Volume 12 | Issue 2 Article 4

1989

Ozone Depletion: International Protective Strategies and Implications

C. Patrick Turley

OZONE DEPLETION: INTERNATIONAL PROTECTIVE STRATEGIES AND IMPLICATIONS

I. Introduction

Mankind may look back on the past century as one of immense technological advancement. But advancement exacts a stiff toll on the Earth's resources. As technology grows and population expands, the environmental reality requires exercising controlled stewardship over those resources. While some environmental issues are best addressed at the local or regional level, an awareness of our "global commons" is fast taking shape as the world community confronts issues such as acid rain, international hazardous waste transport, global warming, and ozone depletion, all of which can be addressed at the international level as well. In the twenty-first century and beyond, humankind must pay homage to this international environmental reality.

The intense heat and drought of the summer of 1988 acted like a catalyst, igniting global interest in the Earth's health and welfare and prompting predictions that the long-anticipated global warming and ozone depletion had finally arrived. As if to emphasize the critical nature of global environmental concerns, the "Endangered Earth" took "Planet of the Year" honors from *Time* magazine.[1]

Although uncertainties remain, the scientific evidence linking ozone depletion to human activities is strengthening. Rather than waiting for all the uncertainties to be disproved, industry, governments, and non-governmental organizations have acted on the carefully marshalled scientific evidence to develop three key documents addressing ozone depletion. These are the Vienna Convention for the Protection of the Ozone Layer,[2] the Montreal Protocol on Substances that Deplete the Ozone Layer,[3] and the Nitrogen Oxides Protocol,[4] all of which will be discussed in this Comment.

To appreciate the complex nature of the issues presented by ozone depletion, it is necessary to understand the atmospheric processes involved in ozone formation and destruction. Part II of this Comment reviews those processes, discusses the substances that deplete the ozone layer, and examines the effects of ozone depletion and

1. TIME, Jan. 2, 1989.
2. *See infra* notes 181-96 and accompanying text.
3. *See infra* notes 198-274 and accompanying text.
4. *See infra* notes 276-82 and accompanying text.

its implications for global warming. Part III briefly summarizes international environmental law and then examines the major international strategies for addressing ozone depletion. The Comment concludes by discussing how ozone remedies can be used as a model for addressing other global environmental problems.

II. THE SCIENTIFIC BACKGROUND

A. Atmospheric Ozone

Ozone is found in the atmosphere from the terrestrial surface to an altitude of at least 100 kilometers.[5] The concentration of ozone in the atmosphere is small, only a few parts per million by volume.[6] Approximately ninety percent of ozone is found in the stratosphere,[7] an area of the atmosphere ten to sixty kilometers above the surface of the earth.[8] In the stratosphere, where atmospheric pressure is small, the ozone layer is spread over an area about 10 kilometers thick.[9] Under pressure and temperature conditions present at the terrestrial surface, the ozone layer would compress to a mere 0.3 centimeters in thickness.[10] The troposphere, which extends from the terrestrial surface to the stratosphere,[11] contains less ozone per volume than the stratosphere. But interactions between ozone and other tropospheric gases play an important role in stratospheric ozone dynamics, the consequence of which is that processes occurring in one atmospheric region have a direct influence on the other.[12]

Ozone, denoted chemically as O_3, is formed by the combination of atomic (O_2) and molecular (O_2) oxygen.[13] A balance of processes

5. WORLD METEOROLOGICAL ORGANIZATION, 1 ATMOSPHERIC OZONE 1985: ASSESSMENT OF OUR UNDERSTANDING OF THE PROCESS CONTROLLING ITS PRESENT DISTRIBUTION AND CHANGE 27 (1985) [hereinafter ATMOSPHERIC OZONE].

6. *Id.*

7. *Id.* at 1.

8. Watson, *Atmospheric Ozone*, in 1 UNITED NATIONS ENVIRONMENT PROGRAMME/ U.S. ENVIRONMENTAL PROTECTION AGENCY, *Effects of Changes in Stratospheric Ozone and Global Climate* 69, 70 (1986) [hereinafter UNEP/EPA]. The atmosphere is commonly divided into different regions according to temperature and distance above the terrestrial surface. In ascending order the divisions are the troposphere, stratosphere, mesosphere, and thermosphere.

9. Farman, *What Hope for the Ozone Layer Now*, NEW SCIENTIST, Nov. 12, 1987, at 50-51.

10. *Id.*

11. The troposphere and stratosphere are actually separated by a region called the tropopause, an area where the temperature gradient between the troposphere and stratosphere changes. Farman, *supra* note 9 at 53.

12. ATMOSPHERIC OZONE, *supra* note 5, at 27.

13. *Id.* For those chemically inclined:

leading to ozone formation and destruction accounts for the amount of ozone in the stratosphere.[14] Solar radiation plays a key role in maintaining this balance by producing the atomic oxygen (O) needed to make ozone[15] and by assisting in ozone destruction through a process called photodissociation.[16]

While the radiative processes maintain the delicate balance of ozone formation and destruction, stratospheric ozone is removed by several catalytic chemical reactions involving hydrogen, nitrogen, chlorine, and bromine radicals.[17] Roughly seventy percent of ozone destruction is attributable to natural processes, primarily those involving nitrogen oxides, which are released by soil bacteria.[18] Human activities account for thirty percent of ozone destruction.[19]

$$O + O_2 + M \rightarrow O_3 + M$$

where M represents a third species needed to carry away energy produced in the reaction. O_2 and O_3 are allotropic forms of atomic oxygen. O_2 is the more stable form, and serves as the vehicle for respiration. O_3 is a more powerful oxidant than O_2, and causes diminished pulmonary function when inspired. Kulle, Sauder, Hebel, & Chatham, *Ozone Response Relationships in Healthy Nonsmokers*, 132 AM. REV. RESPIR. DIS. 36 (1985).

14. *See infra* notes 15-19 and accompanying text.

15. Molecular oxygen undergoes photodissociation in the stratosphere by short wavelength ultraviolet radiation (wavelength less than 243 nanometers, denoted by *hv*) to produce atomic oxygen:

$$O_2 + hv \rightarrow O + O$$

Radiation in this wavelength range contains enough energy to dissociate molecular oxygen, which is relatively strongly bound. ATMOSPHERIC OZONE, *supra* note 5, at 27.

16. Ozone can be dissociated by both ultraviolet and visible radiation to form molecular and atomic oxygen:

$$O_3 + hv \rightarrow O_2 + O$$

where *hv* denotes weak radiation comprised of wavelengths greater than 243 nanometers. Since ozone is comprised of 3 oxygen atoms, it manifests a weaker binding than does molecular oxygen (O_2), and can be dissociated with radiation containing less energy than that needed to dissociate O_2. *Id.*

17. At temperate latitudes, free radicals in the HO_x, NO_x, ClO_x, and Br_x families participate in the reaction forming two molecules of molecular oxygen from atomic oxygen and ozone:

$$\begin{array}{rl} & X + O_3 \rightarrow XO + O_2 \\ & \underline{XO + O \rightarrow X + O_2} \\ \text{net:} & O + O_3 \rightarrow 2O_2 \end{array}$$

where X = H, OH, NO, Cl and Br radicals. As a true catalytic sequence, X produced in the second reaction can be used again in the first reaction, causing the loss of yet another O_3 molecule. Radicals are atoms or molecules possessing an odd (unpaired) electron. *Id.* Minor reactions involving over 50 different chemical species also participate in ozone loss. *Id.* at 28. Ozone depleting reactions at polar latitudes differ from the general scheme outlined above. *See infra* note 98.

18. Johnston, *Systemic Environmental Damage: The Challenge to International Law and Organization*, 12 SYR. J. INT'L L. & COM. 255, 263 (1985).

19. *Id.*

B. Ozone-Depleting Substances

Many substances are involved in the catalytic cycles which deplete stratospheric ozone.[20] Chief among these is chorine.[21] Chorine-containing compounds are so efficient in the catalytic destruction of ozone[22] that a single chorine radical can destroy 100,000 ozone molecules.[23]

Chlorofluorocarbons (CFCs) are a group of chorine-containing substances used primarily as aerosol propellants, refrigerants, electrical cleaners, and blowing agents for making foam.[24] In many ways the CFCs are ideal compounds, being easy to produce as well as having non-toxic and non-flammable properties.[25] They are also extremely stable and can be used for decades as refrigerants or repeatedly as cleaning agents.[26] The CFC market is substantial, now at $600 million in annual domestic sales and $2 billion worldwide, reflecting the pervasiveness of these agents in consumer-based societies.[27]

CFCs were first invented in the 1930s as a replacement for ammonia and ice blocks in refrigeration systems.[28] CFC-12[29] and CFC-11[30] account for the bulk of the CFC market.[31] CFC-114[32] and CFC-

20. *See supra* note 17.

21. *See generally* ATMOSPHERIC OZONE, *supra* note 5.

22. The catalytic cycle is:

$$\begin{array}{rl} & Cl + O_3 \rightarrow ClO + O_2 \\ & \underline{ClO + O \rightarrow Cl + O_2} \\ \text{net:} & O + O_3 \rightarrow 2O_2 \end{array}$$

See supra note 17.

23. D. COGAN, STONES IN A GLASS HOUSE: CFCS AND OZONE DEPLETION 25 (1988).

24. *See infra* notes 29-35 and accompanying text.

25. The inventor of the first CFC is said to have demonstrated these properties to the participants at a scientific meeting by inhaling CFC vapors and blowing out the flame of a candle. D. COGAN, *supra* note 23, at 12. While CFCs are considered non-toxic, consumption of large amounts in an effort to attain a "high" is linked to the development of fatal cardiac arrhythmias. Kaa, *Letal fluorkarbon-sniffing*, 148 UGESKR. LAEGER 3456 (1986) [English abstract].

26. Pool, *The Elusive Replacements for CFCs*, 242 SCIENCE 666 (1988).

27. *Id.*

28. D. COGAN, *supra* note 23, at 12.

29. CFC-12, denoted chemically as CCl_2F_2, is used primarily as a refrigerant, with 68.5 million pounds used in stationary air conditioners and refrigerators, 120.0 million pounds used in auto air conditioners, 48.2 million pounds used in plastic foams, 26.4 million pounds used in medical sterilants, and 15.6 million pounds used in aerosols (domestic U.S. 1985 data). *Id.* at 15.

30. CFC-11, denoted chemically as CCl_3F, is used primarily as a rigid insulation for homes, buildings and refrigerators (150.7 million pounds used domestically in 1985). CFC-11 has minor uses as a refrigerant (14.5 million pounds) and as an aerosol (9.9 million pounds). *Id.*

115[33] are also used primarily as refrigerants, although CFC-114 has some applications in plastic foams.[34] CFC-113[35] is used primarily as a cleansing agent, finding wide use in cleaning microelectronic circuits and artificial hip joints.[36]

While the stability of the CFCs accounts in large part for their effectiveness, the ability of these agents to withstand atmospheric degradation renders them potent ozone depleting agents.[37] Rather than degrading in the troposphere, as do many chemicals, CFCs persist for decades, or even centuries.[38] The past decade has witnessed a steady increase in the amount of atmospheric CFC-11 and CFC-12, with growth rates of about five percent per year.[39] In 1974 Molina and Rowland suggested that ozone-depleting chlorine radicals could be formed from CFC decomposition in the stratosphere.[40] Since that time several studies have linked CFCs to global ozone depletion.[41]

While less damaging substitutes for CFCs have been known for some time, they are difficult to produce.[42] These substitutes modify the chemical structure of CFCs to enhance the ability of these compounds to decompose in the troposphere and to diminish their trans-

---

31. *Id.*

32. CFC-114 has the chemical formula $C_2F_4Cl_2$. *Id.*

33. CFC-115 has the chemical formula C_2F_5Cl. *Id.*

34. *Id.*

35. CFC-113 has the chemical formula $C_2F_3Cl_3$. *Id.*

36. 150.7 million pounds of CFC-113 was used in the United States in 1985. *Id.* As a leading manufacturer of semiconductors, Japan produces half of the world's CFC-113, most of which it uses domestically. Asahi News Service, Jan. 26, 1989.

37. The ozone depleting potential or factor is a numerical value based on that substance's atmospheric lifetime, molecular weight, and ability to undergo photolytic dissociation. For a partial list of ozone depletion potentials, see *infra* note 206.

38. The atmospheric lifetime for CFC-11 is 75 $+32/-17$ years. CFC-12 has an atmospheric lifetime of 111 $+289/-17$ years. 1 ATMOSPHERIC OZONE, *supra* note 5, at 58.

39. *Id.* Measurement of trace gases in air bubbles trapped in polar ice provides an indication of atmospheric chemistry dating back hundreds of thousands of years. The concentrations of CFC-11 and CFC-12 in air bubbles trapped in polar ice are below the detection limits of 10 parts per trillion by volume, suggesting that present atmospheric levels are due entirely to recent emissions. *Id.* at 115.

40. Rowland & Molina, *Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom-catalyzed Destruction of Ozone*, 249 NATURE 810 (1974). CFCs are transported from the troposphere to the upper stratospheric zone where stellar radiation "cleaves" a chlorine radical from the CFC. For example, CFC-11 undergoes the reaction: $CFCl_3 + h\nu \rightarrow CFCl_2 + Cl$. The chlorine radical released participates in the catalytic destruction of ozone as described *supra* note 22. *Id.*

41. In 1988 the Ozone Trends Panel released its Executive Summary describing the evidence linking ozone depletion to CFCs. OZONE TRENDS PANEL, EXECUTIVE SUMMARY OF THE OZONE TRENDS PANEL, National Aeronautics and Space Administration (1988) [hereinafter EXECUTIVE SUMMARY].

42. *See* Pool, *supra* note 26.

port into the stratosphere, thereby reducing chlorine radical formation.[43] In one modification, addition of hydrogen atoms leads to a class of compounds called hydrochlorofluorocarbons (HCFCs).[44] Since the HCFCs contain chlorine they have a small, but noticeable ozone depleting potential.[45] Fluorocarbon compounds lacking chlorine and having negligible ozone depleting effect are called hydrofluorocarbons (HFCs).[46]

CFC producers are working with both HFCs and HCFCs to assess toxicity and utility. HFC-134a[47] appears promising as an alternative refrigerant for replacing CFC-12.[48] Unfortunately, HFC-134a requires more operational pressure to attain the same extent of cooling achieved by CFC-12, so air conditioners and refrigerators will have to be modified to accept the replacement.[49] Alternatively, DuPont has developed a mixture of HCFCs and HFCs which provides the energy efficiency and cooling capacity of CFC-12, while having minimal ozone depleting potential.[50] The total worldwide cost of replacing CFCs with the substitutes is estimated at $27 billion.[51] Two of the world's largest CFC manufacturers plan to produce HFC-134a soon.[52]

Other non-CFC chlorine-containing compounds also may cause ozone depletion. Methyl chloride is the major naturally-occurring source of atmospheric chlorine.[53] Hydrochloric acid released from volcanoes also contributes to the atmospheric chlorine content.[54] However, these natural sources account for less than thirty percent of

---

43. *See supra* note 40.

44. Addition of hydrogen atoms to CFCs promotes their destruction in the troposphere, decreasing stratospheric accumulation. However, since HCFC compounds still contain chlorine, their use as substitutes for CFC-11 and CFC-12 could still lead to an increase in atmospheric chlorine by one part per billion by volume by the year 2100. MacKerron, *EPA Calls for a Ban on CFC Use*, CHEMICAL WEEK Oct. 5, 1988, at 44.

45. Pool, *supra* note 26.

46. *Id.*

47. HFC-134a has the chemical structure CF_3CFH_2.

48. *Id.*

49. *Id.*

50. 12 Int'l Env't Rep. (BNA) 54 (Feb. 1989).

51. D. COGAN, *supra* note 23, at 88.

52. DuPont, the world's largest CFC producer, will begin production in late 1990. Reuter Business Report, Sept. 29, 1988. Imperial Chemical Industries (ICI) of Great Britain, the second largest CFC producer, plans to have a production plant built by late 1991. Xinhua General Overseas News Service, Nov. 24, 1988.

53. ATMOSPHERIC OZONE, *supra* note 5, at 73. Methyl chloride is released from the ocean and from burning vegetation. *Id.*

54. *Id.* at 114.

current levels of atmospheric chlorine.[55]

Carbon tetrachloride[56] and methyl chloroform[57] are important anthropogenic (man-made), non-CFC atmospheric chlorine sources.[58] Because they have ozone-depleting potentials similar to the CFC compounds,[59] some have advocated that they be regulated as well.[60]

Bromine-containing compounds called halons[61] have a higher ozone depleting potential than CFCs.[62] The halons are used primarily as fire extinguishing agents.[63] Unlike CFCs, there are no substitutes for halon compounds in development.[64] Methyl bromide and bromoform are additional non-halon bromine-containing compounds implicated in ozone loss.[65]

Nitrogen compounds also participate in ozone depletion.[66] Nitrous oxide (N_2O) is formed by microbial denitrification[67] and aerobic

---

55. A. MAKHIJANI, A. MAKHIJANI & A. BICKEL, SAVING OUR SKINS 39 (1988) [hereinafter MAKHIJANI].

56. Carbon tetrachloride, which has the chemical formula CCl_4, is a building block in the production of CFC-11 and CFC-12. Small amounts are also used in chemical and pharmaceutical production. Release of CCl_4 into the environment may be substantial in Eastern Europe, U.S.S.R., and China. ATMOSPHERIC OZONE, *supra* note 5, at 72-73.

57. Methyl chloroform, which has the chemical formula CH_3Cl_3, is used in industrial degreasing of metallic or metalloplastic items. *Id.* at 72.

58. *Id.* at 72-73.

59. The ozone depleting factors for carbon tetrachloride and methyl chloroform are 1.06 and 0.10, respectively. D. COGAN, *supra* note 23, at 37. *Cf.* Protocol Annex, *infra* note 206.

60. *See* MAKHIJANI, *supra* note 55, at 41.

61. Halons are bromine-containing compounds which participate in ozone-depleting reactions:

$$\begin{array}{rl} & Br + O_3 \rightarrow BrO + O_2 \\ & \underline{BrO + O \rightarrow Br + O_2} \\ \text{net:} & O + O_3 \rightarrow 2O_2 \end{array}$$

See supra note 17.

62. *See infra* note 206. Bromine monoxide (BrO) and chlorine monoxide (ClO) can react to produce chlorine dioxide (OClO), a powerful ozone-depleting compound thought to be a major contributor to Antarctic ozone loss. Dagani, *Rising Bromine Levels Threaten Ozone Layer*, CHEM. ENG. NEWS, Aug. 22, 1988, at 6.

63. Halon-1211 (CF_2BrCl) is used predominately in portable fire extinguishers. Halon-1301 (CF_3Br) is found in total flooding fire extinguishing systems, and Halon-2402 ($C_2F_4Br_2$) is a general fire extinguishing agent. *See* Zurer, *Search Intensifies for Alternatives to Ozone-Depleting Halocarbons*, CHEM. ENG. NEWS, Feb. 8, 1988, at 18-20.

64. *Id.* A large amount of halon emissions is due to discharge testing of fire extinguishing equipment. While insurance companies and fire departments often require discharge testing, the National Fire Protection Association has backed away from a standard requiring such testing. *Id.*

65. Dagani, *supra* note 62.

66. *See supra* note 17.

67. ATMOSPHERIC OZONE, *supra* note 5, at 78. Under anaerobic (oxygen-depleted) conditions, some bacteria utilize nitrogen compounds in respiration, forming nitrous oxide in the process. *Id.*

degradation of organic detritus.[68] Anthropogenic sources of atmospheric nitrogen include the addition of nitrogenous fertilizers to soils[69] and the combustion of fossil fuels.[70] These human activities account for about thirty percent of total atmospheric emissions of N_2O.[71] Preindustrial atmospheric nitrogen concentrations were approximately twenty percent lower than today.[72] Since nitrous oxide has an atmospheric lifetime of about 150 years,[73] current emissions are expected to have an effect on atmospheric chemistry for a long time to come.

Oxides of nitrogen (NO_X) play an important role in atmospheric chemistry, and it is mainly through nitric oxide (NO) that the ozone depletion process occurs.[74] Sources of NO_X include soil microbial activity, lightning and oxidation of stratospheric N_2O.[75]

C. Radiative Effects

While the balance of ozone formation and destruction is controlled in large part by reactions of oxygen species with solar radiation, these reactions also serve to limit the amount of radiation reaching the terrestrial surface.[76] The sun emits radiation over a wide range of wavelengths.[77] Visible radiation, to which the human eye responds, is in the wavelength range of 400 to 700 nanometers (nm). Ultraviolet (UV) radiation, which the human eye cannot perceive without the assistance of specialized instruments, spans the wavelength range lower than the range for visible radiation. UV radiation is classified in three groups: UV-A (320 to 400 nm), UV-B (280 to 320 nm) and UV-C (0 to 280 nm).[78]

---

68. *Id.* at 80. In aerobic (oxygen-rich) environments, microorganisms convert ammonia derived from organic matter into nitrous oxide. *Id.*

69. *Id.* at 82. Fertilizers contribute only minor (0.5%) amounts of nitrous oxide to the atmosphere. *Id.*

70. *Id.* at 84. Fossil fuel combustion is the major source of atmospheric nitrous oxide. *Id.*

71. *Id.*

72. *Id.*

73. *Id.* at 77.

74. The ozone depleting reaction is:

$$\begin{array}{ll} & NO + O_3 \rightarrow NO_2 + O_2 \\ & \underline{NO_2 + O \rightarrow NO + O_2} \\ \text{net:} & O_3 + O \rightarrow 2\ O_2 \end{array}$$

See supra note 17.

75. ATMOSPHERIC OZONE, *supra* note 5, at 86.

76. *See supra* notes 13-16 and accompanying text.

77. Frederick, *The Ultraviolet Radiation Environment of the Biosphere*, in 1 UNEP/EPA, *supra* note 8, at 121.

78. Scotto, *Nonmelanoma Skin Cancer—UV-B Effects*, in 2 UNEP/EPA, *supra* note 8, at

Virtually all of the stellar radiation in the UV-C range is absorbed by molecular oxygen and ozone and fails to reach the terrestrial surface.[79] As the solar radiation increases in wavelength, it becomes progressively weaker in energy and less efficient in photodissociating ozone. Hence UV-B radiation is more efficient than UV-C in reaching the surface of the Earth, and the amount reaching the surface is inversely proportional to the concentration of atmospheric ozone.[80] The atmosphere actually transmits UV-A radiation, so the amount reaching the surface is large,[81] but the weak energy associated with radiation in this region of the spectrum is not generally harmful.[82]

The concentration of ozone in the atmosphere is affected by at least three natural cyclic phenomena, comprised of the quasi-biennial oscillation (QBO) of stratospheric winds (having a periodic cycle of 26 months), the solar sunspot cycle (having a periodic cycle of 11 years), and seasonal variations.[83] Total atmospheric ozone concentrations in the Northern Hemisphere are greatest in the spring and least in the fall.[84] The converse is observed in the Southern Hemisphere.[85] While the ozone concentration is not as large over the lower, tropical latitudes as it is over the higher, polar latitudes, the seasonal variation in the lower latitudes is much smaller.[86] Non-cyclic events such as the El Nino Southern Oscillation (ENSO) and volcanic eruptions also influence ozone dynamics.[87] These natural variations make it difficult for atmospheric scientists to point to human activities as the real cause of ozone depletion.[88]

33-34. X-rays and gamma radiation comprise the electromagnetic spectrum region from 0 to 20 nm. *Id.*

79. Frederick, *The Ultraviolet Radiation Environment of the Biosphere*, in 1 UNEP/EPA, *supra* note 8, at 122.

80. The fact that UV-B reaches the Earth's surface accounts for its adverse health effects. UV-C radiation, which contains more energy than UV-B radiation, and is potentially more harmful than UV-B radiation, is not as harmful to terrestrial life because of the more efficient atmospheric processes which prevent UV-C radiation from reaching the surface. *Id.*

81. Molecular oxygen (O_2) and molecular nitrogen (N_2) also reflect some UV-A radiation back into space. Titus & Seidel, *Overview of the Effects of Changing the Atmosphere*, in 1 UNEP/EPA, *supra* note 8, at 5.

82. Frederick, *The Ultraviolet Radiation Environment of the Biosphere*, in 1 UNEP/EPA, *supra* note 8, at 121.

83. EXECUTIVE SUMMARY, *supra* note 41, at 8.

84. *Id.*

85. *Id.*

86. Ilyas, *Ozone Modification: Importance for Developing Countries*, in 1 UNEP/EPA, *supra* note 8, at 185.

87. EXECUTIVE SUMMARY, *supra* note 41, at 8.

88. Farman, *supra* note 9, at 53-54.

D. Ozone Depletion

Until recently, the link between reactive substances thought to cause ozone destruction and actual ozone depletion was largely theoretical.[89] In 1982 a British survey team discovered an extensive depletion of the ozone layer in the atmosphere above Antarctica.[90] Concerned about deterioration in their ground-based instruments which recorded this phenomenon, they did not report their findings until 1985, after verifying them with newer instruments.[91] Using Nimbus 7 satellite data,[92] National Aeronautics and Space Administration (NASA) scientists confirmed the existence of the Antarctic ozone hole.[93] By 1985 the hole had spread over a large area, equivalent to the size of the continental United States.[94]

In 1986 NASA, along with the National Oceanic and Atmospheric Administration, the Federal Aviation Administration, the World Meterological Organization, and the United Nations Environment Program, formed the Ozone Trends Panel to investigate evidence of global ozone depletion.[95] The Panel reevaluated both ground-based and satellite data to assess the degree of depletion. The Panel found a substantial amount of Antarctic ozone depletion, with the largest hole (and the most persistent) seen in 1987.[96] The extreme depletion observed over Antarctica is due to unusual atmospheric conditions which occur over the polar terrain. Even though the air is very dry, unique types of clouds called polar stratospheric clouds (PSCs) form over the poles in the early spring.[97] Ice particles in the

89. *Id.*

90. *Id.*

91. Farman, Gardiner & Shanklin, *Large Losses of Total Ozone in Antarctica Reveal Seasonal ClO_x/NO_x Interaction*, 315 NATURE 207 (1985).

92. Two instruments on the Nimbus 7 satellite provide ozone data: the total ozone mapping spectrometer (TOMS), which provides maps of total global ozone, and the solar backscatter ultraviolet recorder (SBUV). *See* Farman, *supra* note 9, at 50.

93. Technically, the area of ozone depletion is not a "hole," but is instead an area of the lower stratosphere having a significantly reduced ozone concentration. *Id.*

94. NASA scientists were in the process of analyzing the Nimbus 7 data when the Farman paper appeared in *Nature. See* Farman, *supra* note 91. Not only was NASA able to confirm the British findings, but it was able to ascertain the extent of depletion through computerized images of the satellite data. D. COGAN, *supra* note 23, at 43.

95. *See* EXECUTIVE SUMMARY, *supra* note 41.

96. The zonal mean amount of ozone at 80 degrees south latitude in October of 1987 was 50% lower than in 1979. The hole lingered until early December, the latest ever recorded. EXECUTIVE SUMMARY, *supra* note 41, at 18. The 1988 hole was not as large as the one observed in 1987. Nimbus 7 satellite data recorded a decrease in ozone concentrations of only 15% in 1988, consistent with the quasi-biennial oscillation (QBO). Lindley, *Surprising New Ozone Data from NASA Satellite*, 335 NATURE 657 (1988).

97. Monastersky, *Clouds Without a Silver Lining*, 134 SCI. NEWS 249 (1988).

PSCs provide a surface for initiating reactions leading to the active forms of chlorine[98] involved in ozone loss in the polar atmosphere.[99]

While the Antarctic loss is substantial, the problem is not limited to the Southern Hemisphere. Ozone losses of between 1.7 and 3.0 percent were observed at Northern Hemisphere latitudes of thirty to sixty-four degrees.[100] A recent investigation of Arctic ozone loss revealed levels of chlorine monoxide similar to those seen over the Antarctic, leading some to believe that Arctic PSCs contribute to ozone depletion at the Northern pole as well.[101]

Although generally accepted as valid, the Panel's report did not escape criticism.[102] Instruments aboard the satellites had deteriorated since they were placed in orbit in the late 1970s.[103] The Panel "corrected" the drift in the satellite instruments by normalizing the readings with data generated by ground-based instruments, a technique criticized by some as "fudging."[104]

For the next few years, an increase in solar sunspot activity could mask further ozone depletion.[105] The low atmospheric concentrations of ozone observed between the years 1979 and 1986 were due in part to diminished sunspot activity.[106] After 1991, when sunspot activity once again subsides, atmospheric ozone concentrations are expected

98. The reactions leading to ozone depletion in PSCs differs from the general reactions involving CFC degradation and chlorine radical formation observed in temperate latitudes, described *supra* in note 17. In polar regions, two molecules of chlorine monoxide (ClO) are linked to form the dimer Cl_2O_2, which undergoes photolysis to form two chlorine atoms and molecular oxygen (O_2). Raloff, *Chemistry Ties CFCs Firmly to Ozone Hole*, 134 SCI. NEWS 373 (1988).

99. Zurer, *Studies on Ozone Depletion Expand Beyond Antarctic*, CHEM. ENG. NEWS, May 30, 1988, at 16.

100. This area covers most of the continental U.S. and Alaska. The decrease is most pronounced in December through March, ranging from 2.3 to 6.2%. EXECUTIVE SUMMARY, *supra* note 41, at 2.

101. Montastersky, *Arctic Air Primed to Destroy Ozone*, 135 SCI. NEWS 116 (1989).

102. Zurer, *supra* note 99, at 24.

103. Data generated by TOMS and SBUV (*see supra* note 92) showed a 3.5 +/− 0.5% decrease in ozone compared to ground-based data generated over the same nine year time frame. EXECUTIVE SUMMARY, *supra* note 41, at 7.

104. One atmospheric scientist pointed out that the Panel ignored some ground-based data that appeared unreliable, and stated that this could be considered "fudging." Zurer, *supra* note 99, at 25. Chlorofluorocarbon producers have obtained the raw data that went into preparing the Panel's report and plan to conduct an independent evaluation. *Id.*

105. The 1988 Antarctic hole was not as severe as in 1987. *See supra* note 96. Ozone losses in the Northern Hemisphere in 1987 were not as large as seen in previous years. *Id.*

106. Sunspot activity participates in ozone formation by increasing the amount of radiation reaching the Earth, causing more extensive photodissociation of molecular oxygen (O_2). *See supra* note 14.

to decrease. These and other natural events[107] will play a major role in interpreting the effectiveness of control measures such as the Montreal Protocol.[108]

E. Effects of Ozone Depletion

Since ozone acts as a shield limiting the amount of solar UV radiation reaching the Earth, a depletion of ozone reduces the effectiveness of the shield, allowing more radiation to reach the terrestrial surface.[109] UV-B radiation poses the most significant hazard.[110] For every one percent decrease in ozone, there is a two percent increase in the amount of UV-B radiation reaching the Earth's surface.[111] Ozone depletion poses a substantial threat to human health, plant life, aquatic ecosystems and man-made materials.[112]

Adverse human health effects associated with increased exposure to UV-B radiation include increased skin cancers, cataracts, immune suppression and infectious processes.[113] Nonmelanoma skin cancers are caused by exposure to ultraviolet radiation and are seen most often in lightly-pigmented individuals.[114] They occur most often at higher global latitudes, where UV-B penetration is more intense and the Caucasian population more extensive.[115] But nonmelanoma skin cancer is not unique to lightly-pigmented populations. Darker-pigmented individuals living at lower global latitudes are also susceptible to developing dermal neoplasms[116] and cannot ignore the higher risk caused by ozone depletion.[117]

---

107. *See supra* note 83 and accompanying text.

108. Pool, *Stratospheric Ozone is Decreasing*, 239 SCIENCE 1489, 1490 (1988).

109. *See supra* notes 76-82 and accompanying text.

110. Scotto, *Nonmelanoma Skin Cancer—UV-B Effects*, in 2 UNEP/EPA, *supra* note 8, at 33.

111. *Id.*

112. *See infra* notes 113-32 and accompanying text.

113. Titus & Seidel, *Overview of the Effects of Changing the Atmosphere*, in 1 UNEP/EPA, *supra* note 8, at 3, 5.

114. The nonmelanoma skin cancers include basal cell carcinoma, squamous cell carcinoma, and premalignant actinic keratosis. Emmett, *Health Effects of Ultraviolet Radiation*, in 1 UNEP/EPA, *supra* note 8, at 129, 138.

115. The highest incidences of nonmelanoma skin cancer are seen in persons of Anglo-Saxon and Celtic descent. *Id.*

116. Individuals with darker skin pigments are thought to be less susceptible to nonmelanoma skin cancer. But one study in Kuwait found that even in darker-pigmented individuals, skin cancer risk on exposed skin is significant. Kollias & Baqer, *The Role of Native Pigment in Providing Protection Against UV-B Damage in Humans*, 2 UNEP/EPA, *supra* note 8, at 173.

117. While the incidence of nonmelanoma cancer may be lower in these individuals, medical care for those afflicted may not be as efficacious as in the industrialized countries, thereby increasing the risk of morbidity and mortality. *Id.*

If present trends in ozone depletion continue, twenty to thirty percent of Caucasians in the United States may develop nonmelanoma skin cancer by the year 2025.[118] Even with implementation of CFC emission controls, the depletion of ozone by agents currently in the atmosphere is expected to cause 141,900 new cases of nonmelanoma neoplasms per year in the United States.[119] Because melanoma skin cancers metastasize easily, they are substantially more fatal than nonmelanoma neoplasms.[120] While the etiology of melanoma is linked to UV-B radiation, the relationship is not as well established as in nonmelanoma skin cancer.[121]

UV-B radiation also has deleterious ocular effects. Acute photokeratosis, also called "snow blindness,"[122] is caused by UV-B damage to the cornea and conjunctiva.[123] UV-B can also damage the lens, leading to formation of cataracts.[124]

UV-B radiation is linked to immune suppression. While increasing over-all cancer risk, suppression of the immune system is also thought to enhance susceptibility to parasitic and viral infections.[125] This can be of particular concern to individuals living in tropical areas where UV exposure is extensive and infectious diseases are endemic. In a world battling a virally-induced form of immune suppression (Acquired Immune Deficiency Syndrome, AIDS), activities causing the immune system to be compromised should be of immense concern.[126]

Laboratory studies reveal that plants are sensitive to UV-B radiation, with adverse effects on crop yield, growth, structure and

---

118. This estimate is based on a model which assumes a 7.5% depletion in ozone, and is expected to result in 256,400 new cases of skin cancer per year. Dudek & Oppenheimer, *The Implications of Health and Environmental Effects for Policy*, 1 UNEP/EPA, *supra* note 8, at 370.

119. This model is based on a scenario whereby CFC emissions are held constant at 1980 levels, and assuming there will be a 2% decrease in atmospheric ozone content by the year 2025. *Id.*

120. While melanomas comprise only 3% of all skin cancers, they are responsible for 65% of all skin cancer deaths. MAKHIJANI, *supra* note 55, at 50.

121. Emmett, *Health Effects of Ultraviolet Radiation*, in 1 UNEP/EPA, *supra* note 8, at 129, 140.

122. Snow reflects UV-B efficiently. *Id.* at 141.

123. *Id.* at 142.

124. A 1% increase in UV-B radiation is expected to cause a 0.5% increase in cataracts. Cataracts are a major cause of blindness. MAKHIJANI, *supra* note 55, at 58.

125. *See* Giannini, *Effects of UV-B on Infectious Disease*, 2 UNEP/EPA, *supra* note 8, at 101.

126. Individuals with compromised immune function are thought to be more susceptible to the AIDS virus. Mann, Chin, Piot, and Quinn, *The International Epidemiology of AIDS*, 259 SCI. AM. 82, 86 (1988).

germination.[127] A twenty-five percent depletion in ozone[128] could lead to a reduction in soybean yield of twenty to twenty-five percent.[129] Moreover, because UV-B radiation can penetrate water at depths of up to twenty meters, it poses a threat to organisms such as phytoplankton and zooplankton, which comprise the foundation of the aquatic food chain.[130]

Building materials such as paints and polyvinyl chloride (PVC) are susceptible to degradation by UV radiation.[131] It is estimated that a twenty-six percent depletion in ozone by the year 2075 would cause building material damage of 2.4 to 9.2 billion dollars in the United States (1984 dollars).[132]

F. Effects on the Global Environment

Depletion of the ozone layer is inextricably linked to global warming.[133] Substances that influence ozone dynamics such as carbon dioxide, methane, CFCs, halons and nitrous oxides are also involved in the global warming process.[134] A study conducted by the National Academy of Sciences concludes that the mean global temperature could increase by as much as five degrees Celsius (°C) in the

---

127. Two-thirds of over 200 plants tested under laboratory conditions revealed radiation-induced damage. But studies indicate that plants grown outdoors in natural conditions are not as susceptible to UV radiation as those grown in artificial environments. Teramura, *Overview of Our Current State of Knowledge of UV Effects on Plants*, in 1 UNEP/EPA, *supra* note 8, at 165.

128. According to EPA estimates, in the absence of controls, the world could experience a 25% depletion in ozone sometime between the years 2050 and 2075. 53 Fed. Reg. 30,566; 30,573 (1988).

129. Teramura, *Overview of Our Current State of Knowledge of UV Effects on Plants*, in 1 UNEP/EPA, *supra* note 8, at 167.

130. Worrest, *The Effect of Solar UV-B Radiation on Aquatic Systems: An Overview*, in 1 UNEP/EPA, *supra* note 8, at 175.

131. Andrady & Horst, *An Assessment of UV-B Radiation Effects on Polymer Materials: A Technical and Economic Study*, in 2 UNEP/EPA, *supra* note 8, at 279.

132. *Id.*

133. Although linked, they are sometimes considered separate issues. Some state that global warming eclipses ozone depletion as the world's principal environmental dilemma. *See* 11 INT'L ENV'T REP. (BNA) 431 (Aug. 1988).

134. Carbon dioxide is traditionally considered the major greenhouse gas and has as its source natural biologic activity as well as anthropogenic processes. Recent studies also link carbon dioxide formation to plate tectonic activity in what is called the geochemical carbon cycle. Berner & Lasaga, *Modeling the Geochemical Carbon Cycle*, 260 SCI. AM. 74 (1989). Other greenhouse gases include methane, nitrous oxide, CFCs and tropospheric ozone. CFCs account for 17% of the total human contribution to global warming. *See* Topping, *Where Are We Headed in Responding to Climate Change?*, 11 INT'L ENV'T REP. (BNA) 555, 556 (Oct. 1988).

next half-century if current trends are not checked.[135]

The Earth's temperature is dependent on the amount of sunlight the planet receives, the amount it reflects, and how much heat the atmosphere retains.[136] The greenhouse gases[137] trap the heat that would normally be reflected back into space, thereby warming the planet.[138] For centuries the mean global temperature has been fairly constant.[139] But human contributions to the amount of atmospheric greenhouse gases have increased substantially in the past decades.[140] Present levels of carbon dioxide, the most potent greenhouse gas, are expected to double sometime between the years 2020 and 2060.[141]

The projected effects of global warming are staggering, if not apocalyptic.[142] Warming is expected to lead to an increase in drought-like conditions in the middle latitudes, adversely affecting agriculture in those regions.[143] Forest Belts at the mid latitudes will shift north, and the forested area in the United States may decrease by thirty-seven percent.[144]

The sea level will rise,[145] with projections as high as 2.3 meters (7.5 feet) by the year 2100.[146] As little as a one meter elevation in sea level could inundate low-lying coastal areas, and "may result in the creation of 50 million environmental refugees from various countries

135. Hansen, et al., *The Greenhouse Effect: Projections of Global Climate Change*, in 1 UNEP/EPA, *supra* note 8, at 199, 208.

136. Schneider, *The Greenhouse Effect: Science and Policy*, 243 SCIENCE 771, 772 (1989).

137. See *supra* note 134 for a list of greenhouse gases.

138. Without the natural greenhouse gases, global temperature would be about 33 degrees Celsius (°C) colder than it currently is. *See* Titus & Seidel, *Overview of the Effects of Changing the Atmosphere*, in 1 UNEP/EPA, *supra* note 8, at 8.

139. *See generally* Schneider, *supra* note 136.

140. *Id.*

141. *Id.*

142. *See* Hansen et al., *The Greenhouse Effect: Projections of Global Climate Change*, in 1 UNEP/EPA, *supra* note 8. For example, in Washington D.C., the number of days each year having a maximum daily temperature above 38°C (100°F) would increase from 1 to 12 sometime in the middle of the next century. *Id.* at 213.

143. Parry & Carter, *Effects of Climatic Changes on Agriculture and Forestry: An Overview*, in 1 UNEP/EPA, *supra* note 8, at 270-97.

144. *Id.* at 290. Conversely, northern countries such as the U.S.S.R. will experience an 85% growth in forested area. *Id.* at 293.

145. Two factors will contribute to the sea level rise: the elevation in water temperature will cause its expansion, and the melting of mountain and polar glaciers will increase the volume of water in the liquid state. *See* Titus, *The Cause and Effects of Sea Level Rise*, in 1 UNEP/EPA, *supra* note 8, at 219.

146. Thomas, *Future Sea Level Rise and Its Early Detection by Satellite Remote Sensing*, in 4 UNEP/EPA, *supra* note 8, at 31. An irreversible deglaciation in the West Antarctic ice sheet could cause an additional six meter rise in the next century. *Id.*

. . . ."[147] A sea level rise could severely damage wetlands[148] and increase the salinity of rivers and aquifers.[149]

While efforts taken to protect the ozone layer will reduce the extent of global warming, the converse—reducing the amount of greenhouse gases in the atmosphere—is not necessarily true, because some greenhouse gases retard ozone loss.[150] Trace greenhouse gases such as nitrous oxide and methane react with chlorine radicals to convert the chlorine to an inactive form which does not participate in ozone depleting reactions.[151] Reduction of the greenhouse gases could lead to an increase in chlorine radicals and a significant increase in ozone loss.[152]

III. OZONE PROTECTION STRATEGIES

A. International Environmental Law

Ozone depletion is a problem made to order for international cooperation.[153] Production or consumption of ozone-depleting sub-

---

147. 11 INT'L ENV'T REP. (BNA) 680 (Dec. 1988). Developing countries may not have the resources to handle coastal flooding. In Egypt a 50 to 200 centimeter increase in sea level would flood land now occupied by 16 to 28% of the population, making 10 million people homeless. Bangladesh could lose 12 to 25% of its land, uprooting 16 million people. *See* Broadus et al., *Rising Sea Level and Damming of Rivers: Possible Effects in Egypt and Bangladesh*, in 4 UNEP/EPA, *supra* note 8, at 165. By contrast, developed countries may be able to protect their coastal areas. *See* Bruun, *Worldwide Impact of Sea Level Rise on Shorelines*, in 4 UNEP/EPA, *supra* note 8, at 99. The estimated cost of protecting dikes in the Netherlands against a one meter sea level rise is less than 0.05% of the annual Dutch Gross National Product. *See* Goemans, *The Sea Also Rises: The Ongoing Dialogue of the Dutch with the Sea*, in 4 UNEP/EPA, *supra* note 8, at 47.

148. Forty to seventy-five percent of existing United States wetlands could be lost by the year 2100. *See* Park, Armentano & Cloonan, *Predicting the Effects of Sea Level Rise on Coastal Wetlands*, in 4 UNEP/EPA, *supra* note 8, at 129.

149. deSylva, *Increased Storms and Estuarine Salinity and Other Ecological Impacts of the "Greenhouse Effect,"* in 4 UNEP/EPA, *supra* note 8, at 153.

150. 11 INT'L ENV'T REP. (BNA) 431 (Aug. 1988).

151. NO_x can react with ClO_x to form chlorine nitrate, thereby reducing the amount of reactive chlorine and nitrogen which would otherwise destroy ozone:

$$ClO + NO_2 \rightarrow ClNO_3$$
$$ClO + NO \rightarrow Cl + NO_2$$

Methane reacts with chlorine radicals to form hydrochloric acid, which falls to the terrestrial surface as acid rain:

$$Cl + CH_4 \rightarrow HCl + CH_3$$

McElroy & Salawitch, *Changing Composition of the Global Stratosphere*, 243 SCIENCE 763, 764 (1989).

152. Ozone loss could be five times the level projected under the Montreal Protocol on Substances that Deplete the Ozone Layer. 11 INT'L ENV'T REP. (BNA) 431 (Aug. 1988).

153. While this Comment will focus on the international efforts to protect the ozone layer, local and national laws address the issue as well. For example, Massachusetts brought suit

stances in one country can have a profound impact, not only in that country, but in nonproducing, nonconsuming countries as well.[154]

An increasing recognition of our "global commons"[155] has brought about a change in environmental law. Furthermore, traditional international law has been influenced by the advent of a heightened awareness of global environmental issues.[156] The expansion of traditional international legal concepts to address global environmental concerns has been accompanied by a shift "from areas where the interests of states were directly and immediately affected (transboundary waters), to other areas and situations in which states' interest are less visibly involved (protection of the marine environment)."[157]

Numerous transnational organizations participate in some fashion in environmental protection activities.[158] The organization most involved in ozone protection is the United Nations Environment Programme (UNEP).[159] The UNEP arose from the United Nations Conference on the Human Environment, held in Stockholm in 1972.[160]

Conference participants developed a twenty-six principle Declaration of the United Nations Conference on the Human Environment (Stockholm Declaration). The Stockholm Declaration contains only recommendations, not binding resolutions.[161] The key to the Stockholm Declaration is Principle 21, which recognizes the two competing goals of permitting nations to exploit their own resources, and insuring that no nation endangers the environment beyond its own

---

against a foam producer for releasing 1300 tons of CFCs per year in violation of a state law requiring release permits. 11 INT'L ENV'T REP. (BNA) 501 (Sept. 1988). For a review of domestic and foreign laws affecting ozone, see Comment, *Thinning Air, Better Beware: Chlorofluorocarbons and the Ozone Layer*, 6 DICK. J. INT'L L. 87 (1987). The current United States strategy for regulating CFC and halon production under the Montreal Protocol is described in 53 Fed. Reg. 30,566 (Aug. 12, 1988).

154. J. BRUNNÉE, ACID RAIN AND OZONE LAYER DEPLETION 78 (1988).

155. Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

156. L. TECLAFF, INTERNATIONAL ENVIRONMENTAL LAW 229 (1974).

157. *Id.* at 251.

158. *See* G. WETSTONE & A. ROSENCRANZ, ACID RAIN IN EUROPE AND NORTH AMERICA 133-55 (1983).

159. *See* Myers, *A Survey of International Intergovernmental Organizations: The Strategies That They Use to Abate Pollution* 63, (Nov. 1978) (Environmental Protection Agency publication EPA-600/9-78-033). UNEP headquarters is in Nairobi, Kenya. It is not a regulatory body, but instead provides environmental information and is a focal point for developing treaties to address international environmental problems. *Id.*

160. *See* L. TECLAFF, *supra* note 156, at 57-66.

161. *Id.* For a discussion of the impact of the Stockhom Conference, see, Kiss, *Dix Ans Apres Stockholm, Une Decennie de Droit International de l'Environnement*, 28 ANNUAIRE FRANCAIS DE DROIT INTERNATIONAL 784 (1982).

borders.[162]

The Stockholm Conference did not have a worldwide impact, largely because Eastern-block nations refused to participate, and because of concern among developing nations that environmental regulations would limit economic growth in their own countries.[163] But much has changed since 1972, and the Eastern-block now recognizes global environmental imperatives.[164] Developing countries are waking up to the environmental reality that rapid, unchecked economic growth often comes wrapped in a package with environmental degradation.[165] In fact, developing countries become parties to international environmental treaties in proportionally larger numbers than industrialized countries, but implementation of those treaties by the developing countries may fall short in comparison to the industrialized nations.[166] Nevertheless, discrepancies in prosperity between the North and South[167] will continue to have a major influence on negotiations leading to global environmental treaties.[168]

---

162. Principle 21 declares:

> States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of national jurisdiction.

J. BRUNNÉE, *supra* note 154, at 84.

163. *See* Anand, *Development and Environment: The Case of the Developing Countries*, 20 INDIAN J. INT'L. L. 1. "The 'disinherited majority' of the world, which desperately needs science and technology to pull themselves up from the quagmire, does not want the concern for environment to keep them down [sic]." *Id.* at 10.

164. Telegraph Agency of the Soviet Union (TASS): Pugwash Conference, Sept. 6, 1988. "To survive, we must recognize that environmental degradation weakens the security of all." *Id.*

165. *See* Okidi, *The Prospects for Cooperation among Developing Countries in Legal Aspects of Control of Transboundary Air Pollution*, in TRANSBOUNDARY AIR POLLUTION 235 (1986). Environmental pollution in developing countries will increase "as the high environmental standards in Europe, the U.S. and Japan force polluting industries to seek refuge in the developing countries where standards and regulatory infrastructures are not yet as developed." *Id.* at 241. *See also De una Tierra a un Mundo*, 5 AMBIENTE Y RECURSOS NATURALES 14 (1988).

166. Okidi, *supra* note 165, at 244.

167. The Northern Hemisphere contains the larger number of developed, industrialized countries, a fact some recognize as a North-South disparity in international relations. *See* Rothstein, *Epitaph for a Monument to a Failed Protest? A North-South Retrospective*, 42 INT'L ORG. 725 (1988).

168. For example, the Brazilian government's recent refusal to participate in a major international environmental conference highlights the tension recognized in Principle 21 of the Stockholm Declaration that a nation should be allowed to exploit its own resources (development of the Amazon) without endangering the environment beyond its own borders (deforestation). President Sarney stated "[w]e are the masters of our destiny and will not permit any interference in our territory." House, *Brazil Declines Invitation to Conference on Ecology*, Wash. Post, March 4, 1989, at A20.

The UNEP coordinates environmental activities among the UN agencies and other environmental organizations. Although the UNEP has been criticized for making eloquent but empty declarations,[169] its stepped-up efforts to coordinate protection of the ozone layer and limit exports of hazardous waste may change that image.[170]

B. Preliminary Ozone Protection Measures

The earliest control measures for protecting the integrity of the ozone layer had nothing to do with CFCs or halons. In the early 1970s, atmospheric chemists demonstrated significant ozone depletion associated with nitrous oxide emissions by supersonic jetliners (such as the Concorde) flying in the stratosphere.[171] Concerned about the environmental impact, the U.S. Congress elected to halt funding of development of an American supersonic transport.[172]

Following the Molina and Rowland report on the theoretical basis for ozone depletion by chlorine-containing compounds,[173] the United States National Academy of Sciences issued a report in 1976 calling for regulatory action on CFCs.[174] In 1978-79 the United States imposed a ban on CFC use in aerosols.[175] Canada, Sweden and Norway were the only other countries to join the U.S. in imposing restrictions on CFC use in aerosols, a situation that U.S. CFC producers complained was competitively unfair.[176] The European Economic Commission (EEC) elected not to ban aerosol use, finding tenuous the scientific evidence linking CFCs with ozone depletion.[177]

In 1977 the UNEP convened a conference addressing ozone depletion, the result of which was the development of the World Plan of Action on the Ozone Layer.[178] The Co-ordinating Committee on the

169. Smith, *The United Nations and the Environment: Sometimes a Great Notion?*, 19 TEX. INT'L L.J. 335, 336 (1984). "[O]perating in the reality of United Nations politics, there is a common understanding and, indeed, a rather pervasive cynicism among the diplomats and representatives of the Assembly that a goodly number of the declarations made will never be implemented." *Id.* at 340.

170. 12 INT'L ENV'T REP. (BNA) 51 (Feb. 1989). "Environmental ministers see larger role for UNEP." *Id.*

171. Johnston, *Reduction of Stratospheric Ozone by Nitrogen Oxide Catalysts from Supersonic Transport Exhaust*, 173 SCIENCE 517 (1971). Johnston estimated that supersonic transports could cause a 22% depletion in ozone over a 10 year period. *Id.* at 522.

172. *See* D. COGAN, *supra* note 23, at 25-26.

173. *See supra* note 40.

174. *See* J. BRUNNÉE, *supra* note 154, at 225.

175. *Id.*

176. *Id.*

177. *Id.*

178. *Id.* at 226.

Ozone Layer, comprised of representatives of various UN bodies, governmental and nongovernmental organizations, and scientific institutions, was created to initiate, monitor, and review research on the ozone layer. In 1981 the UNEP Governing Council established the Ad Hoc Working Group of Legal and Technical Experts. The Working Group had two goals: to broaden research on ozone depletion and to establish a global framework convention for protecting the ozone layer.[179] The Working Group met several times over the following years and established an agreement for the exchange of information, monitoring and research, but failed to arrive at an agreement governing control measures.[180] Nevertheless, in March 1985 the parties signed the Vienna Convention for the Protection of the Ozone Layer.[181]

The Vienna Convention has been hailed as a "landmark event,"[182] with the global community "acting together in anticipation of potential problems."[183] But failure to establish control measures reflected the different interests of the participating nations. For example, the EEC sponsored a plan advocating a thirty percent reduction in aerosol use and a limit on future CFC production. Criticism leveled at the EEC plan emphasized potential adverse impact on the ozone layer before the proposed production cap would go into effect.[184] Similarly, a plan proposed by the United States, Canada and the Nordic countries calling for a protocol governing an eighty percent reduction of CFCs used in aerosols was criticized for ignoring CFC use in air conditioners, the latter application being more common in North America than in Europe.[185] Failing to agree on appropriate control measures, the delegates asked the UNEP to convene international workshops in an effort to develop a protocol for addressing control strategies.[186]

179. *Id.* at 227.

180. *Id.* at 228.

181. Vienna Convention for the Protection of the Ozone Layer, *reprinted in* 26 I.L.M. 1516 (1987) [hereinafter Vienna Convention].

182. Benedick, *International Cooperation to Protect the Ozone Layer*, DEP'T OF ST. BULL. 58 (June 1986) (address made by Richard Benedick, Deputy Assistant Secretary for Oceans and International Environmental and Scientific Affairs, before the U.S. Workshop on Protecting the Ozone Layer on March 6, 1986).

183. *Id.*

184. J. BRUNNÉE, *supra* note 154, at 228. This was a compromise on the original EEC position of opposing any further controls on CFCs. Benedick, *supra* note 182, at 58.

185. J. BRUNNÉE, *supra* note 154, at 229. The Nordic countries initially proposed a draft protocol for controlling all CFC uses, but later joined Canada and the United States in stressing control of aerosol uses. Benedick, *supra* note 182, at 58-59.

186. Johnston, *supra* note 18, at 273.

Despite the participant's failure to establish control measures, the Vienna Convention, consisting of twenty-one articles and two annexes, provides a framework upon which nations can construct more specific plans for protecting the ozone. The Preamble to the Convention expresses the sentiments existing at that time, namely that the parties were "aware of the potentially harmful impact . . . through modification of the ozone layer" and realized the need for "further research and systematic observations to further develop scientific knowledge . . . ."[187] The Preamble also echoes the Stockholm Convention[188] concern that global environmental problems be approached with an eye toward the circumstances and particular requirements of developing countries.[189] The Preamble recalls Principle 21 of the Stockholm Declaration, recognizing both the sovereignty of nations to exploit their own resources and the responsibility toward the environment of others.[190]

The Vienna Convention addresses activities "which have significant deleterious effects . . . ."[191] In Article 2 the parties agree to cooperate in information, research and information exchange; adopt measures to control activities which are found likely to have an adverse effect; and implement the Convention and protocols to which they are a party.[192] The parties are free to adopt measures more stringent than those required under the Convention.[193] Articles 3, 4, and 5 address cooperation in research, monitoring and information exchange. Annex I to the Convention provides detailed information about the scientific areas of concern, including a list of potentially harmful substances. To protect information deemed confidential, Article 4 and Annex II provide that parties need not share information (such as fluorocarbon alternatives) protected by domestic privacy laws. Articles 6 and 7 address administrative issues, namely meetings of Conference parties and the establishment of a secretariat. A dispute resolution provision is contained in Article 11, but it has been criticized for not expressly obligating parties to resort to mediation or arbitration.[194] However, the parties are free to accept arbitration (as adopted by the Conference of Parties) or submit their disputes to the

187. Vienna Convention, *supra* note 181, at 1529.

188. *See supra* note 162 and accompanying text.

189. *Id.*

190. *Id.*

191. Art. 1(2), *supra* note 181, at 1529.

192. Art. 2(2), *Id.* at 1529-30.

193. Art. 2(3), *Id.* at 1530.

194. J. BRUNNÉE, *supra* note 154, at 235.

International Court of Justice.[195]

The Vienna Convention became effective on September 22, 1988.[196] The Convention is limited to governing cooperation in research, monitoring and information sharing. It does not cover specific control measures designed to limit substances which deplete the ozone layer. An instrument addressing such control measures surfaced two years later in the Montreal Protocol on Substances that Deplete the Ozone Layer.[197]

C. The Montreal Protocol

By April 1987 the differences that had prevented incorporation of control measures into the Vienna Convention were essentially resolved.[198] The EEC retreated from its position advocating a production capacity limit for CFCs and expressed a willingness to accept a production freeze and possibly some cutbacks.[199] Rather than calling for a limit on aerosol uses, the United States advocated a gradual cutback on all fully halogenated substances[200] to 95% of 1986 levels.[201] These and other compromises led to the Montreal Protocol on Substances that Deplete the Ozone Layer, which twenty-four nations and the EEC signed on September 16, 1987,[202] and which took effect on January 1, 1989.[203]

The Protocol begins with an acknowledgement of the Vienna

195. Art. 11(3), *supra* note 181, at 1533-34.

196. 12 INT'L ENV'T REP. (BNA) 3 (Jan. 1989). Art. 17(1) of the Vienna Convention states that it "shall enter into force on the ninetieth day after the date of deposit of the twentieth instrument of ratification, acceptance, approval or accession." Art. 17(1), *supra* note 181, at 1535.

197. *See infra* notes 198-274 and accompanying text.

198. J. BRUNNÉE, INT'L LAW AND THE CONTROL OF ACID RAIN AND OZONE LAYER DEPLETION, LL.M. Thesis, Dalhousie Law School, Nova Scotia, Canada, 301, 305 (1987) [hereinafter LL.M. Thesis].

199. *Id.* at 306.

200. This measure would include the brominated halons, methyl chloroform and carbon tetrachloride, in addition to the CFCs. *See supra* notes 56-60 and accompanying text.

201. LL.M. Thesis, *supra* note 198, at 306.

202. Protocol on Substances that Deplete the Ozone Layer, *reprinted in* 26 I.L.M. 1541 (1987) [hereinafter Protocol].

203. 12 INT'L ENV'T REP. (BNA) 3 (Jan. 1989). As of December 30, 1988, the parties include: Belgium, Byelorussian SSR, Canada, Denmark, the European Community, Egypt, Finland, France, Federal Republic of Germany, Greece, Ireland, Italy, Japan, Kenya, Luxembourg, Malta, Mexico, Netherlands, New Zealand, Nigeria, Norway, Portugal, Spain, Sweden, Switzerland, Uganda, Ukranian SSR, Union of Soviet Socialist Republics, the United Kingdom and the United States. INT'L ENV'T REP. (BNA) ¶ 21:3158 (Jan. 1989). At the March 1989 London conference on "Saving the Ozone Layer," 20 additional countries said they would adhere to the Protocol and 19 indicated they were seriously considering it. Randal, *Conferees Differ on Pace of Ozone Phase-Out*, Wash. Post, March 8, 1989, at A30.

Convention and stresses the importance of basing the measures taken on "relevant scientific knowledge."[204] Echoing a position advocated at the Stockholm Convention, the Protocol acknowledges the needs of developing countries.[205] The Protocol is comprised of twenty articles and an annex, the latter listing the substances addressed by the agreement.

The annex list of controlled substances is divided into two groups, CFCs (Group I) and halons (Group II).[206] While it was always assumed during negotiations leading up to the Protocol that Group I substances would be addressed, it was less certain that the Protocol would include CFC-115[207] and the halons in Group II.[208] Although CFC emissions are forty times those of halons, the ozone depletion potential of the halons is eight times higher.[209]

Article 1 of the Protocol defines production as "the amount of controlled substances produced minus the amount destroyed by technologies to be approved by the parties."[210] The Protocol defines consumption as "production plus imports minus exports of controlled substances."[211] Article 3 establishes the method for calculating consumption levels.[212] Exports are not counted towards a party's calculated consumption level, but are instead allocated to the importing country's quota. After 1992 export of controlled substances to non-parties cannot be subtracted from the calculated consumption level of

204. Protocol, *supra* note 202, at 1550. The Protocol recognizes that the measures take account of both technical *and* economic considerations. *Id.*

205. *Id.* at 1551. "*Acknowledging* that special provision is required to meet the needs of developing countries for these substances . . . ." (emphasis in original). *Id.*

206. *See supra* notes 24-64 and accompanying text for a discussion of the uses of the controlled CFCs and halons. The Protocol controlled substances and ozone depleting potentials are:

Group	Substance	Ozone depleting potential
I	CFC-11	1.0
	CFC-12	1.0
	CFC-113	0.8
	CFC-114	1.0
	CFC-115	0.6
II	halon-1211	3.0
	halon-1301	10.0
	halon-2402	(to be determined).

207. *See supra* note 33.

208. J. BRUNNÉE, *supra* note 154, at 242.

209. MacKenzie, *High Noon for Ozone in Montreal*, NEW SCIENTIST, Sept. 3, 1987 at 24.

210. By allowing fresh production to replace the CFCs and halons destroyed, the Protocol encourages the development of destruction technologies. Art. 1(5), Protocol, *supra* note 202, at 1551.

211. Art. 1(6), *Id.*

212. Art. 3, *Id.* at 1554.

the exporting party.[213] Parties are required to provide data supporting their 1986 calculated consumption levels and subsequent yearly production to the secretariat.[214]

Article 2 is the heart of the Protocol. To meet the goal of protecting the ozone, Article 2 mandates both consumption and production cutbacks. It establishes twelve-month "windows" for parties to begin compliance. The Protocol requires that in the time period from July 1, 1989 to June 30, 1990, and for each twelve-month period thereafter, each party freeze consumption of Group I controlled substances at 1986-calculated consumption levels.[215] Commencing with the twelve-month "window" ending June 30, 1994, the Protocol calls for a twenty percent reduction in the 1986-calculated level of consumption and a twenty percent decrease in the 1986-calculated level of production.[216] In the "window" ending June 30, 1999 and after, the annual consumption of Group I substances is not to exceed fifty percent of the 1986-calculated consumption levels. A similar fifty percent restriction on production will begin at that time.[217] Unlike the twenty percent reduction, which is automatic, the parties can prevent the fifty percent cut-backs by a two-thirds majority vote of the parties representing two-thirds of the total calculated levels of consumption.[218] Group II halons will be subject to a freeze at 1986 consumption and production levels by the twelve-month period ending June 30, 1994.[219] Small producing countries can transfer to or receive from other parties production to effect industrial rationalization.[220]

By allowing developing countries to deviate from the consumption and production freezes, Article 2 accomplishes the goal established in the Preamble to the Vienna Convention of addressing the special needs of the developing world.[221] Section 6 allows parties hav-

213. Art. 3(c), *Id.*

214. Art. 7, *Id.* at 1556.

215. Art. 2(1), *Id.* at 1552. The Protocol permits developing countries to increase consumption of up to 10% of 1986 levels "only so as to satisfy the basic domestic needs . . . ." Art. 5, *Id.* at 1555.

216. Art. 2(3), *Id.* A 10% deviation in the production freeze requirement can be extended to developing countries.

217. Art. 2(4), *Id.* A 15% deviation from these requirements can be extended to developing countries.

218. *Id.*

219. Art. 2(2), *Id.* Developing countries are allowed a 10% deviation.

220. Art. 2(5), *Id.* at 1553. Industrial rationalization is defined as "the transfer of all or a portion of the calculated level of production of one Party to another, for the purpose of achieving economic efficiencies or responding to anticipated shortfalls in supply as a result of plant closures." Art. 1(8), *Id.* at 1552.

221. *See supra* note 189 and accompanying text.

ing facilities for production of controlled substances under construction or contracted for by September 16, 1987[222] to add the production from these facilities to its 1986 calculated level.[223] This provision was included to address concerns voiced by the Soviet Union that sudden reductions in production would place parties having planned economies (such as five-year plans) at a competitive disadvantage against market-based economies.[224]

The EEC successfully negotiated a provision allowing "regional economic integration organizations" (such as the EEC) to be treated as a single entity in meeting the consumption cuts.[225] Section 8 allows regional organizations such as the EEC to "jointly fulfill their obligations respecting consumption . . ."[226] so long as all members of the organization become parties[227] and their total combined calculated level of consumption does not exceed the levels otherwise required by Article 2.[228]

The Article 2 control measures will be subject to review beginning in 1990 and at least every four years thereafter.[229] The controlled substances listed in the Annex can be removed or additional ones appended to the Protocol as technical and economic evidence dictates.[230]

Article 4 establishes guidelines for trade in controlled substances with nonparties to the Protocol. The import of controlled substances (bulk shipments)[231] from nonparty nations were to be banned by Jan-

222. There is an additional requirement that these facilities must have been provided for in national legislation by January 1, 1987. Protocol, *supra* note 202, at 1553.

223. Art. 2(6), *Id.* The facilities must also be completed by December 31, 1990. Production must not raise that party's annual calculated level of consumption above 0.5 kilograms per capita. *Id.*

224. Menyasz, *International Agreement to Protect the Ozone Layer Hailed as a Precedent for Global Environmental Solutions*, 10 INT'L ENV'T REP. (BNA) 531, 532 (Oct. 1987).

225. *Id.* A last-minute dispute between the United States and the EEC over this provision almost scuttled the Protocol. The U.S. was concerned that the EEC did not have power to set production limits among its members and that treating the EEC as an entity in a non-trade setting would establish a dangerous international precedent. *Id.* at 532-33.

226. Art. 2(8)(a), Protocol, *supra* note 202, at 1553.

227. Art. 2(8)(c), *Id.*

228. Art. 2(8)(a), *Id.*

229. Art. 6, *Id.* at 1556. Panels of experts will convene one year before each assessment and report their conclusions through the secretariat to the parties. *Id.*

230. Art. 2(10), *Id.* at 1554. Changes in control measures require two-thirds majority vote of the parties present and voting.

231. The export/import of products containing or products produced with, but not containing controlled substances, are treated differently. *See infra* notes 234-35 and accompanying text.

uary 1, 1990.[232] After 1992 developing countries will not be allowed to export controlled substances to nonparties.[233] By 1992 the parties are required to develop an annex which lists products containing controlled substances. One year after the Annex becomes effective, parties not objecting to the Annex will ban imports of those products.[234] By 1994 the parties are to "determine the feasibility of banning or restricting . . . the import of products produced with, but not containing, controlled substances."[235] Within one year after the Annex becomes effective, the nonobjecting parties will ban imports of those products. The trade restrictions were incorporated to create an incentive for countries to join the Protocol, since the controlled substances are deemed necessary for development.[236]

The special needs of the developing countries are recognized in Article 5. The Protocol does not specify the nations which qualify as "developing," but a suitable definition will be developed at the first meeting of the parties.[237] A developing country whose annual calculated consumption of controlled substances is less than 0.3 kilograms per capita is allowed to delay compliance with the control measures of Article 2 (sections 1 through 4) by ten years, provided it not exceed a consumption level of 0.3 kilograms per capita.[238] Article 5 provides that the other parties to the Protocol will undertake to facilitate the developing countries' access to alternative technologies and substances and to assist in providing financial aid in this regard.[239]

Procedures for assessing compliance with the terms of the Protocol were left for development at a later meeting of the parties.[240] Stricter noncompliance language, such as that used in arms-control agreements, was not incorporated into the Protocol because technical

232. Art. 4(1), Protocol, *supra* note 202, at 1554.

233. Art. 4(2), *Id.* at 1555. Developed countries, on the other hand, will not be allowed to subtract exports to nonparties from their calculated consumption levels. *See supra* note 213. The Article 4 restriction is only imposed on developing countries because they are allowed to increase consumption at a time when developed countries are required to institute cutbacks.

234. Art. 4(3), *Id.*

235. Art. 4(4), *Id.*

236. Menyasz, *supra* note 224, at 532.

237. 18 ENV'T POLICY AND LAW 56, 57 (1988). Although the UN has developed a list of "least developed countries," the more expansive term "developing country" is not officially recognized by the UN. *Id. See supra* note 203 for a list of parties to the Protocol.

238. Art. 5(1), Protocol, *supra* note 202, at 1555. By comparison, the annual per capita consumption in the U.S. is 1.1 kilograms. SCIENCE, Sept. 25, 1987, at 1557.

239. Art. 5(2-3), Protocol, *supra* note 202, at 1556.

240. Art. 8 provides in part that the parties "shall consider and approve procedures and institutional mechanisms for determining non-compliance . . . and for treatment of Parties found to be in non-compliance." *Id.*

experts lacked the time to develop compliance language and because there was a consensus among the participants attending the Conference that the parties would comply.[241] Market forces making CFC and halon substitutes more competitive and, therefore, more attractive than the controlled substances could arguably insure compliance with the Protocol.[242] But amendments to the Protocol calling for more drastic cutbacks in CFC production or consumption, which now seem inevitable,[243] could be met with less enthusiasm by the parties,[244] making compliance language critical.

The Protocol has been hailed as establishing a precedent for solving international environmental problems,[245] and called "a tribute to the ability of industry and governments to act in the face of carefully marshalled scientific argument."[246] UNEP director Mostafa Tolba stated that "[n]ever before in the history of science and law has the international community agreed to take such radical steps to avert a problem they anticipate, before that problem has begun to take its toll."[247] However, almost immediately after the close of the Conference, critics averred that the Protocol measures are insufficient.[248] Three major criticisms were leveled: 1) by allowing developing countries to increase their CFC consumption, the net effect of the control measures will be less than a fifty percent reduction of controlled substances, 2) more ozone-depleting agents should be added to the list of controlled substances, and 3) a fifty percent decrease in controlled substances will still allow significant deterioration of the ozone layer.[249]

Critics argue that the Article 2 provisions allowing developing countries to increase their CFC consumption to 0.3 kilograms per capita could result in a fifty percent increase in consumption of CFCs.[250] Considering that by 1999 the developed countries will reduce CFC consumption by the required fifty percent, while develop-

241. Menyasz, *supra* note 224, at 534.

242. J. BRUNNÉE, *supra* note 154, at 251-52.

243. *See infra* notes 259-65 and accompanying text.

244. *See infra* note 262 and accompanying text.

245. Menyasz, *supra* note 224, at 531.

246. McElroy & Salawitch, *supra* note 151.

247. Menyasz, *supra* note 224, at 531.

248. *See generally* D. COGAN, *supra* note 23, at 56-58.

249. *See infra* notes 250-58 and accompanying text.

250. Menyasz, *supra* note 224, at 534. The developing countries currently use about 0.2 kg per capita, but represent about 80% of the global population. The projected increase in CFC consumption assumes that all developing countries would take full advantage of the consumption increases allowable, a scenario UNEP Director Tolba finds unlikely. *Id.*

ing countries take advantage of the consumption increases, the net global reduction in CFC use may be around thirty-five percent, not fifty percent.[251]

There is also concern that the list of controlled substances is incomplete.[252] Other chlorine-containing halocarbons such as methyl chloroform and carbon tetrachloride could see increasing use as CFCs are phased out, with damaging consequences to the ozone.[253]

Critics state that the fifty percent reduction called for under the Protocol is insufficient to protect the ozone layer.[254] Modeling studies conducted prior to the Conference indicated that a fifty percent reduction would have a profound impact on preventing significant ozone loss.[255] However, shortly after the Conference ended, atmospheric scientists discovered that the extent of ozone depletion is greater than earlier believed.[256] Not only have the polar studies revealed more extensive ozone destruction, but the models relied upon by the Conference participants failed to account for the effects of PSCs,[257] which could cause future trends to be underestimated.[258]

In light of these findings the United States Environmental Protection Agency called for a total phase-out of ozone-depleting CFCs and halons.[259] The European Community Council of Environment Ministers agreed to prohibit the production and consumption of the CFCs controlled under the Protocol by the year 2000.[260] President Bush joined the growing worldwide concern by calling for a total ban of CFCs by the year 2000.[261] While recognizing the importance of strengthening the Protocol, the developing nations attending the

251. *Id.*

252. MAKHIJANI, *supra* note 55, at 41.

253. *Id.* If CFCs are completely phased out by 1995, but methyl chloroform and carbon tetrachloride use is allowed to grow at historical rates, the amount of atmospheric chlorine could still increase by 40%. *Id. See alsc* Topping, *supra* note 134.

254. Crawford, *EPA: Ozone Treaty Weak,* SCIENCE 7 Oct. 1988 at 25.

255. EPA estimates that with no controls, there would be a 50% reduction in ozone by the year 2075. With a 50% reduction in CFCs, there would still be a 1.9% depletion in ozone. 53 Fed. Reg. 30,566; 30,575 (1988).

256. Crawford, *supra* note 254.

257. *See supra* note 97 and accompanying text.

258. 19 ENV'T REP. (BNA) 2344 (March 1989).

259. Zurer, *EPA Calls for Total Ban on Chlorofluorocarbons,* CHEM. ENG. NEWS, Oct. 3, 1988 at 8.

260. 12 CHEM. REG. REP. (BNA) 1793 (March 10, 1989). The Canadian government is expected to ban CFCs as well. *Id.* Japan, the world's third largest CFC producer (behind the U.S. and the EEC), will also ban production by the year 2000. Nakanishi, *Japan Steps up Measures to Reduce Ozone Destruction,* REUTER LIBRARY REPORT, March 14, 1989.

261. Weiskopf, *Bush Endorses Phasing Out CFCs by Year 2000,* Wash. Post, March 4, 1989, at A20.

March 1989 London "Saving the Ozone Layer" conference argued that their participation can only be guaranteed by financial assistance from the industrialized countries.[262]

While environmental groups are challenging the EPA to take unilateral action to eliminate these substances, the EPA urges strengthening the Protocol based on the new scientific evidence.[263] The UNEP is working on technical recommendations for a complete phase-out of CFCs by the year 2000 rather than the fifty percent cutback called for by the Protocol.[264] The recommendations will be considered by the parties in 1990.[265]

Following the Ozone Trends Panel Report, E.I. du Pont de Nemours & Company (DuPont), the world's largest CFC and halon producer, announced plans to phase out production.[266] Referring to this decision, one DuPont executive noted that it "is rooted in our longstanding corporate commitment to do what is necessary to protect human health and the environment."[267] Environmentalists charged that DuPont and other producers stand to make windfall profits from price increases caused by the demand for CFCs as production decreases.[268] But DuPont stressed that the decision was consistent with a long-standing policy designed to protect the ozone layer if and when reliable scientific evidence linked CFCs to ozone destruction.[269] The Chemical Manufacturers Association supports a total phase-out of CFCs, but cautions against unilateral action by the

262. 12 CHEM. REG. REP. (BNA) 1794 (March 10, 1989). "Some nations will not find it easy to forego the use of CFCs in their quest for industrialization." *Id.* For example, China, having one-fifth of the world's population, is expected to have a ten-fold increase in refrigerators within the next decade. Such a dramatic increase could make China the world's largest CFC producer. Pearce, *Plugging the Hole in Our Sun Roof*, The Sunday Times (London), March 5, 1989, at F1, col. 1. At the London conference, China and India declined to join the Protocol. McGourty, *London Ozone Meeting Wins Some Hearts*, 338 NATURE 101 (1989). Their participation might be gained by a special fund for developing countries to assist them in phasing out CFCs. Japan and the U.S. have agreed to consider such a fund. Kyodo News Service, March 14, 1989.

263. Zurer, *CFC Production Cuts: EPA Rules Already Under Attack*, CHEM. ENG. NEWS, Aug. 8, 1988 at 4. *See also* Doniger, *Global Emergency*, 5 ENV'T FORUM 14 (1988).

264. 12 INT'L ENV'T REP. (BNA) 50 (Feb. 1989).

265. *Id.* In April of 1989 the parties were to hold a meeting where a panel would be established to review the control measures. The panel findings were to be circulated to the parties by October 1989, and the Protocol can be amended when they hold their second meeting in 1990. 11 INT'L ENV'T REP. (BNA) 584 (Nov. 1988).

266. Reisch & Zurer, *CFC Production: DuPont Seeks Total Phaseout*, CHEM. ENG. NEWS, April 4, 1988 at 4.

267. Steed, *Global Cooperation, Not Unilateral Action*, 5 ENVIR. FORUM 14 (1988). *Cf.* Makhijani, *supra* note 55, at 13.

268. Doniger, *supra* note 263, at 17.

269. Steed, *supra* note 267, at 15.

United States.[270] The Alliance for Responsible CFC Policy, an association of CFC producers, announced that it favors an orderly phaseout of the offending CFCs.[271]

CFC users also responded to the mounting scientific evidence. For example, the Food Service and Packaging Institute, a trade organization representing producers that use CFC blowing agents in the production of styrofoam food packaging,[272] called for a total phaseout of CFC-produced items by the end of 1988.[273]

Although there is increasing pressure to amend the Protocol, its status as a landmark in protective international environmental law should remain intact.[274] The Convention and Protocol can serve as a model for additional environmental legislation addressing problems in the global commons, such as global warming, hazardous waste transport, and acid rain.[275]

D. The Nitrogen Oxides Protocol

On November 1, 1988, the member nations of the UN Economic Commission for Europe (ECE)[276] signed the Nitrogen Oxides Protocol,[277] which calls for a freeze in nitrogen oxides emissions by 1994, based on 1987 emissions levels. The Nitrogen Oxides Protocol is a corollary to the 1979 Convention on Long-Range Transboundary Air Pollution.[278] Twelve of the twenty-five ECE Parties agreed to additional cuts of thirty percent over the next decade.[279]

Although designed primarily to address the adverse effects of ni-

---

270. 12 CHEM. REG. REP. (BNA) 1743 (March 3, 1989).

271. Zurer, *supra* note 263.

272. Although food packaging represents less than 3% of CFC consumption, it is one of the most visible, and therefore politically valuable segments. D. COGAN, *supra* note 23, at 104.

273. Zurer, *Food-packaging Producers to Stop Using CFCs*, CHEM. ENG. NEWS, April 18, 1988 at 5.

274. "The convention and the Montreal Protocol thus represent a significant step in the evolution of international environmental law from a mainly reactive system towards a preventive approach of managing a common resource." J. BRUNNÉE, *supra* note 154, at 253.

275. *See infra* notes 283-302 and accompanying text.

276. The ECE nations include the countries of East and West Europe as well as Canada and the United States. J. BRUNNÉE, *supra* note 154, at 175.

277. The full title is: 1988 Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution Concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes, INT'L. ENV'T. REP. (BNA) Ref. File 21:3041 (Jan. 1989).

278. Like the Vienna Convention for the Protection of the Ozone Layer, the 1979 Convention on Long-Range Transboundary Air Pollution failed to specifically define national responsibilities for implementing the Convention. *See* G. WETSTONE & A. ROSENCRANZ, *supra* note 158, at 140-46.

279. 11 INT'L ENV'T REP. (BNA) 581 (Nov. 1988). The U.S. has been urged to sign the declaration calling for the 30% emissions cuts as well. 23 ENV'T SCI. TECHNOL. 7 (Jan. 1989).

trogen oxide emissions associated with acid rain,[280] the Nitrogen Oxides Protocol will have an impact on ozone depletion as well. Since nitrogen oxides participate in the formation of ozone-depleting nitric oxide,[281] reduction in emissions should enhance ozone protection. But since nitric oxide also reacts with chlorine radicals, making the latter unavailable for catalytic destruction of ozone,[282] the effects of a reduction in nitrogen oxides emissions on ozone depletion remains to be evaluated.

E. Implications for Other Global Environmental Problems

While global warming is inextricably tied to the ozone problem, it is part of a larger picture of global atmospheric change.[283] Although the UNEP is studying global warming, it recognizes that the most practical solution is to cut energy production, a medicine industrialized and developing countries alike are unlikely to swallow.[284] Ozone protection was facilitated partly because alternatives to offensive CFCs are on the horizon and the number of CFC producers is small. However, the number of actors involved in reducing fossil fuel and biomass consumption is much larger, and "achieving a similar level of risk reduction through controls on carbon dioxide emissions during the next fifteen years via diplomatic negotiations would be virtually impossible."[285]

Participants at a recent conference[286] called for developed countries to reduce carbon dioxide emissions by twenty percent of 1988 levels by the year 2005.[287] Not only do the developing countries pose a threat to global warming through activities leading to deforestation,[288] but they also contribute to the greenhouse effect through in-

280. *See generally* G. WETSTONE & A. ROSENCRANZ, *supra* note 158.

281. *See supra* note 74.

282. *See supra* note 151.

283. *See supra* notes 132-51 and accompanying text for a discussion of global warming.

284. *Action to Save Our Environment*, 25 UN CHRONICLE 45 (June 1988).

285. Mintzer, *A Matter of Degrees: Energy Policy and Greenhouse Effect*, 17 ENV'T POLICY AND LAW 247, 253 (1988).

286. The 1988 Environment Canada sponsored conference on The Changing Atmosphere: Implications for Global Security.

287. Menyasz, *Scientists from 48 Countries View Tax on Fossil Fuel Consumption as Way of Helping Pay for Action Plan to Safeguard Global Atmosphere*, 11 INT'L ENV'T REP. (BNA) 414 (July 1988). Participants called for a tax on fossil fuel consumption to fund an action plan to protect the atmosphere. Part of the fund would be used to assist developing countries in adapting to the warming trend. *Id.*

288. Deforestation, which leads to a reduction in carbon-fixing vegetation, and an elevation in atmospheric carbon dioxide, is brought about partly through the demand of industrialized countries. Japan, for example, imports over half of all timber logged in tropical forests. 11

creased reliance on fossil fuels as energy sources.[289] One way of decreasing the reliance on fossil fuels is by expanding the use of nuclear energy.[290] However, it is not entirely clear that all nations look disfavorably on the effects of global warming, since warmer temperatures may make productive some areas currently nonproductive because of ice and snow accumulation.[291]

The strategies learned in negotiating the Montreal Protocol will undoubtedly play a key role in negotiations leading up to a framework convention on global warming.[292] While recognizing that preventing global warming is more difficult than protecting the ozone layer, the long-term cost of failing to take action makes it imperative that nations accept the environmental reality.

International hazardous waste transport is another global environmental issue now being addressed by the UNEP.[293] Like global warming, the solution to hazardous waste is not going to be easy, but regulating transboundary waste shipment may be more palatable to some than reducing fossil fuel consumption. One of the more pressing problems facing the UNEP in this arena is developing a list of what constitutes a hazardous waste.[294] To avoid conflict in the definition of hazardous waste among a treaty on international hazardous waste transport and existing international transport conventions, the UNEP employed strategy put to good use during the negotiations leading up to the Montreal Protocol. It invited legal and technical groups to de-

---

INT'L ENV'T REP. (BNA) 395 (July 1988). *See also* Giaimo, *Deforestation in Brazil: Domestic Political Imperative—Global Ecological Diaster*, 18 ENV'T L. 537 (1988). The cost of re-establishing vegetation in twenty-three "desperate" countries will be about $8 billion. 11 INT'L ENV'T REP. (BNA) 289 (May 1988).

289. 12 INT'L ENV'T REP. (BNA) 60 (Feb. 1989). Economic growth in the developing countries will lead to their dominating the contribution to the greenhouse effect in 30 to 40 years. *Id.*

290. *Id.* at 418. The cost of substituting nuclear for fossil fuel energy would be staggering. Construction of one plant every three days over a period of 40 years at a cost of $229 billion per year would be required to completely eliminate reliance on fossil fuels. *Id.* at 415.

291. Alm, *Global Warming: Is an International Consensus Possible?*, 23 ENV'T SCI. TECHNOL. 151 (Feb. 1989). "One Soviet scientist, for example, perceives global warming as a second 'garden of Eden,' presumably creating new warm water ports and opening up the vast steppes of Siberia to agriculture." *Id. See also* Schneider, *supra* note 136. "If the Cornbelt in the United States were to move north and east by several hundred kilometers, then a billion dollars a year lost in Iowa farms could well eventually become Minnesota's billion dollar gain." *Id.* at 777.

292. Menyasz, *supra* note 287, at 417.

293. *See generally* Vir, *Toxic Trade With Africa*, 23 ENV'T SCI. TECHNOL. 23 (Jan. 1989). *See also* O'Sullivan, *UN Environment Program Targets Issue of Hazardous Waste Exports*, CHEM. ENG. NEWS, Sept. 26, 1988 at 24.

294. *Id.*

velop a plan that could be modified as the Convention developed.[295] In a lesson also learned through negotiating the Protocol, the UNEP insured the participation of the chemical industry in discussions leading up to the Convention. UNEP Executive Director Tolba states: "It's no good having governments agree on something that industry won't be able to implement."[296] This sensible approach recognizes industry as a key player in resolving environmental issues.[297] Since transboundary waste shipment has a profound impact on the developing countries, which are often repositors of the shipments, negotiations require substantial involvement of the developing nations. The Conference of Plenipotentiaries on the Global Convention on the Control of Transboundary Movements of Hazardous Wastes approved a treaty (Basel Convention) governing international hazardous waste transport in March of 1989.[298]

Acid rain is a transboundary environmental problem epitomizing the need for international control strategies.[299] While the Nitrogen Oxides Protocol[300] and other regional agreements[301] designed to minimize the effects of acid rain address the problem, economic growth in the developing countries will lead to conditions causing acid rain in those countries if controls are not established.[302]

Undoubtedly, the future will reveal global environmental problems unknown to present generations. Materials discarded in space by manned flights and by deteriorating manned and unmanned space craft for the moment pose a minimal threat to life on Earth.[303] But increasing activity in space will only exacerbate the problem of "space waste," which will inevitably pose an environmental threat not only to life on Earth, but to humans traveling in space as well.[304] Strategies for protecting the environment of the space frontier lend

295. *Id.*

296. *Id.* at 25.

297. *See* Veldhuis, *The Multi-National Company and the Environment*, 3 EARTH L.J. 164 (1977).

298. 19 ENV'T POLICY AND LAW 38 (1989).

299. *See generally* G. WETSTONE & A. ROSENCRANZ, *supra* note 158.

300. *See supra* notes 276-82 and accompanying text.

301. J. BRUNNÉE, *supra* note 154.

302. *Id.*

303. While most space debris burns up in the atmosphere on re-entry, a few pieces, some containing radioactive materials, manage to reach the lower atmosphere or terrestrial surface. *See* Schafer, *Solid, Hazardous and Radioactive Waste in Outerspace*, 19 CAL. W. INT'L L.J. 1 (1988). While space is not generally considered an "ecosystem" deserving of protection, the threat is real. Space waste "consists of an amazing collection of waste, in a variety of sizes, the detritus of almost thirty years of humanity's exploration of the space frontier." *Id.* at 3-4.

304. *Id.* at 5-11.

themselves well to the lessons learned in negotiating global environmental problems on the terrestrial surface. At this point, one can only dream about how future generations will deal with this and other environmental issues of their day.

IV. CONCLUSION

Scientific evidence is mounting that human activities cause a reduction in atmospheric ozone, endangering health and threatening global ecosystems. That the Vienna Convention, Montreal Protocol, and Nitrogen Oxides Protocol can retard, but not eliminate, the threat should in no manner diminish the importance of these international legal and policy documents. They are an important first step taken toward controlling a global environmental problem and leave open the means for changing the control measures as scientific evidence warrants.

In the early days of space exploration, planetary scientists envisioned one day being able to transform the atmospheres of other, currently inhospitable, planets to make them suitable for human habitation. That process, theoretically feasible, is called "terraforming."[305] But human activities on Earth have changed our own atmosphere. These three control strategies give us hope that humankind can reverse the damage wrought on our own atmosphere, leaving us time to terraform the atmospheres of other worlds. As the inventors of CFCs could not have envisioned back in the 1930s the dangers posed by their product, future generations will no doubt discover that activities considered safe in our time pose a threat to them in theirs. As it is inevitable we will leave them this legacy, we should establish now the means by which to address those problems.

C. Patrick Turley

305. C. SAGAN, THE COSMIC CONNECTION 148 (1973).