

Sudan University of Science and Technology

College of Science

Physics Department

Evaluating atmospheric ozone hole using CFC's data

تقييم ثقب الاوزون في الغلاف الجوي باستخدام بيانات لمركبات
الكلورفلوروكاربون

A graduation project submitted as to complete the 4th year
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Department

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Abstract

The ozone layer was found to be acting as a protective shielding layer that protect our planet Earth from harmful radiations, such as x-rays and UV radiation. Nevertheless, the recent human activities was found to hinder the act of the ozone layer, because the recent industrial and agricultural byproducts such as Coloru-Floru-Carbons (CFC's) affect directly the binding structure of ozone, this destruction in the layer structure was termed as ozone hole. Hence, professional all around the world were collectively agreed of the danger of those components like CFC's and international bodies were organized to mitigate the usage of CFC's and to find other alternatives.

ملخص

طبقة الاوزون تمثل درع الحماية الاول لكوكب الارض والكائنات الحية علي سطحه لانها تحول دون وصول الاشعة المؤينة عالية التردد مثل اشعة اكس و الاشعة فوق البنفسجية وتحت الحمراء وغيرها من الاشعة الضارة . ولكن نجد الانشطة البشرية المزامنة للتطور الحالي في شتى المجالات الصناعية و الزراعية و غيرها ادت لترقيق طبقة الاوزون الحامية لانتاجها مواد مثل الكلورو فلورو كاربون التي تؤثر علي تماسك طبقة الوزون اي تفكك روابطها ويسمي ثقب الاوزون وعليه اجمع العالم علي خطر انتاج تلك المواد وسن القوانين لتخفيض انتاجها باستخدام بدائل اخري وهي توجد في المطافئ ومخلفات المصانع وعوادم السيارات وغازات التبريد (الفريون)

CHAPTER ONE

THE OZONE

1.1 Ozone

Atmospheric ozone is a layer in the upper atmosphere it protects the Earth from harmful rays, i.e. UV waves, organisms, and poisonous gas even in small consent rations and consists of molecules of O_3 .

1.2 The atmosphere of the Earth today

It is a warm blanket rich in oxygen that helps to maintain conditions suitable for life as we know it. That is hardly surprising since life as we know it has evolved to fit the conditions found under that blanket of air part of the concern caused by the discovery of a hole in the sky over Antarctica; however, the atmosphere we know now may be changing, so that conditions never experienced by our kind of life become common on Earth.

The warming falls off with height the further away from the warm surface of the Earth the colder it gets up to an altitude of about 11 km, where the temperature is roughly -60°C . This 'about' is a particularly vague average, which conceals the fact that the cooling stops at some 8 km above the poles but as high as 16 km over the equator.

The layer of the atmosphere below this boundary is called the troposphere the boundary itself is Called the tropopause and marks the beginning of a layer in which the temperature first holds steady with increasing altitude and then begins to increase with increasing altitude. (Gribbin, 1988)

1.3 The atmosphere and absorption of the sun energy

The atmosphere consists of three main layers :

1- Troposphere layer :

Extending from the surface of the earth to a height of 12 km and temperature drop 6 per km.

2- Stratosphere layer:

It follows the troposphere and extending from 12 km -30 km above sea level.

3- Ozone layer:

Consisting of O_3 and at height greater than 30 km -50 km and a absorbs harmful rays emitted by the Sun.

4- Mesosphere layer:

Located at an altitude 50 km where the temperature decreases and the density of air is 0.1 of its density on the surface of the ground.

5- Ionosphere layer :

It is an ionized layer reflect electromagnetic radio waves and contain free electrons (Dirar).

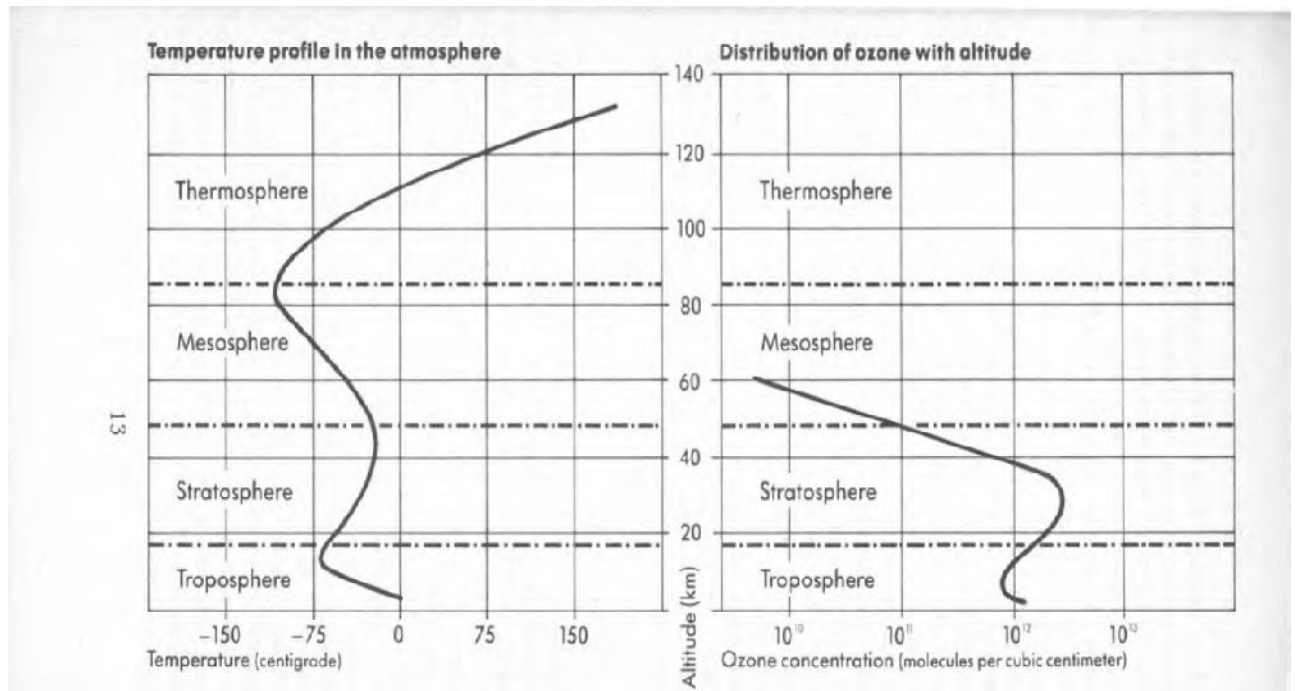


Figure 1.1 The layered structure of the atmosphere is shown by temperature profile ozone is concentrated in the stratosphere especial between 20 km and 30 km altitude .(source: present state of knowledge of the upper atmosphere NASA,1986).

The lowest layer of the atmosphere, the troposphere, is the part that- we breathe, and the part in which weather driven by convection ('hot air rises') occurs. Although the layer is relatively thin because air at the ground is squashed by the weight of the air above it, the troposphere is the densest part of the atmosphere, and contains 85 per cent of the atmosphere's mass. The stratosphere contains virtually all of the remaining 15 per cent the mass of the air below about 40 km altitude is more than 99 per cent of the total mass of the atmosphere. The air in the stratosphere is 'thin' in the other sense of the word, highly rarefied compared with air at ground level .But unlike the troposphere and in spite of its low density the stratosphere absorbs heat from the Sun in the form of ultraviolet radiation . It does so because oxygen seeping up from the troposphere below absorbs energy from the Sun. The solar radiation

breaks the two atoms of oxygen in a molecule apart leaving each one free to link up with another molecule of diatomic oxygen and forming two molecules of ozone as a result. So the term 'ozone layer' is synonymous with 'stratosphere'. Because the stratosphere is warmer at higher altitudes, hot air no longer rises there since the air above is hotter than the air below and convection cannot occur. So, in a very real sense, the stratosphere acts as a lid on the troposphere, keeping convection, and weather, below the tropopause.

1.4 The ozone layer today

The ozone layer exists because oxygen from the troposphere, produced by living things, seeps up into the stratosphere and reacts with sunlight to form triatomic molecules of ozone.

Averaging overall altitudes the air today contains about 75 % cent nitrogen (by mass), 23 % cent oxygen (almost all in the familiar diatomic form), 0.05 % cent carbon dioxide and 1.28 % cent argon, with traces of other gases. It wasn't always like this as we shall see; but the presence of so much free oxygen today explains how the ozone layer is maintained.

The explanation depends on the nature of the radiation emitted by the Sun, and on the way in which both ozone and oxygen (whenever I use the term 'oxygen' without qualification I mean they diatomic form) respond to that radiation. Most of the energy of the Sun is emitted in the form of yellow light, which has wavelengths in the range from about 500 to 600 nanometers (nm; 1 nm is one billionth of a meter, 10^{-9} m). The range of light visible to our eyes is from red, at 760 nm, to violet, at 400 nm, but there is still a significant amount of solar energy radiated either side of this band in the infrared and the ultraviolet. It is the ultraviolet end of the spectrum that plays a part in maintaining the stratosphere.

The energy emitted by the Sun in the ultraviolet part of the spectrum is weak compared with the energy emitted in the yellow band in the sense that there are fewer energy packets emitted with ultraviolet wavelengths. But each of those ultraviolet energy packets packs more of a punch than a single energy packet of yellow light. Oxygen molecules respond particularly strongly to wavelengths below 190 nm, in the ultraviolet band. Energy packets with those wavelengths break the bond between the two atoms in an oxygen molecule, because each energy packet carries more energy than the bond holding the atoms together. The resulting reaction, called photo dissociation, can be represented schematically by the equation:

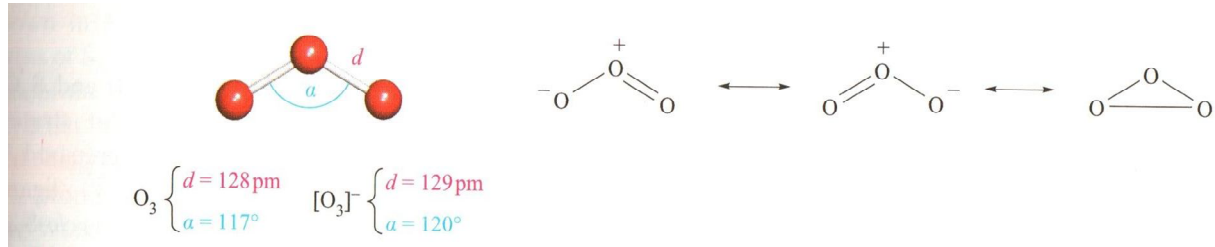


In the next stage of the ozone formation process another molecule has to be present to act as catalyst. This molecule is usually nitrogen the most common constituent of the atmosphere, but it could be almost anything so we can label it M:

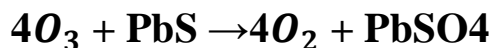
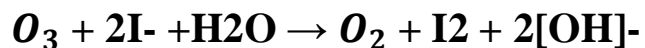
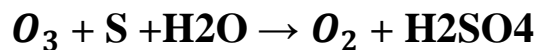
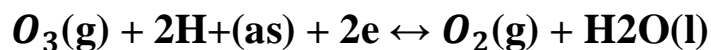


- Ozone, O_3 , is usually prepared in up to 10% concentration by the action of a silent electrical discharge between 2 concentric metalized tubes in an apparatus called an ozonizer.
- O_3 can also be obtained by the action of UV radiation on O_2 , or by heating O_2 at above 2750 K followed by rapid quenching
- In all these processes, O atoms are produced and combine with O_2 .
- Pure O_3 is separated from reaction mixtures by fractional liquefaction; the liquid is blue and boils at 163 K to give perceptibly blue gas.

- Molecules of O_3 are bent.



- O_3 absorbs strongly in the UV region, and its presence in upper atmos. of the Earth is essential the Sun. in protecting the planet's surface from over-exposure to UV radiation form.
- O_3 is highly endothermic. The pure liquid is dangerously explosive, and in the gas phase is very powerful oxidizing agent.



- The presence of high concentration of alkali stabilizes O_3 thermodynamically and kinetically
- O_3 is much more reactive than O_2 , hence is used to purify water.
- Ozonizer salts are known for all alkali metals and ammonium, and are explosive.
- KO_3 is unstable red salt which contains the paramagnetic $[O_3]^-$ ion, whereas, $[Me_4N][O_3]$ is relatively stable & decomposes only > 348 K.



(Norganic Chemistry , 2008)

CHAPTER TWO

THE EFFECT OF CFC'S

2.1. Introduction

Sudan ratified the Vienna Convention and the Montreal Protocol in January 1993.

Subsequently, it signed the London, Copenhagen, Montreal and Beijing amendments: The status of the ratification of this protocol and its amendments is as follows:

Table 1:

Instrument	Ratification	Entry into Force
Vienna Convention (1985)	29- January- 1993	29- April- 1993
Montreal Protocol (1987)	29- January- 1993	29- April- 1993
London Amendment (1990)	02- January- 2002	02 April 2002
Copenhagen Amendment (1992)	02- January- 2002	02 April 2002

Montreal Amendment (1997)	18- May- 2004	18- Aug - 2004
Beijing Amendment (1999)	18- May- 2004	18- Aug – 2004

In order to establish a national aggregate level of HCFC consumption, a countrywide study survey is going on and not yet in its final form. The output of the survey would be used in the future HCF reduction or phase out program in Sudan. The expected outputs of this survey are:

- Situation analysis on HCFC consumption in Sudan regarding its compliance with the Montreal Protocol.
- Historical import data preferably from 1995 and segregated by originating countries.
- HCFC consumption by sector.
- List of HCFC users, segregated by sector.
- List of HCFC users who received assistance under the Montreal Protocol Program
- List of HCFC users who did not receive assistance under the Montreal Protocol Program.
- Approximate population of HCFC-based equipment segregated by sector.

UNIDO, in consultation and agreement with the NOU has identified and selected the University of Sudan of Science and Technology as a qualified national institution represented by Dr. Hassan Adaptive and a team of national experts to carry out the survey. The survey is going-on in close cooperation with the NOU and UNIDO.

2.2. Approach and proration

Based on the accumulated experience as well as the “lessons learnt” by UNIDO and the NOU, University of Sudan of Science and Technology and other national institutions concerned in conducting an in-depth survey for the formulation, implementation and reporting on the ongoing CFC phase out program me, assisted by MLF, the following preparatory steps are considered:

1-Identification, selection and sub-contracting of the University of Sudan of Science and Technology as qualified national institution based on the respective Terms of reference (TOR) prepared by UNIDO in cooperation and consultation with the NOU

2- Review of existing national system of monitoring and reporting of ODS import and consumption (with emphasis on HCFCs).

3- Review of existing national policies, regulations, legislative and institutional framework on control and monitoring of ODS import and consumption.

Note: The list of national legislative documents in place and related to control of ODS and to HCFC in particular will be attached to the Final report of the sub

4- Review of results and the “lessons learnt” of the completed CFC phase out program me with an emphasis on the activities and results relevant to the HCFC phase out program me.

Note: The list of enterprises converted to HFC and HCFC alternatives will be extracted from the Final report under the completed CFC projects assisted by MLF and attached to the Final HCFC survey report.

5-Familiarization of the national survey team with the relevant MLF, Excel and UNIDO documentation as well as with this “Guidelines”. Special training sessions were conducted

For information and easy reference, the following documents were provided to the national survey team along with the “Guidelines”:

-Decision 53/37 of the 53rd Excel Meeting on “Options and defining eligible incremental costs for HCFC consumption and production phase out activities”;

-Draft Guidelines for preparation of HCFC phase out management plans incorporating HCFC surveys (UNEP/OzL.Pro./Excel/54/53);

-Preliminary Discussion Paper on Analysis and Cost Considerations of HCFC phase out (UNEP/OzL.Pro./Excel/54/54);

Revised analysis of relevant cost considerations surrounding the financing of HCFC phase out (UNEP/OZL.Pro/Excel/55/47);

6- Preparation and submission by the University of Sudan of Science and Technology the reports according to the conditions of the TOR and Contract.

2.3. HCFC consumption

According to the recently conducted survey Sudan’s consumption of HCFCs in 2007 amounted to 474,80 (about 26 ODP tones). Sudan is one of the countries, which had not been reporting HCFC consumption systematically before 2007. Thus according to the Ex com Decision 56/16, the country received only U\$ 30,000 to prepare HPMP. UNIDO initiated the

preparation of the HPMP subsequently. The results of the recent survey have indicated that there is a significant consumption of HCFC 141b in the foam and refrigeration production sectors and HCFC 22 in refrigeration servicing sector.

Table 2: Breakdown of consumption of HCFCs 2004-2008

(mt)

Year	HCFC-22	HCFC-141b	Total
2004	98.60	288.60	387.20
2005	122.80	302.80	425.60
2006	148.60	308.50	457.10
2007	156.80	318.00	474.80
2008	183.15	328.50	511.65

2.4. Substitutes for HCFC-141b

Mainly, there are two types of substitutes for HCFC-141b as the blowing agent. The first type is natural substances such as Hydrocarbons, Carbon Dioxide, etc. The second type of technology is synthetic substances such as HFCs. For Sudanese conditions, hydrocarbons are one

of the best alternatives, because cyclopentane, is pentane and normal pentane can be produced in Sudan. However, their flammability has to be overcome by appropriate safety measures and sufficient infrastructure and management. Introducing this technology for HCFC replacement could be very challenging especially for small and medium enterprises. Generally, the replacements for HCFC-141b would need to be evaluated on a case-by-case basis after detailed study of the particular application.

2.5. Substitutes for HCFC-22

Some of the considerations for properties of proper substitutes for HCFC-22, which is mainly used as a refrigerant, are refrigerating effect, volumetric capacity, evaporating and condensing temperatures and pressures, compatibility with lubricants, compatibility with compressors and other system components and materials, etc.

HFC and non-HFC substances such as CO₂, hydrocarbons and ammonia could be used as HCFC replacements. However, for Sudan, the new technology that is usually accepted is the one that has lowest investment costs. Drop-in substitute refrigerants are preferred for existing equipment because no investment is needed. For commercial refrigeration, HFC 134a, Hydrocarbons or HFC blends such as R-407C or R-417 can be used to replace HCFC-22. However, HFC-134a is not widely used for lower temperature refrigeration used in food processing and cold storage. For industrial refrigeration, R-404A or R-410A can be used for R-502 replacement, and R-407C, R-410A, or R-417 can be used for HCFC-22 replacement. These

refrigerants can also be used for transport refrigeration, commercial and residential Air Conditioning.

2.6. Environmental impact

HCFCs have an ozone depleting potential (ODP) and also they have impact on global warming.

The use of substitutes for HCFCs with zero ODP may still have an impact on global warming due to the global warming potential (GWP) and their atmospheric lifetime.

HCFC-22 has an ODP of 0.055 and GWP of 1,520. The expected consumption of 302.40 metric tons of HCFC-22 estimated for 2015, will lead to an environmental impact of about 16.63 ODP tones and global warming impact of about 460000 tons per tones of CO_2 .

HCFC-141b has an ODP of 0.11 and GWP of 630. The expected consumption of 544.88 metric tons of HCFC-141b estimated for 2015, will lead to an environmental impact of about 60 ODP tones and global warming impact equivalent to about 343000 tones of CO_2 .

The challenge is to convert to zero ODP options and at the same time reducing the climate change impact.

In summary, HCFC-141b and HCFC-22 are the predominant HCFCs used in Sudan, in the Foams and Refrigeration & Air Conditioning Sectors. HCFC-141b is used as a blowing agent for rigid polyurethane foams and HCFC-22 is used as a refrigerant.

Sudan's consumption of HCFC-22 increased from 98.60 metric tons in 2004 to 156.80 metric tons in 2007 and 183.15 metric tons in 2008, while HCFC-141b increased from 288.60 metric tons in 2004 to 318.00 metric tons in 2007 and 328.50 metric tons in 2008. Unconstrained HCFC consumption in Sudan is expected to reach 847.28 metric tons by 2015.

It is evident that the availability and costs of HCFCs would almost remain stable for the next few years. This would present potential challenge for compliance with the 2016 freeze in consumption.

Potential replacements for HCFCs include hydrocarbons and HFCs/HFC blends. Their availability and/or techno economic feasibility are not yet favorably established for wider use. Inadequate information and awareness about alternatives is another challenge for the compliance.

Experience gained and lessons learnt during the implementation of CFCs phase-out, as well as infrastructures established for managing CFCs phase-out can be partially applied towards achieving HCFC compliance requirements.

Potential compliance measures include preparation of a national strategy and action plan for meeting the 2016 freeze in consumption and also for future management of HCFCs, reducing dependence on HCFCs in the interim where alternatives can be more easily applied, creating awareness and disseminating information on the 2016 freeze obligations and alternative technologies and providing technical assistance and training for making informed decisions on the transitions. Sudan expects the incremental costs of compliance to be met under the mechanisms of the Montreal Protocol.

2.7. ODS Issue; Development till 2010

Sudan initiated the ODS phase-out actions in 1993 by establishing a temporary Ozone Unit at the Ministry of Industry.

The status of the ratification of the Montreal Protocol and its amendments is as follows:

Table3: Status of the Montreal Protocol Ratification

Instrument	Ratification	Entry into Force
Vienna Convention (1985)	29- January- 1993	29- April- 1993
Montreal Protocol (1987)	29- January- 1993	29- April- 1993
London Amendment (1990)	02- January- 2002	02 April 2002
Copenhagen Amendment (1992)	02- January- 2002	02 April 2002
Montreal Amendment (1997)	18- May- 2004	18- Aug - 2004
Beijing Amendment (1999)	18- May- 2004	18- Aug - 2004

2.8. HCFC consume

2.8.1. Current Situation

According to the survey carried out by the National Ozone Unit and the Sudan University of Science and Technology (SUCT) in November 2009 – January 2010 the HCFC consumption increased from 387.20 metric tons in 2004 to 511.65 metric tons in 2008, i.e. 32 %.

Table 4: Breakdown of consumption of HCFCs 2004-2008 (mt)

Year	HCFC-22	HCFC-141b	Total
2004	98.60	288.60	387.20
2005	122.80	302.80	425.60
2006	148.60	308.50	457.10
2007	156.80	318.00	474,80
2008	183.15	328.50	511.65
2009	210.00	330.00	540.00

(the 2009 figures to be verified)

The consumption structure is simple, HCFC- 22 is used to maintain larger commercial refrigeration equipment and air-conditioning equipment, and HCFC-141b for PU foam production. It seems that the awareness about the alternative technologies utilizing completely ODP free substances as well as substances having a low Global Warming Potential (GWP) is not very extensive within the industry. The recent (and on-going) discussion on the role of HFC-

134a (which has in practice replaced CFC in the domestic and small commercial refrigeration and freezer equipment) is seen as a confusing one. Sudan has one major “desert cooler” manufacturer. One may say that this “natural” cooling technology is very well suited in the generally dry climate of Sudan, but the commercialization of this technology has hardly made progress. The opportunities to use hydrocarbon and $C O_2$ based substances in foam manufacturing and in refrigeration is not widely known in the industry. The possible inflammable characteristics of hydrocarbons seem to overshadow the opinions of those being aware of the technologies. Sudan has in increasing oil-refining capacity producing e.g. LPG for commercial purposes. Producing e.g. propane and butane to replace the HCFCs (as well as HFC-134a) would be technically quite simple, but this opportunity has not yet been searched.

2.9. Foam Production

Sudan has five major companies using 141b as component in rigid polyurethane foam production

-Modern Refrigeration Factory using PU in the insulation of refrigerators and freezers. The refrigeration technology is licensed from the German Libeler Co.). The refrigerant used is 134a only.

-Cold air Engineering Company (www.haggar-cec.com) using PU in the insulation of refrigerators and freezers. The refrigerant used is 134a only. In addition to refrigerators Cold air Engineering Company is producing water coolers (run on 134a) and so called “desert coolers”

-Amino Factory for insulation Panels CO. (www.aminpanels.com) producing sandwich type of insulation panels for the building and construction industry and also producing heat-insulated

portable cabins for several purposes (temporary office spaces, construction site offices, telecom/mast operation cabins etc)

Akadabi Steel Industries CO. (www.alakadabi.com) producing sandwich type of insulation panels for building and construction industry and heat-insulated portable cabins

-Target Group of Industries CO. producing sandwich type of insulation panels for building and construction industry .

2.10. Manufacturing of the refrigeration equipment

Sudan has two major refrigeration equipment manufacturers, the above-mentioned Modern Refrigeration Factory and Cold air Cos. The recent production of refrigeration and freezer units has been approximately 80000-90000 units per year. All in all the Sudan refrigeration market is estimated at 300000 units pa., out of which the domestic, national production covers 25-30 %. All this domestically manufactured equipment stock is run in HFC-134a. Regarding the insulation of cabins and doors reference is made to the previous section; HCFC-141b is used in the foam production.

2.11. Maintenance of the refrigeration and air-conditioning equipment

The refrigeration and air-conditioning sector is the other (and only) consumer of HCFCs is the refrigeration and air-conditioning sector. The relatively rapid economic growth and

continuing growth of the urban population are resulting in the quick increase in the number of the commercial refrigeration equipment as well as of the number of air-conditioning units.

The number of the commercial refrigeration units is difficult to estimate, but it is likely that the number is in the region of 500000 units. In addition to these there are approximately xxxx cold/cool stores serving food industry and storage.

The number of air-conditioning units (window-type and split units) is difficult to estimate. The number of large buildings with central chillers is increasing. These centralized systems use HCFC-22 as refrigerant.

The HCFC-22 charge in air-conditioning units is in average 2 kg.

Provided that annual imports of 210,000 kg is used for the maintenance of commercial units and air-conditioners the amount is sufficient to maintain some 105,000 units. If the maintenance of the equipment is made, in average, every 7-8 year the number of units can be estimated at 700-800,000. The country has some xxx major maintenance companies operating in Khartoum and other major cities.

The implementation of the CFC phase out and training program me resulted in the establishment of seventeen (17) recycling centers. Three hundred (300) service workshops were scheduled to participate in the recovery and recycling system and receive recovery equipment have been identified. The NOU has made all necessary local arrangements for receiving the purchased recovery and recycling equipment by UNIDO and their delivery to selected sites i.e. recycling centers and service workshops throughout the country.

The surveys made in the connection of the National CFC Phase-out Plan (NPP) indicated that there are some 1800 refrigeration maintenance workshops having around 4400 operators/technicians.

2.12. Aims of the National CFC/CTC phase-out plan

The national CFC/CTC phase-out plan aims at achieving the ODS phase-out targets in the agreement between the Executive Committee of the Multilateral Fund for the Implementation of Montreal Protocol and the government of Sudan as stipulated in the table 3 below.

Table 5 : CFC/CTC phase-out for Sudan

PROJECT DATA		2004	2005	2006	2007	2008	2009	2010
CFCs (ODP tones)	<i>Montreal Protocol limits</i>	456.8	228.4	228.4	68.52	68.52	68.52	0
	<i>Annual consumption limits</i>	216	200	130	65	45	25	0
CTC (ODP tons)	<i>Montreal Protocol limits</i>	n.a.	0.33	0.33	0.33	0.33	0.33	0
	<i>Annual consumption limits</i>	1.1	0.33	0	0	0	0	0

2.13. Conclusion

The work with the implementation of the national ODS phase-out plan for Sudan has been continued from 2005. The milestones set for the 3rd tranche were satisfactorily achieved. The maximum allowable limits of 45 ODP tones CFC in 2008 and 25 ODP tones in 2009 have been met with consumption of 44.8 and 21 ODP tones respectively.

Complete CFC phase out in the manufacturing foam and aerosol sectors has been maintained.

No CTC was consumed.

Current legislation is effectively functioning and supporting the CFC phase-out program me.

Progress in the NPP different areas has proceeded satisfactory, i.e., local office set-up, procedures for quotas and licenses issuance , supplementary custom officers training, establishment of additional centers, train-the-trainers, technician training, mentoring bodies and mechanisms, distribution of equipment and awareness raising.

Satisfactory work has been done by customs to control illegal import and mislabeling.

Nevertheless, There is still a need for more advanced refrigerant identifiers as well as diversified recycling and recovery equipment.

Actions on the accelerated phase-out of hydro chlorofluorocarbons have begun. Technical and financial support is needed to sustain compliance status (The Ministryof Lndustry , 2007-2009-2010-2011).

CHAPTER THREE

REVIEW AND CONCLUSION

3.1. History of the understanding of stratospheric ozone

Earlier projections of the future levels of stratospheric chlorine had shown that the Montreal agreement would not be sufficient to actually reduce the size of the problem. Stricter protocols were adopted at conference in Copenhagen in 1992. A projection based on total compliance with these stricter protocols suggested that troposphere levels of the inert chlorine-containing gases should peak around 1994, with stratospheric chlorine levels peaking around the turn of the century, and then starting a slow decline over the next 200 years or so. Measurements of source gases in the troposphere showed that there had been good compliance with the protocols, and by 1994 levels of most of the important gases were increasing at less than half the rates that they had been five years earlier. Nevertheless the levels were still increasing, and only one significant species, carbon tetrachloride, had actually started to show global decline (WMO, 1994, p. xiii; Unmold et al., 1994). The extent of the annual Antarctic ozone phenomenon was

continuing to increase, both in area and duration. Indications of significant Arctic ozone depletion

Were also emerging. it was fully expected that stratospheric chlorine trends would lag behind those in the troposphere by about five to seven years. Even so, there was some disquiet that phenomena that were supposed to be peaking within a few years were still showing such a strongly increasing trend.

Disquiet was also starting to emerge about exemptions from the protocols sought by some nations (Hadfield, 1994), and about a possible 'black-market' where CFCs might be illegally manufactured and 'dressed up' as recycled product (D. Mackenzie, 1994).

Finally, there was increasing concern in the early 1990s about the possibly stronger evidence was starting to emerge that significant warming was reality. The effects of changes in stratospheric ozone on global temperatures were not clearly understood. Nor were the possible influences of changing stratospheric temperatures on the Antarctic and Arctic depletion phenomena.

The interaction and feedback between ozone depletion and global warming was emerging as another important aspect to be factored into the modeling.

As of 1994, then, although the stratospheric ozone problem had moved little away from centre stage in the arena of public concern about scientific issues, there were still several important and ongoing areas for further scientific investigation. There is also a clear need for continuing attention to and fine tuning of public policy about inert chlorine compounds.

3.2. Ozone monitoring stations

The first attempt in 1926 involved measurements with matched and carefully calibrated instruments from stations at Oxford, Shetland Islands, Ireland, Germany, Sweden, Switzerland, and Chile. In 1928 these instruments were removed to give worldwide coverage.

The new network included Oxford, Switzerland, California, Egypt, India, and New Zealand. An attempt to set up an instrument in the Antarctic at this stage, in the care of an Italian team, ended in disaster. The Dobson spectrometer finished up at the bottom of the Southern Ocean (Dobson, 1968b). Between 1928 and 1956 a lot of painstaking work was conducted. The main achievements could be classified in the following areas:

1. The need for a global network of ozone monitoring stations was recognized and protocols were devised to try to ensure that observations from different stations would be directly comparable.
2. Techniques and instrumentation were greatly refined. Initially the spectra taken had to be from direct sunlight (or, with much less accuracy, from scattered sunlight).

racy, from moonlight). Methods were developed initially for clear zenith sky, and then for cloudy zenith sky. A comprehensive monitoring network needs methods that will work on cloudy days, or the data from some locations will be very sparse indeed.

3. New techniques were developed to give information about the vertical distribution of ozone. The only information available from a conventional ozone spectrometer is the amount of ozone in the line between the instrument and the sun. This can be readily and accurately converted to 'total column ozone' – that is the total amount of ozone in vertical column directly above the observer. But there are effects arising from light scattering in the upper atmosphere that can be exploited. Sunlight travels directly from sun to instrument. Skylight travels along one line from the sun to a scattering centre, and another from scattering centre to instrument. Tiny differences between sunlight and skylight spectra can provide information about differences in the amount of ozone along the two paths. If the distribution of scattering centers is known or can be safely assumed, then this data can be transformed to calculate varying distributions of ozone with height.

The results are very approximate. But ground-based instruments can provide some vertical distribution information. Development of methods suitable for balloon-borne experiments was a separate aspect of this work. At that time, balloon-borne instruments were the only practical means of directly probing the stratosphere. Attempts to measure ozone in aircraft in 1952 had mixed success – they did indicate (as expected) that ozone levels were very low throughout the troposphere, and started to increase rapidly above the tropopause.

But the altitude of the ozone layer was well above the operating height of the aircraft. Very little ozone could be measured at altitudes the aero plane was capable of reaching.

4. Gradually a picture was built up of the annual and short term variation patterns for stratospheric ozone. A strong correlation of the short term variations with surface weather patterns was established. Some theoretical explanations for these variations and connections were starting to emerge. The situation was seen almost entirely in circulation terms, with low column ozone levels associated with upwelling of ozone poor tropospheric air, and higher levels associated with downward air movements in the stratosphere.

5. The group of scientists with an interest in stratospheric ozone monitoring gradually increased. The International Ozone Commission was set up in 1948, and atmospheric ozone was one of the major issues addressed in planning the International Geophysical Year (IGY) program for 1957–8. Unlike most years, the IGY lasted for eighteen months before 1960 - 11 months.

At that time the number of ozone monitoring stations increased greatly. Responsibility for collection and publication of data from the worldwide network of ozone monitoring stations was transferred from Oxford to the Canadian Meteorological Service, operating under a World Meteorological Organization (WMO) charter.

Unfortunately, a significantly large proportion of the ozone monitoring stations only operated for a few years after the IGY. In 1957 and 1958, the first measurements of ozone from the British station at Halley Bay in Antarctica were obtained. These showed a pattern which was different from the pattern normally obtained in Northern polar regions, and in temperate regions in both hemispheres. Instead of a fairly regular annual oscillation, with an autumn minimum and spring maximum, the ozone levels remained fairly close to the autumn level throughout winter and

early spring. They then rose rather suddenly to a peak in late spring, and slowly declined, as expected, through the summer.

This effect was known as the 'Southern anomaly' and was placed alongside similar anomalous patterns which were obtained from several other specific regions of the world. Unlike Svalbard (Spitsbergen) and Alaska, inland Northern Canada shows a pattern similar to the Antarctic pattern, but with the springtime rise occurring significantly earlier in the spring season, and at a more variable time. Northern India shows consistently lower ozone levels than other regions at similar latitudes. These other anomalies were known to Dobson when he described the 'Southern anomaly'.

The discussion so far has centered very much on the physics and meteorology of stratospheric ozone. But there was a separate series of chemical issues that called for investigation. Why is ozone present in the atmosphere at all? What chemical reactions account for its presence, but restrict the amount to trace levels? Why is ozone distributed so that its presence is largely restricted to a 'layer' between 15 and 50 km in altitude, rather than, say, being uniformly distributed throughout the atmosphere?

Physics and meteorology deal with air circulation, but circulation alone cannot discriminate between chemical species in order to concentrate particular chemical in a particular region. Any major variation of chemical composition in different regions of the atmosphere requires a chemical explanation.

In 1930, Sydney Chapman published the first moderately successful attempt to provide an explanation of ozone chemistry in the stratosphere (Chapman, 1930a, 1930b). His scheme, which ruled unchallenged until four main reactions.

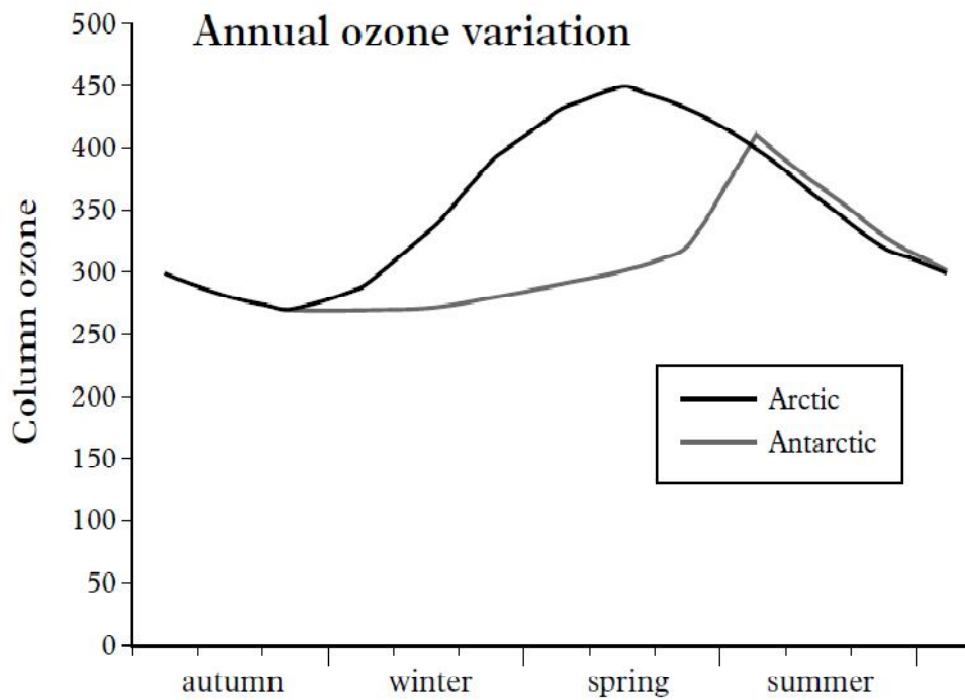


Figure 3.1 The 'Southern anomaly' in annual ozone variation (Maureen Christie ., 2003).

3.3. Conclusion

Because the ozone layer is a shield to protect the natural environment on earth from ionizing radiation in This hole aileron layer allows more radiation to reach the ground and increase the earth surface and Change the balance of the hottest temperature of the earth this in

turn is reflected in the increase of the ozone hole because under these CFC'S appropriate conditions for Chemical equation to me that work on the demolition of the ozone tamale temperature .

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