

**Ozone Layer Depletion and its Prevention:
From Theory to Practice**

Abdul Jabbar and Asif Munir

Working Paper Series # 10
1993

All rights reserved. No part of this paper may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or information storage and retrieval system, without prior written permission of the publisher.

A publication of the Sustainable Development Policy Institute (SDPI).

The opinions expressed in the papers are solely those of the authors, and publishing them does not in any way constitute an endorsement of the opinion by the SDPI.

Sustainable Development Policy Institute is an independent, non-profit research institute on sustainable development.



© 1993 by the Sustainable Development Policy Institute

Mailing Address: PO Box 2342, Islamabad, Pakistan.
Telephone ++ (92-51) 2278134, 2278136, 2277146, 2270674-76
Fax ++(92-51) 2278135, URL:www.sdpi.org

Table of Contents

Abstract	1
Introduction	1
Ozone Depletion and life on Earth	1
Ozone	2
Ozone Layer	3
Formation of Ozone	3
Machanism of Depletion.....	3
Ozone Hole	4
Machanism of Hole Formation.....	4
Current Status	5
Ozone Layer Monitoring	5
Ozone Depleting Substances (ODS)	6
Effects on Ozone Layer	8
Bowing Agent.....	10
Measures of Reduction	11
Alternative Cleaning Agents	12
Alternative Cleaning Technologies	12
Measures for Reduction of Carbontetrachloride (CTC).....	13
Measure of Reduction of Fire Extinguishers.....	13
Specific Measures of Reduction.....	15
Ozone Depleting Substances in Pakistan	18
Current Situation of the Use of Ozone Depleting Substances	18
Technical Problems to Reduce the use of Ozone Depleting Substances.....	19
Awareness Among the Relevant Industries	20
Efforts of user Industries to Reduce the use of Ozone Depleting Substances	20
Pakistan and the Ozone Issues	21

References..... 23
Annex I 26
Annex II 27
Annex III..... 30

The Sustainable Development Policy Institute is an independent, non-profit, non-government policy research institute, meant to provide expert advice to the government (at all levels), public interest and political organizations, and the mass media. It is administered by an independent Board of Governors.

Board of Governors:

Mr V. A. Jafarey
Chairman of the Board

Khalid Ahmed
Editor, AAJ KAL

Syed Babar Ali
Advisor, Packages Ltd.

Dr Tariq Banuri
Executive Director, SDPI

Dr Parvez Hassan
Senior Partner, Hassan & Hassan Advocates

Aban Marker Kabraji
Country Representative, IUCN-Pakistan

Sohaib Sultan Khan
Senior Advisor, NRSP

Dr G. M. Khattak
Co-ordinator, Sarhad Provincial Conservation Strategy

Abdul Rahim Mahsud
Regional Representative for West Asia, Nippon Gieken Associates

Dr Atta-ur-Rahman
Director, HEJ Research Institute, Karachi University

Imtiaz Ahmed Sahibzada
Secretary, Environment and Urban Affairs Division

Dr Arshad Zaman
Former Chief Economist to the Government of Pakistan

Under the Working Paper Series, the SDPI publishes research papers written either by the regular staff of the Institute or affiliated researchers. These papers present preliminary research findings either directly related to sustainable development or connected with governance, policy-making and other social science issues which affect sustainable and just development. These tentative findings are meant to stimulate discussion and critical comment.

Ozone Layer Depletion and its Prevention: From Theory to Practice

Abdul Jabbar and Asif Munir

Abstract

This paper attempts to serve a dual purpose. Firstly, it provides background information on the process of stratospheric ozone depletion with the intention to exploit the existing global information on the measures to reduce the use of ozone depleting substances, existing alternatives, the current developments and hence creating a supportive frame work for Pakistan to control the domestic problem. Secondly it provides an overview of the state of ODS in Pakistan i.e. in which industries they are used, problems in the reduction of their use, awareness and efforts to reduce its use in Pakistan.

We are hopeful that this paper will provide necessary information to the policy makers to tackle this problem e.g., by providing alternatives, by enumerating the role of the environment protection agencies, user industries and the government itself to reduce the use of these substances. We are confident that the general public who have a genuine concern over ozone depletion will derive benefit from our effort.

Introduction

The fact that environment influences terrestrial life is readily apparent. At the same time, it is all too clear that humans and other constituents of the biosphere affect environment significantly. Human activities during the last century involving particularly landscape modification, resource exploitation and effluent flow have reached sufficient magnitude as to bring unpredictable effects on eco-system. These anthropogenic changes have raised many serious global environmental issues, particularly the destruction of earth's protective stratospheric ozone layer by manmade chemicals (Frederic 1990 and Caldwell et al. 1989) like **chloro-fluorocarbons** (CFCs), **halons** (H), **carbon-tetrachloride** (CTC), **1,1,1-Trichloro-ethane** (TCA), **methyl bromide** and various others (Annex A and B). According to Mostafa K. Tolba, former executive director United Nations Environment Programmes, "Life on Earth depends on the presence of this ozone as it does on the presence of oxygen and water. Without it, lethal levels of ultraviolet radiations would reach the Earth's surface, extinguishing life on the green planet". One of the detrimental outcome is the appearance of **ozone hole** over Antarctic due to the release of these chemicals (Farman et al. 1985), thus shifting the natural radiation balance and creating problems for existence.

Ozone Depletion and Life on Earth

The major effect of the stratospheric ozone depletion is an increase in the amount of Ultraviolet Beta radiations (290-320 nm) reaching the biosphere (Lubin et al. 1989 and Frederick et al. 1988). This increase in solar Ultraviolet Beta radiation has potential impacts on the biosphere, human health and natural eco-systems, both aquatic and terrestrial, and agriculture (UNEP 1991). Some of the possible harmful effects are damage to the eye (Jones R. 1987), development of skin cancer (De Fabo et al. 1979, Yukio Takizawa 1990), erythema

(Parrish et al. 1983) and suppression of the immune system (UNEP 1989). It was predicted that a 1% reduction in the amount of ozone gives an approximate 2 % increase in UV-B (Yukio Takizawa 1990) and then a 2.5% increase in the basal skin cancer (Yukio Takizawa 1987) and 2% increase in overall skin cancer (Henricsen et al. 1990). Apart from these effects to the human beings, ozone depletion also effects terrestrial plants, aquatic ecosystem, tropospheric air quality and material like wood and plastics.

Numerous studies have been conducted on the effect of UV-B on plant growth and development, (Teramura et al. 1983; Bacionmy 1982; Cen et al. 1990 and Krizek 1975) anatomy, and physiology (Caldwell 1971; Teramura 1980 and Teramura 1983). Effects on plants include reduced growth (measured by leaf area and plant height) and photosynthesis (Tevini et al. 1989). Action of intense UV-B (280-320 nm) on the photosynthetic apparatus has been studied by several workers (Brandle et al. 1977; Iwanzik et al. 1983 and Renger et al. 1989). PS II electron transport system was found to be effected by UV-B radiations. Field and green house studies have shown that growth and photosynthesis are negatively affected by enhanced UV-B radiation in some trees species (Termura et al. 1991).

The effect of depleted ozone layer might be a reduction in the Phytoplankton population (Bidigare et al. 1989; El-Sayed et al. 1989 and Hader et al. 1987). In the oceans phytoplankton may move closer to the sea bed to avoid additional ultraviolet radiation, which would result in the reduction of the photosynthesis and the population of the phytoplankton. According to one estimate the total phytoplankton population will decrease 1% for each 1% loss of ozone (Hader 1991). This decrease in phytoplankton population may have an adverse impact on the aquatic food chain as aquatic ecosystem contributes more biomass (104/Gt/a) than all terrestrial ecosystem (100/Gt/a) combined (UNEP 1991). Current data suggest that predicted increase in UV-B radiation could have important negative effects on the marine environment (D,-P Hader et al. 1991).

The effects on biological system are very well documented (Coohill 1991) and damage to the DNA molecule is alarming. These include such photochemical changes as pyrimidine dimers, 6-4 photo products, DNA-protein cross links and lesions that may lead to single and double strand breaks (Peak et al. 1990; Mitchell et al. 1989 and Ananthaswany et al. 1990). If these lesions remain unpaired it can lead to mutation or even cell death. The biodiversity, nitrogen assimilation and sink capacity for atmospheric carbon dioxide, will decrease, thus increasing the green house effect. These resulting UV-B radiation can also effect the tropospheric air quality by producing some very reactive radicals molecules, thus increasing the chemical reactivity of the troposphere, resulting in an increase level of ozone and other harmful oxidized products, such as hydrogen peroxide and acids (Gery 1991). Exposure to the solar radiation causes degradation of material such as wood and plastics thus leading to their shorter out door life time (Andrady et al. 1991). The continued emission of the Ozone depleting substances would thus deplete the stratospheric ozone layer with adverse consequences for global ecological systems.

Ozone

Ozone (O₃) was first discovered by C. F. Schnbein in 1839. It is a triatomic allotrope of oxygen (a form of oxygen in which the molecule contain three atoms instead of two as in the common form). It is an irritating, pale-blue gas that is explosive and toxic, even at low concentration (Encyclopaedia Britannica). It occurs naturally in small amounts in the Earth's stratosphere, where it absorbs solar ultraviolet radiation. Under certain conditions, photochemical reaction between nitrogen oxides and hydrocarbon in the lower atmosphere can produce ozone in concentrations high enough to cause irritation of eyes and mucous membrane (Encyclopaedia Britannica).

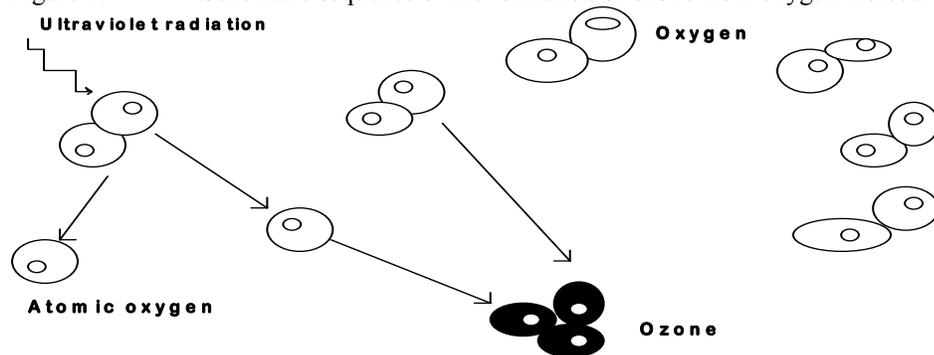
Ozone Layer

The ozone layer refers to a layer in the atmosphere, which spreads in the stratosphere and is in high concentration. This layer has its maximum partial pressure in the lower stratosphere at a level of 19-23 Kms above the Earth. The stratosphere contain 90 % of all ozone in the atmosphere. If all the ozone molecules in the atmosphere were transferred to the Earth surface, they would assume a thickness of only 2.5-3.5 mm at average surface temperature and pressure (WMO 1992). Ozone, being a molecule composed of more than two atoms has many absorption bands and particularly in the UV range at wavelengths less than 0.3 μm . Stratospheric ozone layer plays a very important role for the protection of human life and the whole ecosystem. It filters most of the **ultraviolet beta** radiations from the sun, buffer the ecosystem from harmful ultraviolet rays and also absorbs the solar energy for warming the stratosphere to maintain the present climate conditions familiar to the ecosystem.

Formation of Ozone

In the stratosphere ozone is produced as a result of the dissociation of oxygen molecule by the intense UV component of the sunshine. The single oxygen atom (O) combines with other oxygen molecule (O_2) to form ozone (O_3) as shown in figure 1.

Figure 1: Schematic sequence of the formation of ozone from oxygen molecules.

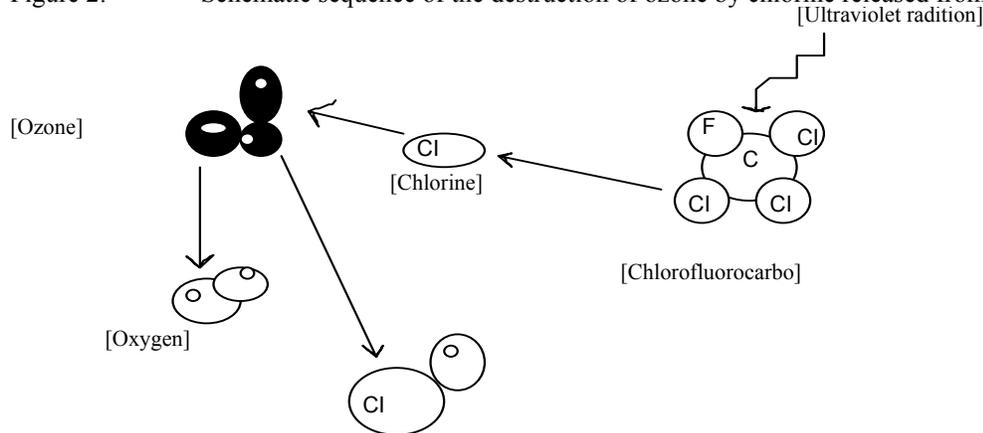


Mechanism of Depletion

Stratospheric ozone is gradually broken down to O and O_2 by the absorption of short wavelength UV radiations, but are created simultaneously when this atomic oxygen combines with other oxygen molecules, thus there exists an equilibrium between the rates of creation and destruction. The growing body of scientific evidence which is clear that this equilibrium was disturbed by the introduction of man made substances that increase the rate of conversion of O_3 back to O_2 . In 1974 Professor F. S. Rowland and Dr. M. J. Molina, University of California, Irvine, in the United States, presented a report on the possible effects of **Chlorofluorocarbons** (CFCs) on the ozone layer, human beings and the ecological system. According to Dr. Robert T. Watson adviser to the United Nations Environment Programme (UNEP) "There is no doubt that ozone depletion is occurring primarily because of the human activities". CFCs, because of their thermal and chemical stabilities, rise to the stratosphere and are decomposed by UV-B radiation from the sun, releasing **free chlorine atoms**. These free chlorine atoms react with ozone

and form short lived ClO and oxygen (shown in figure 2). This ClO again reacts with a free oxygen atom to form oxygen molecule, leaving the free chlorine atom ready to decompose another ozone molecule, thus shifting natural **ozone balance**.

Figure 2: Schematic sequence of the destruction of ozone by chlorine released from a CFC molecule.



Ozone Hole

One of the adverse effects of this shift in the natural balance is the appearance of **Ozone Hole** (Farman et al. 1985). The ozone hole over Antarctica, appears every austral spring since late 1970s. It is a region remarkably small in total ozone¹. In 1987 an ozone hole with the total ozone decreased to less than 50 % of the mean value of the 1970s appeared around 75⁰S. This ozone hole is not confined to Antarctic. A UNEP report by Kelvin Fay, executive director of the Alliance for a responsible CFC Policy, said "Ozone layer depletion is no longer confined to Antarctica and the Northern Hemisphere in winter at mid-high altitudes, but now exists in the middle and high latitudes of both hemispheres in spring, summer and winter. Ozone depletion in the middle and high latitudes means it covers almost all of North America, Europe, the Commonwealth of independent States, Australia, New Zealand and a sizeable portion of Latin America".

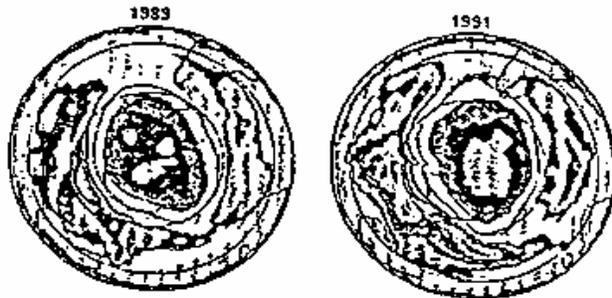
Mechanism of Hole Formation

The mechanism of ozone hole formation is very complex. At south pole the polar vortex is formed in winter and if the polar vortex grows sufficiently it restricts the exchange of air between the inside and outside of the vortex. In winter the polar night region not exposed to sunlight spreads around the pole and so the vortex temperature inside drops even upto -90°C (Tomoyuki 1992). At -78°C, nitric acid and water in the stratosphere are frozen to form clouds composed of ice particles of micron size i.e., Polar stratospheric clouds (PSCs). Laboratory experiments confirmed that on the surface of these ice particles, **chlorine nitrate** react with **hydrogen chloride** and **water**, to form **chlorine gas** and **hypochlorous acid**, thus increasing the concentration of chlorine and hypochlorous acid in the stratosphere. These two are photo dissociated to discharge active **chlorine atom** to deplete ozone, thus decreasing the ozone in the polar vortex. The absorption of solar energy in the period from spring to

1. Total ozone is defined as being equal to the amount of ozone contained in a vertical column of base 1 cm² at standard pressure and temperature

summer gradually raises the temperature, finally destroying the vortex and allowing the exchange between the air inside and outside of the polar vortex, thus fritter away the ozone hole. The devastating effect of the ozone depletion, as observed by the satellite (NIMBUS-7) is shown in the figure 3.

Figure 3: Total ozone over southern hemisphere on 1st October 1989 and 1991 (Source NASA-GSFC)



Current Status

The ozone values, in different parts of the world, recorded in 1992 are very alarming. The regional average ozone in January over Northern Europe was 20% below the normal values, Canada 16%, and Russia, during whole of February and March it was 15% (UNEP 1991). At the end of January 1992, for a few days, total ozone values as low as 190-210 m atm cm were observed over Central Europe and the European part of the Russia which is 40-45 percent below the normal, thus showing a more negative deviation over the entire period of systematic ozone measurements since 1950 (UNEP 1991).

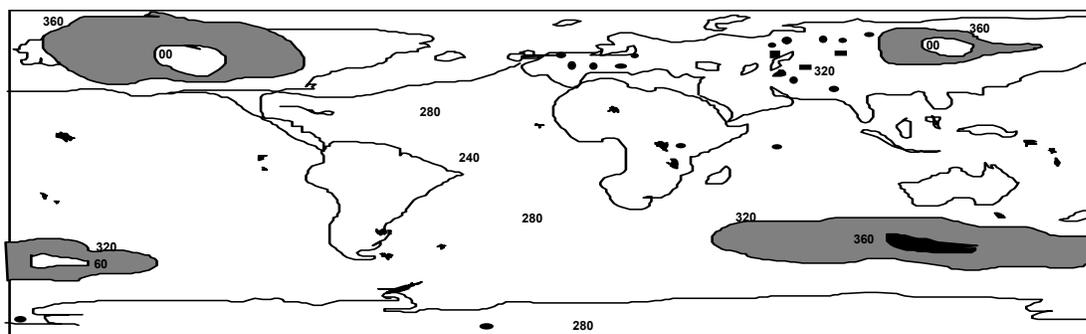
Ozone Layer Monitoring

Following the International Geophysical Year (IGY) in 1957 World Meteorological Organization (WMO 1992) assumed the responsibilities of ozone observation and the Global Ozone Observing System (GO₃OS) was established. At present GO₃OS plays a key role in the international systematic observation of the ozone layer. The network of GO₃OS conducts the observation by a variety of instruments, at ground based and balloon born stations. These include:

1. Dobson Spectrophotometer
2. Brewer Spectrophotometer
3. Ozonometer.

Measurement is also conducted by **rockets**, ground based **UV-photometer**, **laser heterodying system** and **microwave radiometry**. (Mitra 1991). The observation stations of GO₃OS include about **140 ground observation stations**, **121 total ozone observation stations** and **40 Umkehr** observation stations in **60** countries round the world. The observation data are collected at the World Ozone Data Center (WODC), located in the Atmospheric Environment Service Toronto, Canada. The center performs the basic quality checks of data stores, and distributes to the relevant agencies. Location of different ozone monitoring stations is shown in the figure 4

Figure 4: Location of the active Ozone observing stations with an indication of ozone distribution (source WMO 1992)



Ozone Depleting Substances (ODS)

It is now clearly evident that Chlorofluorocarbons specially those given in Table 1 are the major substances responsible for the depletion of ozone layer. These compounds have a multiple usage because of their properties as refrigerants, aerosol propellants, solvents, blowing agents and fire extinguisher.

Table 1: Ozone Depleting Substances

Substances	Chemical formula	Name of the compound
CFCs		
CFC-11	CFCl_3	Trichlorofluoromethane
CFC-12	CF_2Cl_2	Dichlorodifluoromethane
CFC-113	$\text{C}_2\text{F}_3\text{Cl}_3$	1,1,2-Trichlorotrifluoromethane
CFC-114	$\text{C}_2\text{F}_4\text{Cl}_2$	Dichlorotetrafluoroethane
CFC-115	$\text{C}_2\text{F}_5\text{Cl}$	Pentafluorochloroethane
Halons		
H-1301	CF_3Br	Bromotrifluoromethane
H-1211	CF_2ClBr	Bromochlorodifluoromethane
H-2402	$\text{C}_2\text{F}_4\text{Br}_2$	Dibromotetrafluoroethane
Chlorinated solvents		
CTC	CCl_4	Carbontetrachloride
TCA	$\text{C}_2\text{H}_3\text{Cl}_3$	1,1,1-Trichloroethane
Fumigant		
Bromomethane	CH_3Br	Methyl bromide

Source: Article 3 of the Protocol, Annex A and B.

Chlorinated Solvent

Several chlorinated hydrocarbons have been manufactured on industrial scale, mainly as solvents in surface treatment, dry cleaning and extraction facilities or as feed stock for the production of essential products. As a result of the amendment to the Montreal Protocol adapted in London on June 1990, two chlorinated compounds **Carbontetrachloride** and **1, 1, 1-trichloroethane** have been specified as ozone depleting substances, because only these two have sufficiently long life time in the atmosphere to enable them to be transported to high altitudes, thus effecting the ozone layer. On the other hand most chlorinated hydrocarbons are broken down in the lower atmosphere chemically or by photolysis.

1,1,1-Trichloroethane (TCA)

TCA is a versatile multipurpose solvent and has been used in large quantities in a variety of industries because of its solvent properties, non-flammability under normal condition of use and relatively low toxicity. However, its degrading capability is high and solvency with organic substances is exceptional. It is possible to reclaim and recycle its contaminated solvent through distillation. Other properties include low viscosity and surface tension, high permeability, high vapour density. It is because of these properties that the demand for TCA has been increasing rapidly in the recent years. In the year 1988, for cleaning purpose, 580,000 tons of TCA was used by United States, Europe and Japan. The use of these cleaning agents by percentage in these countries is 55%, 75% and 76% respectively. 1 to 13% is used for aerosols, adhesives, electronics and coatings (Manual for reduction in the use of ODS 1992). Because of its long life time 10 to 15% of total emission of TCA reaches the stratosphere where its chlorine contributes to the depletion of the stratospheric ozone layer. (H. Kurita 1993)

Carbontetrachloride (CTC)

Carbontetrachloride is mainly used as a reaction medium because of its characteristic properties like inertness, solubilization of resinous material and reaction products. It is for special purpose solvent and intermediate for synthesis in the industrial countries because of its high toxicity. The current main use of carbontetrachloride is shown in Table 2.

Table 2: Current Main Use of Carbontetrachloride

Carbontetrachloride	Purpose of use	Product	Usage
	Chlorinated Solvent	Rubber chloride, chlorinated polyethylene	Paint, adhesive, printing ink.
	Chlorosulfonated solvent	Chlorosulfonated polyethylene	Water proofed cloth, paints, general forming

Source: Manual for reduction of ODS.

Methyl Bromide

Methyl bromide (CH_3Br) or Bromomethane is a colourless liquid, which forms a colourless odourless gas and has a chloroform like smell at high concentration (Pesticides Manual 1983). The gas can penetrate many substances, including impermeable materials such as concrete, leather and rubber. It forms a crystalline hydrate with ice water: soluble in most organic solvents, stable, non-flammable, corrosive to aluminium, magnesium and their alloys. It is an effective methylating agent reacting with basic amines to form methylammonium bromide derivatives, practically soluble in water and a voluminous crystalline hydrate below 4°C . It is highly toxic to man, the threshold limit value being 65 mg/m^3 above which concentration respirators must be worn. It is packed in glass ampoules (upto 50 ml), in metal cans and cylinders for direct use. Chloropicrin upto 2% is sometimes added, as a warning agent. Some of the physical properties are shown in the Table 3

Table 3: Properties of Methyl bromide

Freezing point (1 atm).	-93°C
Boiling point.	3.56°C
Critical temperature.	194°C (H)
Autoignition temperature.	536.7°C
Density	
20°C	3.974kg/m^3
0°C	1730kg/m^3

Source: Pesticide Manual

It is a potent insecticide with some acaricidal properties and is mainly used for space fumigation and for the fumigation of plants and plant products in stores, mills and ships. It is also a soil fumigant used for the control of fungi, nematodes and weeds (Maw 1973). It is a broad spectrum fumigant biocide applied to soil prior to planting to control arthropods, bacteria and other pests for crops such as tomatoes, strawberries, peppers, tobacco and ornamental nurseries (Encyclopaedia Britannica). In France and United States it was effectively used for killing stored pests and soil pests since 1930s. Out of total annual production and sales of methyl bromide for the years 1984-1990, about 66,644 tons, Asian region (excluding India, China etc.) utilized 14, 605 tones of it for different uses like soil fumigation, quarantine and non-quarantine commodity treatments, including fumigation of durable and perishable food commodities and as a structural fumigant.

Effects on Ozone Layer

Observation of stratospheric bromine show that bromine is directly involved in the catalytic destruction of the ozone layer in the lower stratosphere, and is considerably more effective than chlorine in destroying ozone on a per molecule basis. The substantial role of bromine in polar ozone loss, as well as in mid latitude ozone destruction has become clear through a variety of direct observations. Although bromine is present in the stratosphere in concentrations a hundred-fold less than chlorine yet after the elimination of long lived CFCs and Halons under regulations, the release of short lived chlorine and bromine containing compounds becomes more important in the depletion of ozone layer. Methyl bromide is the major contributor to the stratospheric bromine. According to WMO estimate of 1992 if the global methyl bromide abundance was reduced by only 10%, the ozone layer protection achieved would be approximately equivalent to an advance of the CFC phase out schedule by upto three years. The mechanism of depletion is similar to that of chlorine. In the stratosphere methyl bromide is decomposed by photolytic reactions, thus releasing the **bromine** that contribute to the depletion of the ozone layer. The catalytic destruction of ozone layer by the bromine varies significantly with latitude, altitude and seasons. Bromine is responsible for 20-30% loss of the ozone during the formation of ozone hole in the Antarctic stratosphere.

Chlorofluorocarbons (CFCs)

The term "fluorocarbon" is used for a group of **alkane**, which contain **fluorine** atom in their molecules. It is completely halogenated i.e. containing **chlorine, fluorine** and no hydrogen. They are very stable in the troposphere, then diffuse to stratosphere and decompose by Ultraviolet beta radiation from the sun and deplete the ozone layer. CFCs were introduced for the first time to the world as a safe refrigerant, in 1930 by Toma Midgley, since then the application have been steadily expanded. Various CFCs currently in use, with their ODPs are shown in Table 4.

Table 4: CFCs with their Ozone Depleting Potentials

Substance		Ozone depleting potential
CFCl ₃	(CFC-11)	1.0
CF ₂ Cl ₂	(CFC-12)	1.0
C ₂ F ₃ Cl ₃	(CFC-113)	0.8
C ₂ F ₄ Cl ₂	(CFC-114)	1.0
C ₂ F ₅ Cl	(CFC-115)	0.6

Source: Handbook on Montreal Protocol

Other include **CFC-13, CFC-111, CFC-112, CFC-211, CFC-212, CFC-213, CFC-214, CFC-215, CFC-216 and CFC-217** with ozone depleting potential of **1.0**. These substances are used in a number of industries because of their characteristics properties such as thermal stability, non flammability, low toxicity, low corrosiveness, heat conductivity, selective solubility, no colour and no odour. These and many other properties resulted in a multiple usage of these substances as refrigerants, aerosol propellant, blowing agent in foam industry and cleaning agent.

Aerosols

Aerosol packaging is a very popular method for storing and dispensing consumer and industrial products including insecticides sprays, household products (air freshners, cleaners polishes and laundry products), personal products (hair sprays and other hair care products, shaving foam, colognes and perfumes, medical and pharmaceutical sprays), automotive (anti fog sprays). Generally aerosols contain active ingredients, the solvent or carrier and the propellant (usually liquified gasses). They are contained in a can or bottle as a liquid under pressure and have the ability to ensure constant pressure throughout the life of the aerosol.

The choice of the propellant or solvent in an aerosol product depends on the type of the product. CFCs are the ultimate choice as propellant in different type of aerosols. Although CFC-11, CFC-12, 113, 114 and 1,1,1-trichloroethane can be used in aerosol products, the most commonly used world wide are CFC-11, and CFC-12. In the mid 70s these aerosols accounted for approx. 60% of the total use of CFC-11 and CFC-12. The total sale of CFC-11 and CFC-12 as aerosol propellant dropped from 432,275 tones (1976) to 95,739 metric tones (1989). About 65,000 tones of CFC-11 and 12 was used by Russia only in aerosol products in 1986 while the estimated figure for China is about 4,700 tones for 1990. Roughly, the total amount of controlled CFC, in aerosol products 1989 world wide is around 180,000 tones which is approximately 20% of the total CFCs produced that year (JICA 1993).

Refrigerant

The ability to absorb heat without increase in temperature is the basis for refrigerant. CFCs are proved to be the exceptional choice due to their characteristics properties. R-11 has been used for the refrigeration capacity range from 1000 to 3000 US tons, being a refrigerator with a low operating pressure R-11 not only features operational safety and ease of use but is also characterized by its high theoretical cycle efficiency which is best for energy saving operations, moreover they are chemically stable and hard to dissolve. These CFCs when discharged into the atmosphere become more stable which helps them stay longer in the atmosphere and cause ozone depletion with the joint effect of UV from the sun.

The quantity of R-11 used for centrifugal refrigerating machines is estimated to be about 8 to 9% of the total consumption of the R-11, because of its properties like small specific volume, high performance coefficient and thermal conductivity, low viscosity and reactivity, non-corrosive, non-toxic and non-stimulant, cheap and good market availability. For commercial refrigeration CFC-12 and R-502 (containing 51.2% CFC-115) are used as refrigerant in automobile air conditioners and household electric refrigerators, depending on the compressor type and working temperatures, R-502 (low temperature) and CFC-12 or HCFC-22 (medium temperature) are used (JICA 1993). In Japan a total of 28,800 tones of CFCs were used as refrigerant for different applications. For R-12 the figures grow from 9000 tones (1986) to 24,900 tones (1989). In Pakistan many commercial buildings are using R-22 (an HCFC) as refrigerant, where as for automobile and air conditioners R-12 is being used. According to a survey United States accounted for 50%, Europe 21%, Japan 13% and rest of the world 16% of the total use of HCFC for the year 1991 (JICA 1993).

Blowing Agent

Foams are widely applied in different areas ranging from automobiles, electric appliance, plants and buildings to goods for every day life. CFCs are mainly used as **blowing agent** in the foam industries, specially CFC-11, CFC-12, CFC-113 and CFC-114. According to an estimate made by the manufacturers of CFCs, the consumption of CFCs as blowing agent was 32000 tones in 1986 which grew to 39000 tones in 1988. The foams are of different types for example **flexible polyurethane foam, rigid polyurethane foam, rim urethane, polystyrene foam and polyolefin foam**. These different types of foams and their application fields are shown in Table 5

Table 5: Various Type of Foam with Specific Area of Use

Types	Application Fields
Flexible foam	Automotive upholstery (seat, crash pad, head rest, arm rest), bedding pad and furniture, sound absorbing material and insulating material
Rigid foam	Insulating material, electric refrigerators, plant and buildings materials, shipping and vehicles, packing
RIM	Automotive bumpers, steering wheel and arm rest etc.

Source: Manual for reduction in the use of ODS

CFCs are used alone or in combination with other CFCs in various industries. Various type of CFCs with specific area of use are shown in Table 6 .

Table 6: Specific Area of Use for CFCs

CFC-11/12	Area of specific use
Refrigerant	Automobile air conditioners, household refrigerators, industrial refrigerating machines, centrifugal refrigerating machine.
Blowing agent	Polystyrene, rigid polyurethane, flexible polyurethane
Aerosols	Products applied to human body, medical and pharmaceuticals

CFC-113 is utilized as **cleaning agent** for **precision cleaning**. In spite of their excellent characteristics properties, the use of these substances is alarming because of their ozone depleting potential as shown in the Table 4.

Halogenated Hydrocarbons (Halons)

These are acyclic saturated hydrocarbons in which one or more of the hydrogen atoms have been replaced by atom from the **halogen** series i.e. **Fluorine, Chlorine, Bromine** and **Iodine**. Most widely used halons are shown in Table 7.

Table 7: Halons (Chemical name and formulae)

Bromochlorodifluoromethane	CF ₂ ClBr	H-1211
Bromotrifluoromethane	CF ₃ Br	H-1301
Dibromotetrafluoroethane	C ₂ F ₄ Br ₂	H-2402

Most of the Halons designated by the Protocol are used for fire extinguishing. They possess exceptional fire fighting and explosive prevention or suppression effectiveness because they are non conductive, safe for human use and suitable for storage. Due to these properties they have been the choice for many fire fighting/protection situations, specially **communication rooms, research laboratories, warehouses, aircrafts facilities, ships** and **electronic equipments**. Categories for the location of installed fire extinguisher are shown in Table 8.

The total imports and exports of controlled substances reported by the Parties to the Protocol for the year 1986 is shown in the annex. Similarly the consumption of the controlled substances by the parties and non-parties for the same year is shown in Table 1 (Appendix VIII) of the Protocol. The estimated world production of H-1211 was 16,182 metric tones (1989) and 14,852 MT (1990), the same figures for H-1301 were 11,152 MT(1989) and 9,115 MT (1990). A significant reduction is very clear from these figures. In spite of their properties these substances have relatively higher **ozone depleting potential (ODP)** as shown in Table.

Table 8: Specific Areas for Installation of H-1121 Fire Extinguisher

Automobile parking lot	Automobile repair room, parking lot (mainly highrised mechanical system)
Electricity	Dynamo room, cable room, film depository.
Dangerous objects	Reservoir, paint handling workshop, workshop for using hydraulic equipment.
Communications	Communication room, studios.
Machinery room	Machinery room, kitchen.
Art objects	Exhibition room for art objects
Controlling	Control room, etc.

Table 9: Ozone Depleting Potential of Halons

Name of the substance	ODP
Bromochlorodifluoromethane	3.0
Bromotrifluoro methane	10.0
Dibromotetrafluoroethane	6.0

Source: Manual for the reduction of ODS

Measures of Reduction

The Vienna Convention for the protection of the Ozone layer in 1985 and the Montreal Protocol on Substances that deplete the ozone layer in 1987, were the starting points of global cooperation for protection of the ozone layer in the stratosphere. Basic measures for reduction of controlled substances include reduction in the short term and replacement with alternatives and transitation technologies in the middle and long term

1,1,1-Trichloroethane

The basic measure of reduction in the short and middle term for 1,1,1- trichloroethane include improvement in the operation of cleaning equipment, introduction of proper recycling and reclamation systems, and alternative cleaners and improved technologies.

Alternative Cleaning Agents

Alternate cleaners like alcohols, hydro chlorofluorocarbons, hydrocarbons and aqueous cleaning agents are shown in Table 10.

Some of the synthetic solvent with higher boiling points like **Acetophenone**, **N-methyl pyrrolidane**, and extracts from plant, i.e., **Xanthan gum** etc. can be used as alternatives. Some of the above mentioned cleaning agents like aqueous cleaning agents are still in the development stages, while some of them are already in market.

Table 10: Alternate Cleaning Agents

Aqueous cleaning agent	Alcohols	Hydrochlorofluorocarbons ²	Hydrocarbons
Combination of water with alkali, acid, surfactant, organic solvents	Ethyl alcohol Isopropyl alcohol Higher alcohols	HCFC-123 HCFC-141b HCFC-225ca HCFC-225cb	Distillate of petroleum Terpenee

Source: Manual for reduction in the use of ODS.

Alternative Cleaning Technologies

These include cleaning with liquids, solids and gases. Phase out plan set out by the Protocol for 1,1,1-trichloroethane is shown in Table 11.

Table 11: Schedule³ of Phase Out of 1,1,1-Trichloroethane

Period for reduction	Limitation Standard
After 1 January 1993	100 %
After 1 January 1995	70 %
After 1 January 2000	30 %
After 1 January 2005	0 %

Measures for Reduction of Carbontetrachloride (CTC)

Carbontetrachloride (CTC) finds limited use as a solvent in the manufacturing industry because of its high toxicity. In case of other uses like intermediate for pharmaceutical and agrochemicals, and catalyst sweetener in the oil industry, it is converted to substances which are non-ozone depleting. Basic measures of reduction include increase in recovery and recycling ratio, introduction of alternative solvents and development of alternative material.

Continued studies are essential to evaluate new substances to substitute CTC, at present, no solvent with a performance identical to CTC has been found. Phase out plan for Carbontetrachloride is shown in Table 12.

2. These are used as a substitute for some limited areas, for example HCFC-123, 141b and their mixture are used in precision and electronic cleaning.
3. Montreal Protocol

Table 12: Phase Out Plan of Carbontetrachloride

Period of Reduction	Limitation Standards
1989	100 %
1995	85 %
1999	0 %

Measures of Reduction for Fire Extinguishers

Many cases in which halones have been employed, alternative fire technologies or protection methods can be used to reduce the risk, although it may not provide the same degree of fire protection. For most applications considerable research and developmental work is required to obtain acceptable agent which has the efficiency of the existing halones. Basic measures of reduction include prevention of any accident like prevent leaks and faulty operations, use during testing of the instrument, research or experiments, restrict use only during the fire accidents and use of alternative fire extinguisher.

Alternative Fire Extinguisher

The available fire extinguishers are shown in Table 13.

Table 13: Available Fire Extinguishers

HCFC-125	CF ₃ CHF ₂
HCFC-125	CF ₃ CHF ₂
H-1201	CHF ₂ B

These are internationally agreed as alternatives. These substances have low ozone depleting potentials as compared to the substances currently in use as shown in Table 14.

Table 14: ODP of Halons

Substance	ODP
HCFC-125	0.02
HCFC-125C	0.0
H-1201	0.1

Basic and applied experiments and investigation of these alternatives are being carried out. Apart from these halogenated alternatives, there are non-halogenated fire extinguishing equipment like sprinklers, water spraying, bubbling fire extinguisher, carbon dioxide and powder fire extinguisher.

Another important step in the reduction for use of halons is the establishment of the **Halon Bank** under the decision **IV/26** of the parties to the Montreal Protocol. It urged the international recycled halon bank management. The most promising aspect of this bank will be the exchange of recyclable and recycled halons between national and international banks of parties to the Protocol for their essential use, thus eliminating the threats to the ozone layer by fresh productions. Phase out plan for halons is shown in Table 15.

Table 15: Phase Out Plan for Halons

Date of enforcement	Annual
1 January 1992	100% or less
1 January 1995	50% or less
1 January 2000	0%

Measures of reduction in the short and middle term include improvement in the methods of utilization of these compounds, improvement of instrument/equipments, improvement of recovery and recycling systems, reduction in the use of CFCs by introducing new blends of CFCs and other substances, development of alternative technologies and reduction through the use of existing alternatives. Existing fluorocarbons with specific area of use are shown in Table 16.

Table 16: Existing Fluorocarbons with Specific Area of Use

Area of use	Existing Fluorocarbon
Refrigerant.	CFC-114, HCFC-22, R-502, HCFC-152a, HCFC-142b.
Aerosols.	HCFC-22, HCFC-142b.
Blowing agent.	HCFC-123, HCFC-141b, HCFC-22,

Non fluorocarbons for use as refrigerant, aerosols, blowing agent and cleaning agent are also available. These are shown in Table 17.

Table 17: Non Fluorocarbon

Refrigerant	Aerosol	Blowing agent	Cleaning agent
Ammonia, adsorption refrigerator, lithium bromide.	LPG, DME, CO ₂ , N ₂	Water, air, propane, butane	Warm water, water/surfactant, IPA, ethanol, terpene, hydrocarbon.

Source: Manual for reduction in the use of ODS

New fluorocarbons with reference to specific area of use are also under development to substitute the controlled CFCs. These are shown in Table 18.

Table 18: New Fluorocarbon with Specific Area of Use

CFCs	Developing substitutes
CFC-12	HFC-134A, HFC-134a
CFC-11	HCFC-123, HCFC-141b
CFC-12/CFC-11	HCFC-134/HCFC-123
CFC-13	HCFC-225ca,cb, HCFC-123/HCFC141b/stabilizer

Source: Manual for reduction in the use of ODS

The above mentioned substances have very low or zero ODP as shown in the Table 19.

Table 19: Ozone Depleting Potential of New Fluorocarbons

Substances	Ozone Depleting Potential
HCFC-22	0.05
HCFC-123*	0.02
HCFC-134*	0.02
HCFC141b*	0.1
HCFC-142b	0.06
HCFC-225ca*	0.01
HCFC-225cb*	0.01
HFC-125*	0.00
HFC-134a*	0.00
HFC152a	0.00

Note: * = these substances are under development

Specific Measures of Reduction

CFCs

CFCs are playing an important role not only in bringing about comfortable environment with air conditioning equipment in hotels, homes and workshops etc., but also in transportation and distributions systems. It is therefore difficult to accept the immediate ban on these compounds.

Refrigerants

No refrigerants that substitute R-11 and R-12 are available in the market with equal potential. HCFCs are the transitional materials on the path to chlorine free, non-ozone depleting refrigerants. HCFC-22 is used upto 10,000 tons of cooling capacity, where as the use of HCFC-123 is restricted to chillers due to its low allowable exposure toxicity limits of 10 ppm. HCFs like 134a contain no chlorine, therefore, no ozone depleting potential. This special factor makes the HFC type refrigerant the most promising choice, although the price is high at present, HFC-134a (\$ 7.00/lb) as compared to HCFC-22 (\$ 1.20/lb) and HCFC-123 (\$ 5.60/lb).

In order to reduce the use of refrigerant various measures have to be taken in the short and long term. Short term measures include reduction of leaks and least emission into the air when repairing or charging air conditioners, improvement of equipment's (Air tightness, use of welded structure where possible to prevent leakage, use of special material for **sealing, filling and hoses**, proper fastening of the piping joints, over charging of the refrigerator and enhancement of the efficiency of the heat exchanger. Where as long term plans include development of alternative refrigerants, new equipments or alterations in the current system to cope with the alternatives and research on new refrigerating systems.

Blowing agents

CFCs blown foam contributed significantly to energy saving purpose because of their heat insulation properties. Both foams **flexible** and **rigid** yield many kinds of products which are widely used in automobile, electric appliance plant and building goods for every day life. Different type and their application fields are shown in Table 20.

Table 20: Type and Application Field of Foams

Type	Blowing agent	Application field
Slabstok foam	CFC-11	Automobile upholstery, bedding pads, sound absorbing and insulating material
Flexible molded foam	CFC-11	Automotive seats, crash pads, head rest , arm rest
RIM	CFC-11	Automotive bumpers, steering wheel, arm rest
Rigid foam	CFC-11	Insulating material, packing, plant and building material

Source: Manual for reduction in the use of ODS

Specific measures of reduction involve increase in the proportion of water blowing, use of known alternatives, evaluate foaming with higher mold temperature, minimize and control exhausting of CFC-11 in different steps, shift to high density products, use of HCFCs with low ozone depleting potentials, evaluate foaming with water only, improvement of manufacturing process to increase thermal insulating properties and improvement of instrument to cope with the alternatives.

Aerosols

Reduction measures to reduce the use of ODS in aerosol products include use of substituted propellant e.g. liquified petroleum gas, dimethylether, compressed gases and alternative fluorocarbons, use of substituted solvents like petroleum solvent, alternative fluorocarbons, introduction of substitute propelling mechanism and prevention of leakage from equipment during manufacturing. Some of the possible alternative propellant and solvents are show in Table 21.

Table 21: Alternative for Reducing the Use of ODS in Aerosols

Propellant	Compressed gases	Alternative solvent
Propane, n-butane, Isobutane and dimethylether	Nitrogen, carbon dioxide	n-Hexane, n-heptane, cyclohexane, methylcyclohexane, ethylcyclohexane, toluene and xylene.

Source: Manual for reduction in the use of ODS

Substitute propelling mechanisms like pumping package using rubber traction elasticity, propelling mechanism with a two layered structure for generation of internal pressure, finger pump and trigger pump and mechanical pressure dispenser system are available. Compressed gases like CO₂ and N₂ are being used as propellants. HCFC-123, HCFC-141 and HCFC-225cb and penta fluoropropyl alcohol have been studied as possible substitutes. The percentage of inflammability of aerosol product could be increased. Liquified and compressed gasses can be used as propellants in place of CFCs. The internationally available liquified petroleum gasses are (LPG) and dimethylether (DME). LPG is a mixture of hydro-carbons, mainly composed of propane, n-butane, isobutane. It is the most popular alternative propellant with moderate price and preferable properties. It emits no odour and will not corrode containers or attached parts. Thus it is appropriate for use in aerosol produced. The risk of flammability can be reduced by improving the structural design of the aerosol. Dimethyl, because of its high solubility, chemical stability and little odour, can be used alone or in combination with LPG specially in hair spray and parts.

For certain aerosol products for specialized industrial or technical purpose, it is difficult to use substitute for CFCs in the short time. The candidates are HFC-134a and 227 for medical products because of their low toxicity. Some existing fluorocarbons to replace CFC-11 and 12 are also available like HCFC-22, 142b, HFC-152a. Newly developed AF are HCFC-123, HCFC, 141b and HFC-134a. These substance are selected as substitutes due to their similar properties but low ozone depleting potentials.

Methyl Bromide

Due to the difference in the purpose, target pest and types of commodities to be treated no single alternative would be possible for the immediate phase out of methyl bromide. World-wide methyl bromide is mostly used for agriculture purposes, so the best approach for reduction should be the application of the Integrated Pest Management system and for composite pest control, a combination of treatments which may involve chemical and non-chemical methods, cultural and biological controls. In this way the intensity of use can be reduced to a considerable extent. The basic measures include changing the frequency of use, treatment of the specific area but only when the pest problem is properly identified. Chemical pesticides like 1,3-dichloropropane, dazomet, methamsodium, aldicarb, fenamiphos, ethaprop, carbofuran, benomyl, metalaxyl, and chloropicrin may be applied in combination with or without methyl bromide to reduce the use. The Netherland has developed systems that demonstrates the technical and economical feasibility of totally eliminating extensive use of methyl bromide in glasshouses and also in the raised beds and open fields. Other measures include:

- Improved pest detection technologies, so as to reduce the use in cases where methyl bromide is used as assurance measure.
- Improvement in the structures of the stores or buildings to eliminate the danger of leakage.
- Alternatives like Phosphine could be used for the fumigation of durable food commodities.
- Use of existing, and development of improved recovery and disposal methodology.
- Proper filling operations.
- Use of improved detection and volume displacement procedures for the use of methyl bromide as structural fumigant.

Biological and non-chemical control like **soil solarization** can be used for a wide variety of crops, without any harm to the humans, to control nematodes, weeds, soilborne fungi, and other plant soil pests. Biological control agents e.g., **plant growth promoting rhizobacteria** and **fungal antagonists** of nematoda can be used to reduce soil borne diseases and promote the growth of the plants without any adverse environmental impacts. Cultural controls i.e., crop rotation/crops grown in mixture can reduce soil borne diseases and nematodes. In addition to this the plantation of resistant crops can also be of great help.

The growing depletion in the ozone layer demands a quick phase out of these ozone depleting substances. To cope with this revisions were made for a quicker phase out plan in the Montreal Protocol in Copenhagen 1992. Revised dates of phase out are shown in Table 22.

Table 22: Revision of the Montreal Protocol Nov. 1992 in Copenhagen

CFCs	25 % in 1994 Phase out by 1996
Halons	Phase out by 1994
Carbontetrachloride	15 % in 1995 Phase out by 1996
1,1,1-trichloroethane	50 % in 1994 Phase out by 1996
Methyl bromide	Freeze from 1995

Source: Manual for reduction of ODS

Ozone Depleting Substances in Pakistan

Today in Pakistan, environmental destruction is recognized as a serious problem. Some of the issues need to be tackled with global efforts. Phase out of ozone depleting substances is an example. Ministry of Environment is active with regards to its role in protecting the environment. Environmental division and its subordinate agencies such as Pakistan environmental protection agency (PEPA) and provincial protection agencies (EPAs) have a vital role to play in the protection of the natural environment from manmade industrial pollutants. The existing framework for the protection of the environment is shown in annex 1. Realizing the seriousness of the ozone layer depletion over the Antarctic (Farman et al. 1985) and the recent phenomenon of thinning of the layer over the Scandinavian countries, Pakistan signed the Vienna Convention (1985)⁴ and the

4. refers to the convention for the protection of ozone layer concluded at Vienna on 22 March, 1985.

Montreal Protocol (1987)⁵, on December 18, 1992 (UN Journal No. 1992/274). It is the first step towards preparing an action program for the phase out of ozone depleting substances in Pakistan.

Current Situation of the Use of Ozone Depleting Substances

Pakistan is located in an area with values of ozone layer around 300 Dobson units⁶. Pakistan does not manufacture any ozone depleting substances. But substances like CFC-12, HCFC-22, Halon-1211 (BCF), Carbontetrachloride (CTC), Methyl bromide etc. are used in different industries e.g. refrigerators, deep freezers, air conditioners (house hold/automobile) and in agriculture. These are imported from different countries. Main area of use and the types of ozone depleting substances used in Pakistan are shown in Table 23.

Table 23: Ozone Depleting Substances Used in Pakistan

Type of ODS	Specific area of use
CFC-12, HCFC-22, H-1211, CTC Methyl bromide	Auto mobile air conditioners, air conditioners/house hold Refrigerators, Deep freezers, Blowing agent for foam. Fire extinguisher Pest control

Source: Relevant industries in Pakistan

The total quantity (Nos. of units) of equipment utilizing ODS imported in Pakistan from 1989 to 1992 are shown in Table 24⁷

Table 24: Import Data on Equipment Using ODS in Pakistan

#	Item	Units Imported in Pakistan			
		1989	1990	1991	1992
1	Refrigerators	115397	94416	55925	55747
2	Deep freezers	1085	428	277	281
3	Air conditioning machines	1117	1256	847	1401
4	Car air conditioners	822	440	430	4

Source: Federal Bureau of Statistics Karachi

In Pakistan there is a growing need of refrigeration fluid which is used in a number of local manufacturing units. CFC-12 (R-12) are most commonly used in refrigerant and HCFC-22 (R-22) for automobile air conditioning systems and house hold refrigerators. The data on the use of R-12 automobile manufacturing unit, Suzuki motors and some of the industries responsible for bringing comforts in our homes through the manufacturing of household refrigerators/deep freezers and air conditioners, is shown in Table 25.

Table 25: Extent of ODS Used by Industrial Sector

Name of Industry	Type of ODS	Amount ODS used in tons	
		1991	1992
Suzuki motors	R-12	12	13
Candy freezers	R-12	-	28.17
	R-12	13-	7.3

5. refers to the Montreal Protocol on substances that deplete ozone layer concluded at Montreal on 16 September, 1987.

6. corresponds to an average atmospheric concentration of approximately one part per billion by volume (1ppbv) of ozone.

7. The figure only include those items which have been imported legally i.e after payment of the requisite duties. They do not take into account units brought inside the country by passing the customs department e.g via smuggling

PEL	R-12	40	13.5
	R-12		41

Source: Manufacturers

Indus motors a newly established unit plans to use only 1.65 ton of CFC-12 upto September 93. The annual consumption of R-12 by railway carriage factory Rawalpindi is 0.9 tons. Other users include Pakistan International Airlines, foams industries (diamond foam, dura foam), various hotels, electronic and heavy industries. We were unable to collect any information from these because of lack of interest on the part of these users. H-1211 is mainly used in Pakistan as the sole material for the fire protection system and also for computer repair workshops, textiles and art galleries. Most of the fire extinguishers are imported from China. Carbontetrachloride is also used as fire extinguisher. The total amount of the CTC imported in 1989 was 303 tons, that grew to 370 tons in 1992. Total amount of CTC and other ozone depleting substances imported in Pakistan from 1989 to 1992 are shown in table 26.

Table 26: Import Data on Ozone Depleting Substances (ODS) in Pakistan

#	Name of Substance	Quantities (tons) imported in Pakistan			
		1989	1990	1991	1992
1	Carbontetrachloride	303	220	208	370
2	Trichloromethane	271	306	318	166
3	Trichloroethylene	1860	1463	1047	1400
4	Chlorofluoromethane	30	81	29	35
5	Dichloromethane	854	107	1045	906

Source: Federal Bureau of Statistics, Karachi

Technical Problems to Reduce the Use of Ozone Depleting Substances

Most of these substances are in "bank" of refrigeration equipments and fire protection system, thus the problem seems to be minimal as long as they are inside this closed system, but the slow release of these compounds continue to impact the "chlorine" equivalent peak and the time before returning to the acceptable level⁸. One of the major problems for Pakistan is lack of technical and financial assistance for recovery and recycling of the CFC-12 and CFC-22 used for testing equipment. The annual output for most of the manufacturers of deep freezer and refrigerator exceeds 10000⁹ units, the CFCs used for testing equipment is treated as waste and is released in the atmosphere, thus increasing the threat to the depletion of the ozone layer. The wastage percentage varies from less than 1% to 5%¹⁰. This low percentage of wastage is mainly because of the use of **Nitrogen** and **Dry air** for testing the leakage in the new equipment. Another problem that seems to be of negligible value at present but can cause adverse effects on the environment is the fate of the chloroflourocarbon present in the existing equipment after their destruction by the phase out dead line.

Awareness Among the Relevant Industries

At present awareness in the relevant industries is limited. Industries having International information system e.g. Pak. Suzuki motors Karachi, Indus motors Karachi (Toyota) and some of the importers of Halons and Carbontetrachloride such as Pakistan Global Corporation (Pvt) Limited, Haseen Habib Corporation

8. refers to the level of chlorine loading in the stratosphere after the complete phaseout of the ozone depleting substances

9. Candy freezers.

10. PEL and Candy freezers

Rawalpindi are well aware of the damage caused by the ODS and are willing to use the available alternatives as soon as possible. Besides the quantities already held, they are not purchasing or importing these compounds any more. Local manufacturers of air conditioners, refrigerators and deep freezers are fully aware of the consequences of these substances and are ready for any shift implemented by the exporters of the CFCs. The situation in some of the government departments (Fire department Islamabad and National Institute of Fire Technology) is also encouraging as they are aware of the restrictions on the use of CFCs under Montreal Protocol and are prepared to use alternate available (CO₂, dry chemical powder).

However the extent of awareness needs to be enhanced among the relevant industries and the general public to reduce the use of ozone depleting substances. One of the most powerful tools could be the electronic media. During the last decade the role of print as well as of electronic media in inculcating environmental awareness in masses has been quite admirable. The general public in common, and the industrial elites in particular, are from time to time being briefed on the environmental hazards. Talk shows on radio, documentaries on television and reporting of seminars on global environmental problems in national dailies increase awareness to some extent. But we believe that mass scale programmes and regular article are needed to further enhance awareness on global environmental issues. We also believe that quality not quantity of knowledge matters in developing a proper sense of awareness among the masses. The role of the environmentally conscious people and experts in these areas should be to provide factual information on existing problems in order to make people not only sympathetic towards the environment but also enable them to take necessary steps to eradicate the problem. One of the best example is television trust for the environment (TVE) in London, established in 1984 by United Central Television and United Nation Environment Programme, designed with the aim of informing and mobilizing public opinion on environmental matters.

Efforts of User Industries to Reduce the Use of Ozone Depleting Substances

The step taken by the "user" industries can contribute a lot to the promotion of more effective utilization of controlled CFCs, and can help in the smooth reduction of the ozone depleting substances. In this connection a seminar titled "ozone depleting substances and their substitutes" was organized by Dupont (USA) in Islamabad on 16 August, 1992. This seminar was held with a view to provide to the participants an opportunity to discuss this problem, exchange their experiences and evaluate methods and procedures which can help in reducing the use of ODS. Australia achieved a reduction of 45% in its use of ODS in a record period of five years. Keeping their success as example many recommendations were suggested during the seminar for the phase out of CFCs in various industries. According to the market segment survey conducted in 1991 the Pakistan use of CFCs and the target reduction is shown in the Table 27.

Table 27: Reduction of ODS in Pakistan (34%)

End use	CFC	OEM consumption	Target reduction
---------	-----	-----------------	------------------

Blowing agent	11	180.00	90.00
Refrigeration	11	87.00	NIL
	12	288.00	NIL
	502	15.00	NIL
Aerosol	11	8.00	8.00
	12	12.00	NIL
	114	5.00	5.00
Halons	1211	42.00	42.00
	1301	5.00	5.00
Solvent	113	58.00	Nil

Source: Du pont (USA)limited

Currently no substitute with zero ozone depleting potential (ODP) is available. As a consequence the only solution to this problem is to use **transitional substances**¹¹. Thus Pakistan Suzuki motors which are presently using CFC-12 (12-13 ton/year) and Indus motors, manufacturers of Toyota cars in Pakistan, are planning to shift to HCFC-134a. After September 93, the new Toyota cars will have HCFC-134a as refrigerant instead of CFC-12. For precision cleaning many workshops are already using ozone friendly E-series substances with low ODPs. Many of the importers of H-1211 and CTC in the form of fire extinguishing equipment are planning to stop importing and marketing extinguisher containing CTC, one example is that of Pakistan Global Corporation, Rawalpindi.

Pakistan and the Ozone Issue

The evolution of a global plan of action to control CFC's emission faced serious difficulties right from the outset. Whereas global justice, equity, and sustainability which should be at the heart of any such endeavour are often absent. Leaders of the third world (South) have not yet clearly perceived their developmental issues in environmental context and the leaders of the advanced industrial countries (North) have yet to accept full historical responsibility for degradation of the environment.

Although several decisions at various International Conventions regarding the phase out of ODS appear to make concessions to the South such as ten years delay in the phase out of ODS, multilateral fund, etc. nevertheless the spirit of "Polluter Pay Principle" (PPP) is still far from being fulfilled.

If we consider Pakistan's share in CFCs emissions, the current figures depict extremely meagre contribution. Pakistan does not produce CFCs. Her annual import is 3000 tones. The per capita use of CFCs is only 0.027 KG and her contribution in the global context is practically zero. Even the futuristic estimates of increase in the local use of ODS shall not rise, according to a careful analysis, beyond 5-15% by the year 2030 (Murtaza 1992). In order to enforce the countrywide programme for the phase out of ODS, Pakistan will have to spend enormous amounts in addition to the grants advanced to her under the provisions of Montreal Protocol which, in our opinion, are not fully in line with PPP.

Such expenditure is likely to weigh heavily on an already crisis-ridden economy. However, the urgent need for reduction in ODS consumption by a realistic and well-thought out strategy is not being

11. Substances with low ODP, which can be used until substances with zero ODP are made available

undermined by such opinion. We wish to assert that the fiscal responsibility to achieve such end should be borne by the industrialized countries.

Since the adoption of the Vienna Convention and the Montreal Protocol in December 1992 Ministry of Environment in Pakistan has been making steady progress in policy making to protect the stratospheric ozone depletion. Recently, the first step that was taken by the Environment and Urban Affairs Division (EUAD) was the establishment of a separate section E 3. Its main objective is to deal with the various problems regarding the reduction in use of ozone depleting substances in Pakistan. E 3 will aim at making policies and will try to implement the control measures that are set by the international conventions. E3 manifesto also includes administrative guidance to the relevant industries in Pakistan. Its major responsibilities includes:

- Investigation and study of the extent of use of ozone depleting substances in Pakistan such as total output of the industries which are using ODS as their sole material, total consumption of these substances and the amount imported from other countries.
- To promote activities for phasing-out of the ozone depleting substances in the industrial sector.
- To provide relevant information to the policy makers.

Currently, E 3 is in a phase of conducting a countrywide survey for an overview of the extent of the use of ozone depleting substances, import and the present demand of the industrial sector in Pakistan. The main intention is to provide a reference guide to the policy makers to convert the Convention and Protocol into Laws and thus be able to rectify ozone depleting substances through legislative channel in Pakistan. The framework of proposed activities is shown in annex II of this study

In Pakistan during legislation or policy formulation top down approach is applied. Decisions are framed and notified for implementation without taking the relevant industries into confidence. In countries like Japan bottom up approach is preferred. The basal units are briefed about the problem and solutions sought. Since the industries and the management gets a chance to debate the issue well in time, decisions are taken and all implementing agencies respond and find no difficulty in implementation. On the contrary in Pakistan the government generally holds itself responsible for policy making and implementing. Owing to deficiency in man power either unnecessary expansion occurs in government agencies or many institutions are involved in the process. This practice results in delays, lack of cooperation, half achieved objectives etc. We think there is a need to change the approach and involvement of NGOs and private sector is necessary.

The environmental concerns are attracting attention but what is needed most is motivation of ground level actions to reduce the use of ODS in a systematic and smooth way, with minimal economic apprehensions. This, according to our perception, is possible only through the development of an interacting network between the government agencies and the relevant industries. During the survey of the related industries we found that there was a lack of environmental concern, mainly because no information or network to deal with the issues is available. Individual sector can make a significant impact, both in promoting environmental consciousness and in translating that momentum into pragmatic action. The question is what are the prerequisites for developing such a system that enables the industrial sector to cope with the environmental problems effectively and promptly. The answer to this question in our opinion is formation of a liaison community in the industrial sector to deal with environmental aspects of business. The main objective should include assessment of possible harm by individual industry, possible measures to reduce the hazard, dissemination of current information on the issue, interaction with national and international agencies and development of a legislative channel to manage the problem. The best way is to develop individual liaison offices by private industries with one main control unit in the Chamber of Commerce.

This unit shall interact with the concerning agencies through a participatory process in which there should be a committee having members from government and relevant industries to deal with any incoming problem through all the possible means including legislation or voluntary control. This network will help in developing the process of environmental awareness in the industrial sector and reduce the use of ODS in Pakistan.

References

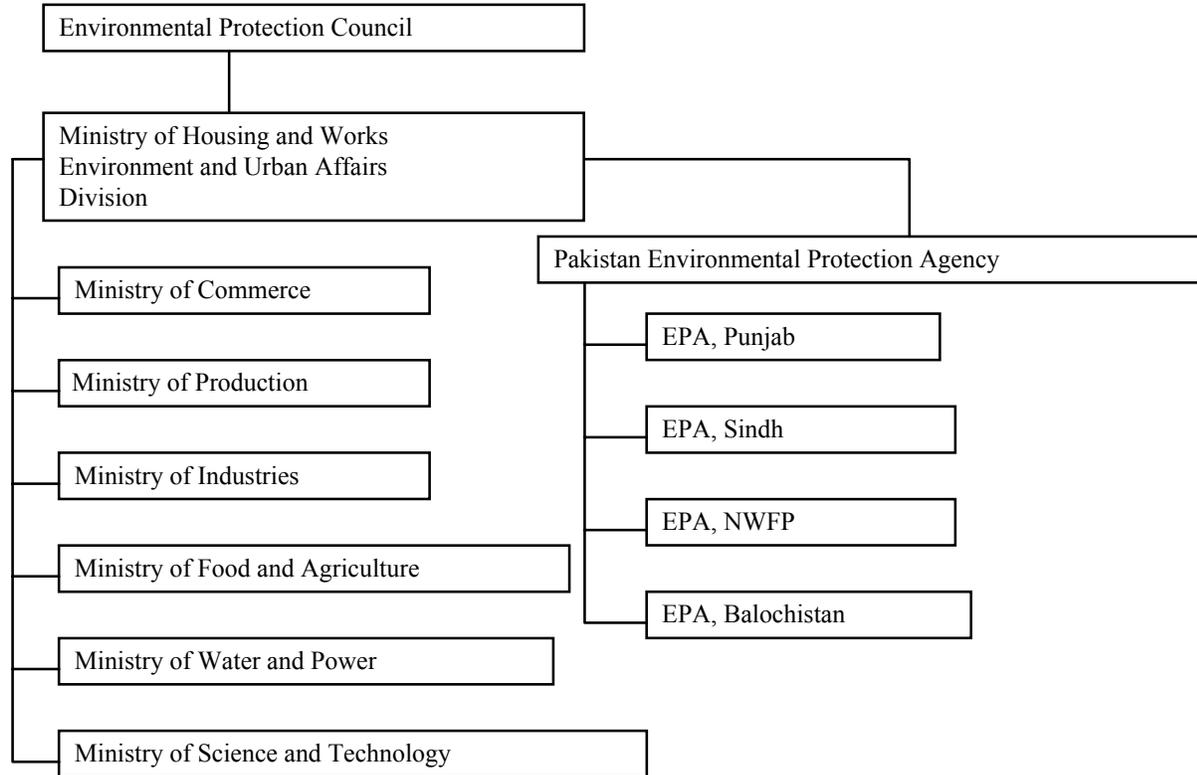
- Andrady, A. L., M. B. Amin, S. H. Hamid, X. Hu K. Fueki, and A. Torikai. 1991. *Panel Report Environmental Effects of Ozone Depletion: 1991 Update*. Material Damage, United Nations Environment Programme.
- Ananthaswamy, H. N. and W. E. Pieccall. 1990. Molecular Mechanism of Ultraviolet Radiation Carcinogenesis. *Photochemistry and Photobiology* 52: 119-1136.
- Basioumy, F. H. 1982. Effects of UV-B Irridation on the Growth and Development Different Vegetable Crops. *Proceedings of Florida State Horticultural Society*. 95: 356-359.
- Bidigare, R. R. 1989. Potential effects of UV-B Radiation on Marine Organisms of the Southern Ocean: Distribution of Photo Plankton and Krill during Austral Spring. *Photochemistry and Photobiology* 50: 469-477.
- Brandle, J. R., Campbell, W. F., Sosson, W. B. and Cladwell, M. M. 1977. Net Photosynthesis, Slectron transport capacity, and Ultra Structure of Pisum Sativum L. Exposed to Ultraviolet-B radiation. *Plant Physiology* 60: 165-168.
- Caldwell, M. M, S. Mardronich, L, O. Bjorn and M. Ilyas. 1989. Ozone Reduction and Increased Solar Ultraviolet Radiation. In *Environment effects panel report*. United Nations Environment Programme. ISBN 92 807 1245 4.
- Cen, Y.-P. and Bornman, J. F. 1990. The Response of Dean Plants to UV-B Radiation under Different Irridiances of Background Visible Light. *Journal of Experimental Botany* 41: 1489-1495.
- Cladwell, M. M. 1971. Solar UV-Radiation and the Growth and Development of Higher Plants. In *Photo Physiology*, ed. A. C. Giess 6: 131-171. New York: Academic Press.
- Coohill, T. P. 1991. Stratospheric Ozone Depletion as it Affects Life on Earth: The Role of Ultraviolet Action Spectroscopy. In *Proceeding Indo-US workshop Global Climatic Changes: Photosynthesis and Plant Productivity*. Jan 8-12. New Delhi.
- Hader, D. P., R. C. Worrest, and H. D. Kumar. 1991. *Panel Report Summary*. Aquatic Ecosystem, United Nations Environment Programme.
- De Fabo, E. C. and Kripke, M. L. 1979. *Photochemistry and Photobiology* 30: 385.
- El-Sayad, S. Z., C. Stephens, R. R. Bidigore and M. E. Ondrusek. 1989. Potential Effects of Solar Ultraviolet Radiation on Antarctic Phytoplankton. In *Effects of Solar Ultraviolet Radiation on Biogeochemical Dynamics in Aquatic Environment* WHO I-90: 141-142.
- Encyclopedia Britannica. 1992. 9. 40:3a.
- Encyclopedia Britannica. 1992. 9. 40:1b.
- Encyclopedia Britannica. 1992. 9. 40:2a.
- Farman, J. C., Gardiner, B. and Shanklin J. D. 1985. *Nature*. 315-207
- Frederic, J. 1990. Trends in Atmosphere Ozone and Ultraviolet Radiation: Mechanism and Observation for the Northern Hemisphere. *Photochemistry and Photobiology* 51: 757-763.
- Fredrick, J. E. and D. Lubn. 1988. Photochemmistry. In *The Science of Photobiology*, ed. K. Smith 87-112. New York: Plenum Press.
- Gery. 1989. *Panel Report Summary*. Environmental effects of Ozone Depletion: 1991 update. Tropospheric Air Quality, United Nations Environment Programme.

- Iwanzik, W., Tevini, M., Dohnt, G., Voss, M., Weiss, W., Graber, O. and Renger, G. 1983. Action of UV-B Radiation on Photosynthetic Primary Reaction in Spinach Chloroplasts. *Plant Physiology* 58: 401-407.
- JICA. 1992. *Manual for Reductions in the Use of Ozone Depleting Substances*. Tokyo: Japan International Cooperation Agency.
- Jones, R. R. 1987. *The Lancet* 443.
- Krizek, D. T. 1975. Influence of Ultraviolet Radiation on Germination and Early Seedling Growth. *Physiology Plant* 34(3): 182-186.
- Kurita, H. 1993. *Chlorinated Compounds and their Substitutes in relation to the Montreal Protocol 1992*. Presented at the group training course in measures to reduce the use of Ozone depleting substances, JICA, Tokyo.
- Lubin, D., J. E. Fredrick, C. R. Both, T. Locas and D. Nueschuler. 1989. Measurements of Enhanced Springtime Ultraviolet Radiations from Plamer Station Antarctica. *Geophysics Research Letters* 16: 783-785.
- Maw, G. A. and R. J. Kempton. 1973. *In Soils Fertility* 36, 41.
- Mitchell, D. L. and R. S. Nairn. 1989. The Biology of the (6-4) Photoproduct. *Photochemistry and Photobiology* 49: 805-819.
- Murtaza, N. 1992. *The Greenhouse Effect and its Impacts on the Region*. Environment and Urban Affairs Division Government of Pakistan.
- Manual for Reductions in the Use of Ozone Depleting Substances 1992. Japan International Cooperation Agency (JICA) Tokyo.
- Parrish, J. A., Jaenicke, K. F., Anderson, R. R. 1983. *Photochemistry and Photobiology* 37, 53.
- Pesticide Manual. 1983. 7th. ed. ISBN 0-901436-77-1. London: British Plant Protection Association. .
- Peak, M. J. and G. Peak 1986. DNA--Protein Crosslinks and Backbone Breaks caused by Far-and Near-ultraviolet, and Visible Radiations in Mamalian Cells. In *Mechanisms of DNA and Repair: Implications for Carcinogenesis and Risk Assessment*, ed. M. G. Simic, L. Grossman and A. C. Upton, 193-202. New York: Plenum Press.
- Renger, G., Volder, M., Eckwrt, H. J., Fromme, R., Hohn Veit, S. and Graber, P. 1989. On the Mechanism of Photosystem II Deterioration by UV-B Irridation. *Photochemistry and Photobiology*. 49: 97-105.
- Rowland, F. S. 1989. Chlorofluorocarbons and the Depletion of Stratospheric Ozone. *American Scientist* 77: 36-45.
- Takizawa, Yukio. 1987. Some Possible Effects of Ultra Violet Effects of the Incidence of Skin Cancer among Japanese due to Modification of Ozone Layer. Proceedings of NIPR Symposium . *Polar Meteorology and Glaciology* 1: 59-68.
- Takizawa, Yukio. 1990. Present State of Knowledge of the Health Effects of Ozone Depletion. *Photomedicine and Photobiology* 12, 53.
- Teramura, A. H. 1980. Effects of Ultraviolet-B Irridance on Soybean. I. Importance of Photosynthetically Active Radiation in Evaluating Ultraviolet-B Irridance Effects on Soybean and Wheat Growth. *Plant Physiology* 48: 333-339.
- Teramura, A. H. 1983. Effects of Ultraviolet-B Radiations on the Growth and Yield of Crop Plants. *Plant Physiology* 58: 415-487.
- Tevini, M. and Teranura, A. H. 1989. UV-B Effect on Terrestrial Plants. *Photochemistry Photobiology* 50(4):479-487.
- Tevini, M. and Teramura, A. H. 1989. UV-effects on terrestrial plants. *Photochemistry and Photobiology* 50: 479-487.

- Tomoyuki, Ito. 1993. *Present Status of Ozone layer Monitoring Network and Scientific Findings on the Depletion of the Ozone Layer*. Presented at the group training course in measures to reduce the use of Ozone depleting substances, JICA, Tokyo.
- United Nations Environmental Programme. 1989. *Environmental Effects of Ozone Depletion: 1991 Update*. Nairobi: UNEP.
- United Nations Environmental Programme. 1991. *Environmental Effects of Ozone Depletion: 1991 Update*. Nairobi: UNEP.
- United Nations Environmental Programme. Ozone Secretariat. 1991. *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer*. 2nd Edition. Nairobi: UNEP.
- WMO. 1992. *WMO and the Ozone Issue*. WMO No. 778. Geneva: World Meteorological Organization.

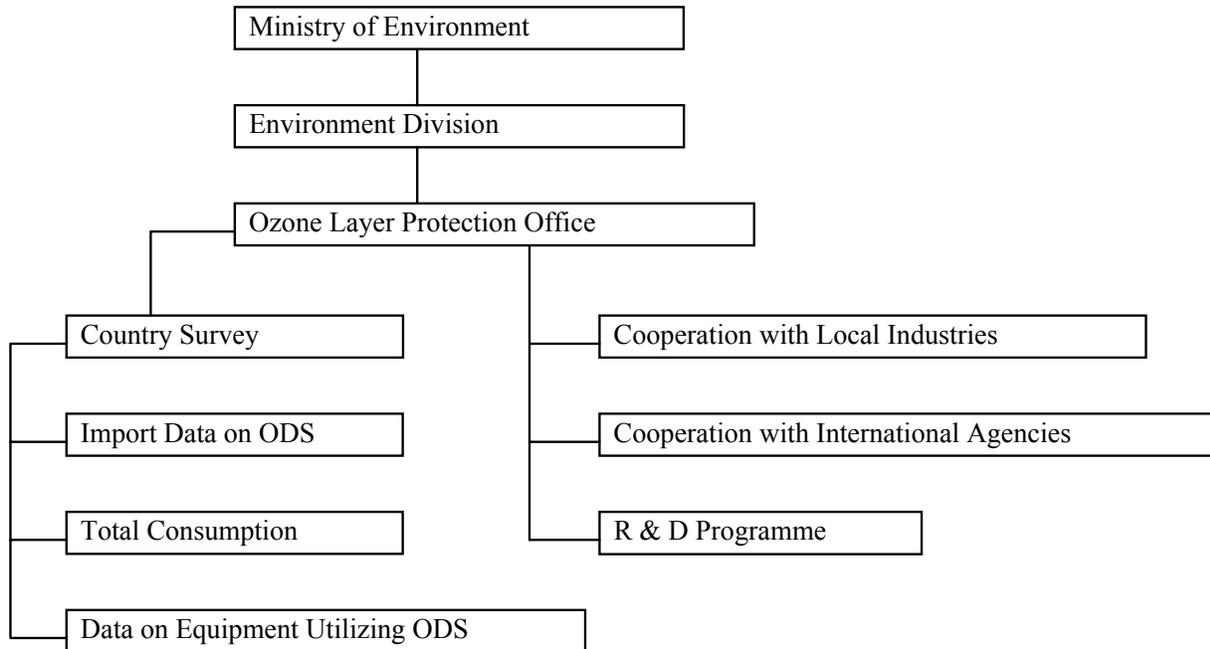
Annex I

Environment Protection Framework of Pakistan



Annex II

Suggested Framework for the Promotion of Ozone Layer Protection



Annex A

Controlled Substances

Group	Substance	Ozone Depleting Potential */
Group I		
	CFC1 ₃ (CFC-11)	1.0
	CF ₂ Cl ₂ (CFC-12)	1.0
	C ₂ F ₃ Cl ₃ (CFC-113)	0.8
	C ₂ F ₄ Cl ₂ (CFC-114)	1.0
	C ₂ F ₅ Cl (CFC-115)	0.6
Group II		
	CF ₂ BrCl (halon-1211)	3.0
	CF ₃ Br (halon-1301)	10.0
	C ₂ F ₄ Br ₂ (halon-2402)	6.0 ¹²

Note: */ = These ozone depleting potentials are estimates based on existing knowledge and will be reviewed and revised periodically.

12. The *First Meeting of the Parties* decided in *Dec. 1/9* to accept the value for the Ozone Depleting Potential (ODP) for halon 2402, AS 6.0, and to request the secretariat to inform the depositary that the parties agreed to accept this figure by consensus at their first meeting and that accordingly the Depositary should insert this figure to replace to words " to be determined" in annex a to the montreal protocol.

Annex B

Controlled Substances

Group	Substance	Ozone-depleting potential
Group I		
CF ₃ Cl	(CFC-13)	1.0
C ₂ FCl ₅	(CFC-111)	1.0
C ₂ F ₂ Cl ₄	(CFC-112)	1.0
C ₃ FCl ₇	(CFC-211)	1.0
C ₃ F ₂ Cl ₆	(CFC-212)	1.0
C ₃ F ₃ Cl ₅	(CFC-213)	1.0
C ₃ F ₄ Cl ₄	(CFC-214)	1.0
C ₃ F ₅ Cl ₃	(CFC-215)	1.0
C ₃ F ₆ Cl ₂	(CFC-216)	1.0
C ₃ F ₇ Cl	(CFC-217)	1.0
Group II		
CCl ₄	carbon tetrachloride	1.1
Group III		
C ₂ H ₃ Cl ₃ *	1,1,1-trichloroethane (methyl chloroform)	0.1

Note: */ = This formula does not refer to 1,1,2-trichloroethane

Annex III

Status of Ratification of the Vienna Convention as of 30 September 1991.

Country	Signature	Ratification	Entry into force
Argentina ⁶	22.03.1985	18.01.1990(R)	18.04.1990
Australia		16.09.1987(Ac)	22.09.1988
Austria	16.09.1985	19.08.1978(R)	22.09.1988
Bahrain ⁸		27.04.1990(Ac)	26.07.1990
Bangladesh		02.08.1990(Ac)	31.10.1990
Belgium	22.03.1985	17.10.1988(R)	15.01.1989
Brazil		19.03.1990(Ac)	17.06.1990
Brunei Darussala		26.07.1990(R)	24.10.1990
Bulgaria		20.11.1990(Ac)	18.02.1991
Burkina Faso	12.12.1985	30.03.1989(R)	28.06.1989
Byelorussian SSR	22.03.1985	20.06.1986(At)	22.09.1988
Cameroon		30.08.1989(Ac)	28.11.1989
Canada	22.03.1985	04.06.1986(R)	22.09.1988
Chad		18.05.1989(Ac)	16.08.1989
Chile ⁷	26.03.1985	06.03.1990(R)	24.06.1990
China		11.09.1989(Ac)	10.12.1989
Colombia		16.07.1990(R)	14.10.1990
Costa Rica		30.07.1991(Ac)	28.10.1991
Czechoslovakia		01.10.1990(R)	30.12.1990
Denmark	22.03.1985	29.09.1988(R)	28.12.1988
Ecuador		10.04.1990(Ac)	29.07.1990
Egypt	22.03.1985	09.05.1988(R)	22.09.1988
Equatorial Guinea		17.08.1988(Ac)	15.11.1988
Fiji		23.10.1989(Ac)	21.01.1990
Finland	22.03.1985	26.09.1986(R)	22.09.1988
France	22.03.1985	04.12.1987(Ap)	22.09.1988
Gambia		25.07.1990(Ac)	23.10.1990
German Dem. Rep.*		25.01.1989(Ac)	24.04.1989
Germany, FR. ^{2*}	22.03.1985	30.09.1988(R)	29.12.1988
Ghana		24.07.1989(R)	22.10.1989
Greece	22.03.1985	29.12.1988(R)	29.03.1989
Guatemala		11.09.1987(Ac)	22.09.1988
Hungary		04.05.1988(Ac)	22.09.1988
Iceland		29.08.1989(Ac)	27.11.1989
India		18.03.1991(Ac)	16.06.1991
Iran		03.10.1990(Ac)	01.01.1991
Ireland		15.09.1988(Ac)	14.12.1988
Italy	22.03.1985	19.09.1988(R)	18.12.1988
Japan		30.09.1988(Ac)	29.12.1988
Jordan		31.05.1989(Ac)	30.08.1989

Continued.....

Country	Signature	Ratification	Entry into force
Kenya		09.11.1988(Ac)	07.02.1989
Libyan Arab Jamahiriya		11.07.1990(Ac)	09.10.1990
Liechtenstein		08.02.1989(Ac)	09.05.1989
Luxembourg	17.04.1985	17.10.1988(R)	15.01.1989
Malawi		09.01.1991(Ac)	09.04.1991
Malaysia		29.08.1989(Ac)	27.11.1989
Maldives		26.04.1988(Ac)	22.09.1988
Malta		15.09.1988(Ac)	14.12.1988
Mexico	01.04.1985	14.09.1987(R)	22.09.1988
Morocco ¹	07.02.1986		
Netherlands ³	22.03.1985	19.09.1988(Ac)	18.12.1988
New Zealand ⁴	21.03.1986	02.06.1987(R)	22.09.1988
Nigeria		31.10.1988(Ac)	29.01.1989
Norway	22.03.1985	23.09.1986(Ac)	22.09.1988
Panama		13.02.1989(Ac)	14.05.1989
Peru	22.03.1985	07.04.1989(R)	06.07.1989
Philippines		17.07.1991(Ac)	15.10.1991
Poland		13.07.1990(Ac)	11.10.1990
Portugal		17.10.1988(Ac)	15.01.1989
Singapore		05.01.1989(Ac)	05.04.1989
South Africa		15.01.1990(Ac)	15.04.1990
Spain		25.07.1988(Ac)	23.10.1988
Sri Lanka		15.12.1989(Ac)	13.03.1990
Sweden	22.03.1985	26.11.1986(R)	22.09.1988
Switzerland	22.03.1985	17.12.1987(R)	22.09.1988
Syrian Arab Republic		12.12.1989(Ac)	12.03.1990
Thailand		07.07.1989(Ac)	05.10.1989
Togo		25.02.1991(Ac)	25.05.1991
Trinidad-and Tobago		28.08.1989(Ac)	26.11.1989
Tunisia		25.09.1989(Ac)	24.12.1989
Uganda		24.06.1988(Ac)	23.09.1988
Ukrainian SSR	22.03.1985	18.06.1986(At)	22.09.1988
United Arab Emirates		22.12.1989(Ac)	22.09.1988
U.K. 5/9/70	20.05.1985	15.05.1987(Ac)	22.09.1988
U.S. A.	22.03.1985	27.08.1986(Ac)	22.09.1988
USSR	22.03.1985	18.06.1986(At)	22.09.1988
Uruguay		27.02.1989(Ac)	28.05.1989
Venezuela		01.09.1988(Ac)	29.11.1988
Yugoslavia		16.04.1990(Ac)	15.07.1990
Zambia		24.01.1990(Ac)	24.04.1990
EEC	22.03.1985	17.10.1988(Ap)	15.01.1989
Total		28	80

Note: * R = Ratification
 * Ac = Accession
 * Ap = Approval
 * At = Acceptance