upon the speed and magnitude of supplementary emission cutbacks. Stabilizing chlorine abundances at current levels would require "a 100% phase out of the fully halogenated compounds, with 100% participation globally, at least a freeze on methyl chloroform use, and substitution of partially halogenated compounds at relatively conservative rates."[48] However, time is of the essence. Hoffman and Gibbs predict that delaying a full phase out from 1998 to 2008 would increase the maximum chlorine level by approximately 0.7 ppbv and would delay a decline back to 1985 levels by about seventy years.[49]

Beyond the publication of these pathbreaking scientific studies, the period since the signing of the Montreal Protocol has witnessed a number of other significant developments in the control of ozone-depleting compounds. In response to growing concern regarding the ozone depletion problem, as well as the imminence of the Protocol's control requirements, certain key governmental and industrial institutions have begun to recognize the need for a total phase out of ozone-depleting gases. Shortly after publication of the *Executive Summary of the Ozone Trends Panel Report*, for example, E.I. DuPont de Nemours and Company, a United States corporation,

45. *Id.* at 2. In fact, even if CFC emissions were immediately and totally eliminated, stratospheric chlorine levels would continue to grow for 6 to 8 years as a result of transport delays and long atmospheric residence times.

46. *Id.* at 3.

47. *Id.*

48. *Id.* Stabilization of atmospheric bromine levels requires about a 100% phase out of Halon 1301 and a 90% to 100% phase out of Halon 1211, with 100% global participation. *Id.*

49. *Id.* at 26-27. The report also concludes that stabilizing chlorine and bromine levels in the atmosphere would not reverse past depletion. Furthermore, stabilizing chlorine at current levels would not completely prevent the occurrence of future depletion associated with continued dilution from the existing hole. Regrettably, "the global ozone layer may already be *committed* to a residual amount of depletion at current levels of chlorine and bromine which has not yet had time to occur." *Id.* at 6.

poration which accounts for approximately twenty-five percent of the world's production of CFCs, took the position that it is "reasonable" to plan for a ninety-five percent reduction in CFC output around the globe by the end of the twentieth century, a considerable modification of that firm's earlier public views.[50] A few weeks later, representatives of the food service and packaging industry announced that the industry would phase out all use of CFCs by the end of 1988, would set up a system to monitor their own compliance with that commitment and would participate in a cooperative effort to develop safe alternative products to CFC-11 and CFC-12.[51] In September 1988, Lee Thomas, then administrator of the United States Environmental Protection Agency (EPA), advocated a complete global phaseout of CFCs and a world-wide freeze in the use of methyl chloroform, another ozone-depleting compound which is not presently covered by the Montreal Protocol.[52]

On another front, considerable progress has been made by the chemical industries of several countries in developing safe substitute products for CFCs.[53] The research has progressed so well that, in September 1988, E.I. DuPont de Nemours and Company announced plans to build a full-scale commercial plant to produce a substitute product for CFC-12 which would not contain any ozone-depleting compounds.[54]

In addition, the EPA has begun to implement the Montreal Protocol within the United States by issuing several sets of final and proposed rules regarding the production of ozone depleting substances. These rulemakings have sought information regarding production, import and export of ozone destroying gases,[55] and

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50. Shabecoff, *DuPont to Halt Chemicals that Peril Ozone*, N.Y. Times, Mar. 25, 1988, at A1, col. 2; *DuPont Backs "Orderly Transition" to Total Phase Out of Halogenated CFCs*, Env't. Rep. (BNA) No. 10, at 2388-89 (Apr. 1, 1988). *See also* Steed, *Global Cooperation, Not Unilateral Action*, 5 ENVTL. F. 15 (1988). According to Steed, "DuPont is committed to an orderly transition to a total phase out by the turn of the century." *Id.* at 19.

51. *Food Packaging Industry Announces Nine-Month CFC-Phaseout*, INSIDE EPA, Apr. 15, 1988, at 13-14.

52. Shabecoff, *EPA Chief Asks Total Ban on Ozone Harming Chemicals*, N.Y. Times, Sept. 27, 1988, at A20, col. 1.

53. *DuPont Backs "Orderly Transition"*, *supra* note 50, at 2389. In addition, Allied-Signal, Inc. and Atochen, a wholly owned subsidiary of a French chemical concern, the ELF Aquitaine Group, have agreed to work together to develop non-ozone depleting substitutes for CFCs. *Id.*

54. *CFC Substitutes: DuPont Alternative to Ozone Depleting Substance*, ENVTL. POLICY ALERT, Oct. 5, 1988, at 7.

55. EPA Protection of Stratospheric Ozone, 52 Fed. Reg. 47486 (1987) (to be codified at 40 C.F.R. § 82).

have proposed a system of allocated production and consumption allowances.[56] Despite these developments, however, questions remain and changes are needed.

V. What Should Be Done? Towards a Revision of Certain Montreal Protocol Requirements

How useful is the Montreal Protocol in light of the scientific and technical developments which have taken place since its signing? How effective will the treaty be in reversing stratospheric ozone loss? What further steps, if any, can the world community take to make the Protocol succeed in achieving its stated goals?

One point which some critics of the Montreal Protocol often overlook is the treaty's significance as the first joint measure taken by the world's industrialized nations to force future action to curb ozone depletion. The Protocol provides an extremely useful framework for further steps to protect the integrity of the stratosphere. Whatever its flaws, the Protocol's built-in system for periodic reassessment of its control requirements[57] is a far-sighted contribution to the ultimate protection of our planet's ozone shield. For this reason, the Montreal Protocol represents an important international achievement in pollution control. It is a credit to the earnest and professional efforts of those who labored so diligently for its creation.[58]

At the same time, however, the recent advances by the scientific community in understanding the nature and seriousness of ozone layer depletion around the globe have pointed out the urgent

56. EPA Protection of Stratospheric Ozone, 53 Fed. Reg. 30604 (1987) (to be codified at 40 C.F.R. § 82). These EPA rulemakings have all proven highly controversial. For a description of the conflicting positions taken with respect to them by environmental organizations and chemical manufacturers, see *NRDC Charges EPA "Too Little, Too Late" on CFC Rule, Promises Court Challenge*, Inside EPA, Aug. 5, 1988, at 7-8; *EPA Rule on CFCs Not Stringent Enough to Halt, Remedy Ozone Depletion, NRDC Says*, Envt. Rep. (BNA) No. 19, Aug. 12, 1988, at 605. *See also* Steed, *supra* note 50, at 19.

57. *See supra* text accompanying notes 29-32.

58. Indeed, many people worked to make the Montreal Protocol a reality. Among United States government officials, considerable effort was expended by Lee M. Thomas, Administrator of the EPA; U.S. Ambassador Richard E. Benedick; Steven Shimberg, Counsel, U.S. Senate Comm. on Env't & Pub. Works; and former State Department official John D. Negreponte, among others. For a summary of Mr. Negreponte's important contributions to the negotiation of the Montreal Protocol, see Shabecoff, *The Environment as a Diplomatic Issue*, N.Y. Times, Dec. 25, 1987, at A24, col. 3. In acknowledging the contributions of these individuals, this author does not wish to denigrate the fine efforts of other people who worked toward the creation of other international pollution agreements.

need for revisions in some of the Protocol's requirements. In particular, the Protocol is now critically deficient because of its lax provisions regarding control of ozone-depleting compounds, its weak enforcement mechanisms, and its failure to commit adequate resources to further scientific research into the nature, causes, and effects of stratosphere ozone destruction.

As noted earlier,[59] the Montreal Protocol requires a short-term freeze on the consumption of certain halon and CFC-products to be followed by a fifty percent cutback in the use of CFC products by 1999.[60] These provisions are woefully inadequate. Since the Protocol was signed, scientists have found that stratospheric ozone loss in the populous Northern Hemisphere is far more serious than originally predicted.[61] Further, the growing "ozone hole" over Antarctica has been conclusively linked to the presence of man-made contamination.[62] In view of this, a 100 percent elimination of ozone-depleting CFCs and halons is rapidly needed. In addition, prompt steps must be taken to cut back the production and release of chemical compounds not currently regulated by the Montreal Protocol, including methyl chloroform, methane, and carbon tetrachloride.[63]

The world's nations must take a hard look at the mechanisms which the Montreal Protocol contains with respect to the enforcement of its action-forcing requirements. As noted earlier,[64] the treaty does contain prohibitions on trading ozone-depleting chemicals with states not parties to the treaty. The Protocol also has a provision intended to discourage the export to such states of the technology for producing or using such chemicals.[65] At the same time, however, the Protocol is utterly silent as to the sanctions to

59. *See supra* text accompanying notes 15-16.

60. *See supra* text accompanying notes 15-17.

61. *See supra* texts accompanying notes 41-42. While the Executive Summary of the Ozone Trends Panel Report indicates that existing data are "not adequate to determine total column ozone changes in the tropics, sub-tropics or Southern Hemisphere outside Antarctica," NASA, *supra* note 36, § 2.0, ¶ 3, there seems little reason to doubt that increased ultraviolet radiation resulting from ozone layer depletion is a *global* phenomenon.

62. *See supra* text accompanying note 35. It is notable in this regard that the ozone layer hole over the Antarctic was not factored into the negotiations which led to the Montreal Protocol. Benedick, *supra* note 3, at 3. This deficiency must be eliminated.

63. Hoffman and Gibbs have identified methyl chloroform as an "important relative contributor" to future atmospheric chlorine levels. *See* HOFFMAN & GIBBS, *supra* note 43, at 21. Carbon tetrachloride and methane were also viewed as ozone depleting substances by the Ozone Trends Panel. *See supra* note 39.

64. *See supra* text accompanying notes 18-20.

65. *See supra* text accompanying notes 21-25.

be imposed on nations which sign and ratify it, and then fail to comply with its terms. These shortcomings must be remedied. In view of the urgent and obvious need for full global compliance with more effective limitations upon production and consumption of ozone-depleting substances, the Montreal Protocol must be amended to allow for the imposition of strict trade sanctions on participating nations that fail to live up to their pollution control commitments. In addition, the Protocol's language must be changed to "prohibit," rather than merely "discourage,"[66] the export of chemical production technology to non-party states, and to strengthen the trade sanctions which will be imposed upon non-party states.

Finally, the current version of the Montreal Protocol must be altered so that it more effectively promotes further scientific research into the ozone depletion problem. This research is vitally needed. Even a casual review of the recent literature reveals many unanswered questions on ozone depletion and the photochemical mechanisms which cause it.[67] These questions merit careful study. Without a firm and generous commitment by the world community of the monetary resources needed for expanded scientific investigation, the answers may be forever unknown.[68]

In sum, the Montreal Protocol is a progressive document which creates a workable framework for addressing the global problem of stratospheric ozone depletion. Since its signing, how-

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66. Montreal Protocol, *supra* note 1, art. 4, para. 5.

67. For example, it is still unclear precisely what role meteorological conditions play in the depletion of stratospheric ozone. Similarly, it is not known whether our present catalogue of ozone-depleting substances should be expanded to include nitrogen oxide emissions from aircraft, along with other gases, and whether ozone depleting compounds interact in the atmosphere in a harmful way. Furthermore, no systematic exploration has been made to determine whether any relationship exists between stratospheric ozone depletion and the tropospheric ozone pollution. Such an exploration becomes increasingly vital because of the prevalence of tropospheric ozone pollution which is relatively common in populated urban areas.

68. In this regard, it is encouraging that the EPA has been developing plans for a 5 year research strategy regarding stratospheric ozone and global warning issues. *Global Warming, EPA Maps R & D Plan, Underscoring Program Urgency*, ENVTL. POL'Y ALERT, Oct. 19, 1988, at 3. This approach is consistent with the recommendations contained in a far-sighted report of the EPA's Science Advisory Board which advocates a systematic expansion of the EPA's research efforts. *See* ENVTL. PROTECTION AGENCY SCIENCE ADVISORY BOARD, SERIES No. SAB-EC-88-040, FUTURE RISK: RESEARCH STRATEGIES FOR THE 1990S, (Sept. 1988). At the time of this writing, however, it is unclear whether the EPA will appropriate the resources to increase its current research in this area. In any event, a unilateral research campaign by one nation can hardly substitute for a broad-based international effort, subsidized by all nations that produce or consume substances that harm the stratosphere.

ever, significant new scientific findings have called into question the effectiveness of the Protocol's control measures and its enforcement and research provisions. Unfortunately, regardless of the Montreal Protocol, the earth's ozone shield is being consumed at an alarming rate by man-made chemicals—a phenomenon which threatens to open a Pandora's box of disease, crop failure, and ecological damage in an increasingly crowded world. It is the responsibility of the world's nations to strengthen the Protocol in a forthright and expeditious manner and to renew the commitment that the Protocol represents to the integrity and health of our skies.