Halons, Will They Become Hazardous Wastes?
Decision VIII/17: Availability of Halons for Critical Uses

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INTRODUCTION

Since its inception, two major parts of the Montreal Protocol have been that: (1) control measures placed on the man-made chemicals, **known** collectively as ozone-depleting substances (ODS), are limits to production and consumption, and (2) the control measures (placed on production and consumption) **are** based on the scientific assessment of stratospheric ozone depletion. While some have inadvertently taken the term consumption to mean use, particularly early on, consumption is rigidly defined within the protocol. For example, consumption equals the sum of production plus newly produced imports minus newly produced exports. The terms consumption and use are not synonymous and in fact may not relate. Restrictions on the use of halons have never occurred within the Protocol.

The first major push toward seriously considering control measures on use began in 1995 when the Parties to the Montreal Protocol passed Decision VII/12, "Control Measures for Parties Not Operating Under Article 5 Concerning Halons and Other Agents Used for Fire-Suppression and Explosion-Inertion Purposes" [1]. Decision VII/12 marked the first step toward changing the emphasis within the Montreal Protocol from production and consumption of halons to use. It contained three primary areas of concern that can be summarized as follows:

- Recommendation to limit halon systems only to "Critical Applications;"
- Promotion of the environmentally safe destruction of surplus halons; and
- Advocation to include other environmental issues in determining halon alternatives.

Decision VII/12 generated only moderate concerns because it was a 'voluntary' measure. Within the halon sector, the reaction to Decision VII/12 was more one of indifference than concern. It was generally felt that such a major policy change would not take place. Some countries indicated that they would not perform these voluntary measures. However, the lack of strong opposition to the potential for use restrictions has added to its momentum. Such a drastic change in policy to even consider restricting uses of ODS within the Montreal Protocol represents a significant alteration of the historic role of the Protocol.

Decision VIII/17, "Availability of Halons for Critical Uses," is an escalation of the policy shift toward use controls on halons. The intent is to determine the quantity of banked halons that will be needed to support only critical uses. (Article 5(1) Countries' production requirements are not included.) It states the following [2]:

"Noting with appreciation the work done by the Technology and Economic Assessment Panel and its Halons Technical Options Committee pursuant to Decision VII/12 of the Seventh Meeting of the Parties,

1. Requests the Technology and Economic Assessment Panel and its Halons Technical Options Committee to carry out, on the basis of existing information, further studies on the future availability of halons to meet the demands for use in applications that are deemed critical by Parties not operating under Article 5, and to report to the Ninth meeting of the Parties;

2. Requests Parties not operating under Article 5 to estimate the approximate surplus or deficit relative to their assessment of their critical needs, and to submit this information, together with an explanation of how it was determined, to the Industry and Environment Programme Activity Centre of the United Nations Environment Programme by 31 December 1997;

3. Requests the Technology and Economic Assessment Panel and its Halons Technical Options Committee to evaluate the information received from Parties and make an assessment, if possible, for the Tenth meeting of the Parties of whether there will be adequate halon to meet future needs for critical applications of Parties not operating under Article 5; and

(a.) If there is a shortfall, either overall or in individual Parties, to propose action which may be taken to enable that shortfall to be overcome; or

(b.) If there is a surplus, either overall or in individual Parties, to provide guidance on appropriate policies for disposal or redeployment, bearing in mind the needs of other Parties not operating under Article 5, as well as the needs of Article 5 Parties, and to identify potential harriers to such disposal and what steps may be needed to overcome them."

A striking aspect of Decision VIII/17 is the acceptance for the concept of 'Critical Uses.' This phrase was first used in late 1995 in Decision VII/12 and has since become an accepted concept. Previous analysis of the critical use policy showed that defining critical uses across national boundaries may have far reaching impacts that would likely have adverse effects on the global supplies and availability of halons [3,4,5]. Although there are significant policy and implementation problems with the concept of critical uses, Decision VIII/17 not only advocates the policy, but appears to take its existence as granted.

While the critical use concept and policy have clearly taken hold, the demonstration of the need for such policy is questioned. The original rationale behind the critical use policy came from the 1994 Scientific Assessment of Ozone Depletion. A review of that assessment as it pertains to halons will provide insight into answering the question of need. While it may be demonstrated that the critical use policy is not required and may in fact be detrimental, it is nonetheless becoming the accepted policy. It is, therefore, also important for continued users of halons to understand the implications of Decision VIII/17.

RATIONALE - 1994 SCIENTIFIC ASSESSMENT

A basic premise of the Montreal Protocol **has** been the use of the scientific assessment process in demonstrating, within the ability of the science, the need for the proposed control measures. This is performed through the Scientific Assessment Panel ***(SAP).*** In their 1994 Scientific Assessment, the *SAP* provided a graphical representation of the quantity of equivalent stratospheric chlorine abundance for three scenarios (1) without the Montreal Protocol, (2) 1987 Montreal Protocol control measures, and **(3)** Copenhagen Amendment control measures [6]. At the seventh meeting of the Parties in Vienna, 1995, the ***SAP*** presentation also included the effects of the London Amendment control measures [7]. The quantity of equivalent stratospheric chlorine for these four scenarios is depicted in Figure 1. The term 'equivalent stratospheric chlorine loading' is used to denote that the effects of bromine are also included.

The quantity of equivalent chorine loading is directly proportional to stratospheric ozone depletion. The ozone 'hole' forms above approximately **2000** parts per trillion by volume (pptv) of equivalent stratospheric chlorine. As can be seen from Figure 1, until the London Amendments, the scientific assessment indicated that the ozone hole would continue to grow for the predictable future. Assuming that the data on production and emissions of ODS available to the Science Panel were correct, the current provisions of the Protocol, i.e., Copenhagen Amendments, allow for the closing of the ozone hole in the year 2045, i.e., the year in which equivalent stratospheric chlorine drops below 2000 pptv. While the current control measures appear to be adequate for the ozone hole to close, this will not occur until well into the 21st century.

The SAP included several scenarios in which the closing of the ozone hole could be hastened or postponed [6,7]. Among them was the effect on ozone depletion if the quantity of 'banked' halons was not emitted. They reported that the effect on integrated ozone depletion from 1995 to the point where the ozone hole closed would be a decrease of 10%. The SAP analysis **was** used as the basis **for** suggesting the need for further control measures above those of the Copenhagen Amendments. When the process of moving toward use controls started, i.e., Decision VII/12, the 1994 Scientific Assessment Report was not published. The results were presented in a the briefing by one of the *SAP* co-chairs and may not initially have been fully understood. Regardless, the justification behind Decisions VII/12 and VIII/17, and the policy of defining and limiting halons to critical uses, has its basis in the 1994 Scientific Assessment.

Since the original *SAP* briefing and the production of the report, further analysis and clarification of the 1994 Scientific Assessment have been made possible. It is important to note that the value **of** a potential 10% reduction in ozone depletion only relates to the portion in Figure 1 above 2000 pptv (i.e., ozone hole) and after the year 1995. It does NOT relate *to* the entire amount of ozone depletion. Secondly, there is an approximate three-year lag between tropospheric emissions and changes in the stratosphere. Under the assumptions used by the SAP, peak stratospheric chlorine loading occurs in approximately 1997 based on tropospheric emissions that occurred prior to 1995. It is not possible **to** affect the quantity of peak chlorine loading or the timing of the peak as these were determined by the pre-1995 emissions. The area of ozone depletion that could still be affected by further control measures in 1994 is shown graphically in Figure 1.

The 1994 Scientific Assessment estimated that the reduction to integrated ozone depletion **as** a result of not emitting banked halons would be approximately 10% [6]. Under this scenario the chlorine concentration would fall below 2000 pptv in 2043, i.e., the ozone hole closes two years earlier than assuming full compliance to the Copenhagen Amendments. The development of the Copenhagen Amendment 'baseline' and the other scenarios required an estimation of the emissions of all ODSs. It is important to note that the 1994 Scientific Assessment does not claim that destruction of halons is required, only that they not be emitted to the atmosphere. While it is generally taken that destruction may be one means of reducing emissions other means are also available. To understand what these may be it is important to **know** the emission scenario used in the 1994 Scientific Assessment. Any reduction in actual emissions versus the *SAP* estimated emissions will result in a reduction of integrated ozone depletion from that shown in Figure 1.

The halon emission scenario used by the SAP to determine the Copenhagen Amendment curve in Figure 1 is as follows [6].

- Entire Halon 1211 bank emitted in equal amounts 1993 - *2000* (12.5% of 1990 Bank/yr);
- Entire Halon 1301 bank emitted in equal amounts 1993 - 2010 *(5.6%* of 1990 Bank/yr);
- Consumption for Article 5(1) countries based on
  - 5% of 1992 global production in 1992,
  - grows to 10% by 1996, constant to 2002
  - linear decrease to zero 2003 - 2006

Since the 1994 Scientific Assessment has been completed, new data and information on halon production and emissions have become available. This new information shows that the assumption that all halon 1211 would be emitted by the year 2000 and that all halon 1301 would be emitted by the year 2010 is not proving to be valid. It is also not valid that Article 5(1) countries will only produce through *2006*. The Parties have decided that the Article 5(1) Countries' 10-year grace period for production begins from the London Amendment phase-out date, 1 January *2000* and not the Copenhagen Amendment date. China and other Article 5(1) Countries may legally produce halons until the year 2010. The SAP estimated global production of halons in Article 5(1) countries as 5-10% of the global production in 1992. (The 1992 halon production data was not yet reported so it is assumed that the 1990 production data was used.) Using the 5-10% values for halon 1211 and the 1990 global production from McCulloch [8], the total Article 5(1) production would be 743-1485 metric tons per year. The production in China alone is 7500 metric tons. In addition, it has been reported that the emissions from these production plants may be as high **as** 100% of yield. If this is correct, the minimum that Article 5(1) countries are both producing and emitting on a yearly basis is 7500 metric tons, 5 to 10 times the value used in the 1994 Scientific Assessment.

The significant difference in the China production quantity has both an immediate and a long term effect. Larger quantities of production will lead to larger quantities of installed base, **i.e.,** a bank, that may be emitted in the **future.** It is not clear what value, if any, was used in the 1994 Scientific Assessment for the bank of **halons** in China from 1991. Other Article 5(1) countries are also producing halons, and Russia **has** an Essential Use production allowance for halon 2402. These will serve to further increase the emissions of halons over the 1994 Scientific Assessment estimates.

The emission scenario used in the 1994 Scientific Assessment greatly exaggerates the likely emissions from the halon bank. It is possible to develop new emission estimates using (1) the McCulloch **data** to estimate the size of the bank in 1992 and 1994, (2) the reported production quantities for **China,** and (3) emission patterns that better represent the actual emissions within the halon sector. To perform the estimation in this work, it was assumed that the McCulloch data accurately represented the bank until 1990. To determine the size of the bank in 1992 and 1994, the difference between the 1990 emission and production quantities were assumed for 1991-1994.

The emissions for halon 1301 were calculated based on the McCulloch 1992 data, but instead of relating the quantity of emissions **as** a percent of production, it **was** derived as a percentage of the bank for 1992. In each year, it is assumed that 5.4% of the bank is emitted. It would appear that the ***SAP*** performed a similar analysis but kept the quantity derived at 5.56% (an even 18 year distribution), from the first year, constant until the bank was depleted. **As was** true for halon 1301, the first year emission of halon 1211, 12.5% percent of the bank, appears to be the same as used in the 1994 Scientific Assessment. Instead of keeping the quantity constant as the SAP did, a percentage of the bank is used. Unlike halon 1301, however, the percentage is not kept constant. Through 1995, the emissions are assumed to be 12.5% of the bank. The halon 1211 emissions are reduced to 9% for the period 1996 - 2000, and 5% past the year 2000. The decrease in emissions is due to the recognition that many of the largest users of halon 1211 have seriously reduced their emissions. For example, one of the largest uses of halon 1211 **was** for training. In most instances, training with halon 1211 has been stopped or greatly reduced. It is likely that additional reduction in emissions will also result from the use of alternatives in some applications.

The results for halon 1301 are provided in Figure 2. This emission scenario does not include any provisions **for** production in Article 5(1) countries. The likely emissions are greatly less per year than the ***SAP*** assumed for the 1994 Scientific Assessment. This is consistent with **the** fact that many halon 1301 **users** have plans and stocks for continued reliance over the next 20 **to** 40 years.

Figure **3** shows the results for halon 1211. As can be seen, the emissions from China are quite large. It has been reported unofficially that the production of halon 1211 in China could be more than the size of the halon bank, and might even be greater than all of the production of halon 1211 from all developed countries. The emission values assumed for China are 100% of the production, taking into account the reports of yield, plus the same percentage of their bank as used for the developed countries' bank.

The *SAP* emission patterns and the ones derived in this work both assume that the size of the bank in McCulloch 1992 is correct. Anecdotal data from countries that have mandated registration or collection of halon indicate that less halon is available in the global bank [3,4,5]. The emissions from a smaller bank would be even less than estimated here. The larger bank values are used to remain conservative in this analysis.

An analysis was performed to illustrate the effect that halon emissions have on integrated ozone depletion. The 1994 Scientific Assessment Report included graphs (Figure 13-2) that depict the contribution of various portions of total equivalent chlorine loading [6]. It was possible to measure the difference in chlorine loading due to halons from those graphs. The result is labeled "SAP Halons" in Figure 4. The curve labeled "Conceptual Halons" was developed by keeping the same area under the curve as for SAP Halons recognizing the slower, longer emissions of halons. (Figure 4 should only be considered qualitative because of (1) the inherent limitations of measuring from reprinted graphs, (2) measurements were only taken at 20 year intervals, and **(3)** the 'smoothed' curves are created for visual effect only. Further, it is recognized that this total would also include the Article 5(1) countries production assumed by the SAP. Within the level of accuracy of this report, it is approximated that under the emission assumptions made by the *SAP* the majority of ozone depletion after 2000 due to halons can be attributed to banked halons. While this is not true, it will keep the estimations conservative.)

A further estimation was made by subtracting the estimated chlorine loading from SAP halons and adding the chlorine loading from Conceptual Halons to the chlorine loading assuming compliance to the Copenhagen Amendments. This is labeled "Conceptual Total Ozone Depletion" in Figure 4. This curve shows that it is possible that the 1994 Scientific Assessment is over predicting the amount of integrated ozone depletion that will occur from 1995 to 2045 as a result of banked halons.

If the depiction shown in Figure 4 is assumed "correct," then the following conclusions may be drawn. Compared to the 1994 Scientific Assessment, there is an approximate 5% reduction in ozone depletion before the ozone hole closes, and assuming that the same quantities of halon are emitted in this scenario as in the Copenhagen Amendment scenario, a 5% increase AFTER the ozone hole closes. While total ozone depletion has to be the same with the same quantity emitted, the time period when the ozone depletion takes place can be altered. (In the emissions scenarios developed in this work, a portion of the bank still remains through 2025. This would further reduce the total ozone depletion). If half of the halon bank were destroyed in the immediate future, it is possible that the only savings to ozone depletion will occur after the ozone hole closes. Further, it is not unreasonable to believe that collection and destruction schemes can result in losses on the order of 5-10% of collected material. These losses are the same order of magnitude as the projected emissions of the bank.

While the analysis is more qualitative than quantitative, it shows that the rationale that 10% of integrated ozone depletion between 1995 and the year the ozone hole closes may be saved by not emitting banked halons is likely to be false. While the banked halons may not be emitted at the worst time, the Article 5(1) countries' production is. Based on the quantities estimated in this work, significant savings to ozone depletion before the ozone hole closes are more likely achieved through affecting current production. Immediate reductions in emissions from productions losses and longer term reductions from smaller banks would result.

APPLICATIONS RELYING ON HALON

While the above analysis shows the importance of better estimations in yearly emissions, it is not a rationale for Decision VIII/17. The data required to be collected on quantities of banked halons under Decision VIII/17 are not for the production of a more accurate scientific assessment. The purpose is tied to the critical use agenda. While this is not the first time that there has been an interest in developing estimates of global halon supplies, it is the first internationally coordinated effort. Previous estimates have been more geared toward concerns that there would not be enough halons and that Essential Use Production exemptions may have to be given. Decision VIII/17 is a continuation of the premise that there is an abundance of halons in "non-critical" uses that need to be regulated. By removing the halon from these frivolous uses, surpluses will be created that may then be destroyed.

One of the many difficulties in the current policy is gaining accurate data on global quantities of banked halons. The militaries around the world have some of the best data available. A temptation exists to extrapolate from the military data to the commercial sector. This, however, will not necessarily provide any better data than is currently available. For example, the U.S. Navy reports that they have approximately 3600 aircraft with 69,000 pounds of installed halon 1301 [9]. This yields an average of approximately 19 pounds per aircraft. The U.S. Army has approximately 5000 aircraft with halon 1301 installed. Using the U.S. Navy derived 19 pounds per aircraft would result in an estimate that the U.S. Army has 96,000 pounds of halon 1301 installed on aircraft. In actuality, the U.S. Army only has 23,500 pounds installed on aircraft [10]. The discrepancy is due to the fact that the Army mainly has helicopters, and the Navy has helicopters, fighter jets, cargo aircraft, and a small number of commercial aircraft. It must also be noted that the overall error was reduced by only including U.S. Army and Navy aircraft that are known to contain halon. The Army has a significant number of helicopters without fixed halon systems. If data from the U.S. Navy cannot be used to accurately estimate halon quantities for the U.S. Army, it is not very likely that data from the military of one country will be useful in estimating the quantities for another country. The estimation gets even worse going from the military sector to the commercial sector. Based on data for civil aviation around the world, the average commercial aircraft contains about 45 pounds of halon [11]. Using the military data would greatly underestimate supplies and needs for commercial aviation.

To obtain accurate quantities, extrapolations must be kept to a minimum. However, it is unlikely that accurate data from all sources will be obtained. Some extrapolation will have to occur. It is important not to overestimate the accuracy of the data. The implication of Decision VIII/17 is that estimates for quantities of halons needed for decades will be made over the next several months. The decisions and assumptions used now will greatly affect the availability of halons in the future. The accuracy of the available data will likely not be high enough for the types of assessment that will be made. It may be even worse than the adage Garbage In - Garbage Out (GIGO). GIGO may become Garbage In Gospel Out. This is particularly true if the estimates indicate that there might be **an** excess of halons to meet critical uses. Users who rely on personal reserves **or** commercial banking schemes face the same problems. The intent of the current policy is to limit the quantities that will remain in commerce. The 'excess' halons would become a hazardous waste that needs to **be** collected and destroyed.

SUMMARY

A more complete understanding of the 1994 Scientific Assessment indicates that the assumptions used by the *SAP* for halon emissions are not valid. The ***SAP*** underestimated the production and emissions for Article 5(1) Countries and overestimated the near term emissions of halons from the bank. These assumptions overestimate the amount of ozone depletion as a result of the banked halons and greatly underestimate the amount of ozone depletion from continued production of halons in Article 5(1) Countries.

The most immediate savings to ozone depletion can come from a reduction in the emissions due to production. Affecting the Article ***5*** countries' production will have an immediate reduction and a longer term reduction. Smaller banks will be created ***so*** that long term emissions will be reduced. Based on production data and the emissions estimated in this work, the savings can be significant.

Decision VIII/17 is a continuation of the move toward changing the control measures within the Montreal Protocol to **use.** By intending to limit the quantities of halons allowed in the global bank to only that needed to support critical uses, it is essentially controlling the use of halons. The estimations to determine the quantities of halons needed for critical **uses** are underway. The actions taken over the next few months may have a large impact on the global bank of halons.

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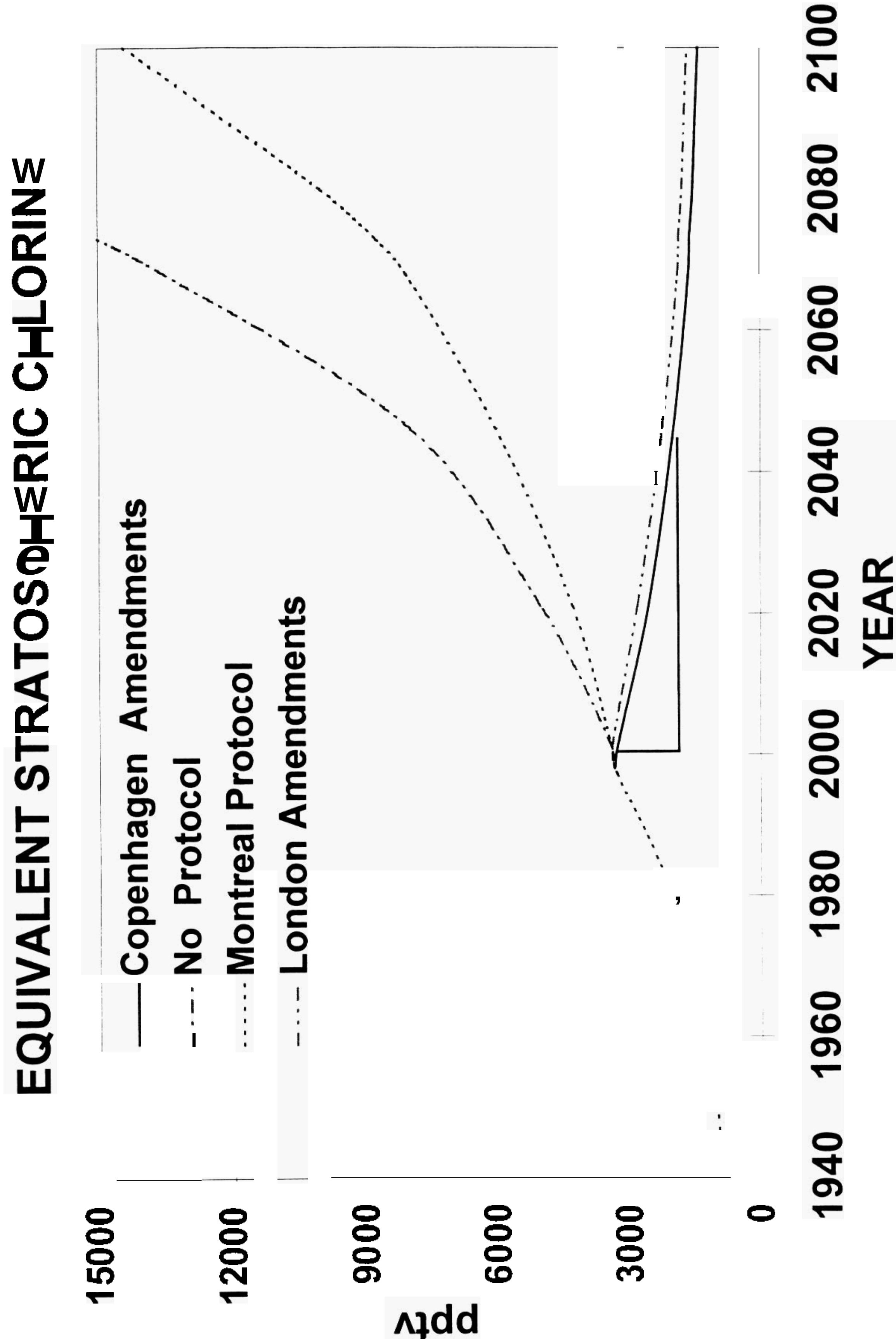
Figure 1



EQUIVALENT STRATOSPHERIC CHLORINE
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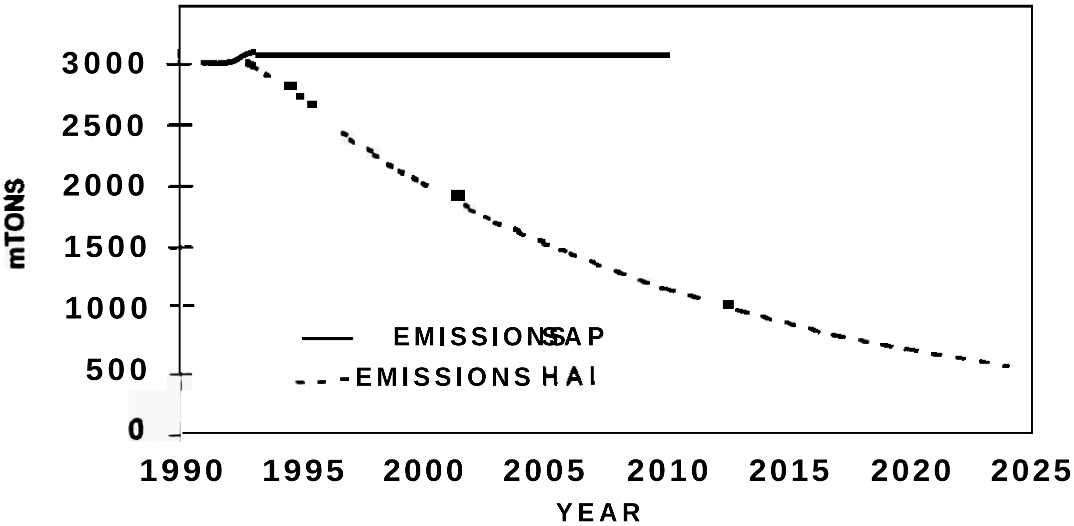

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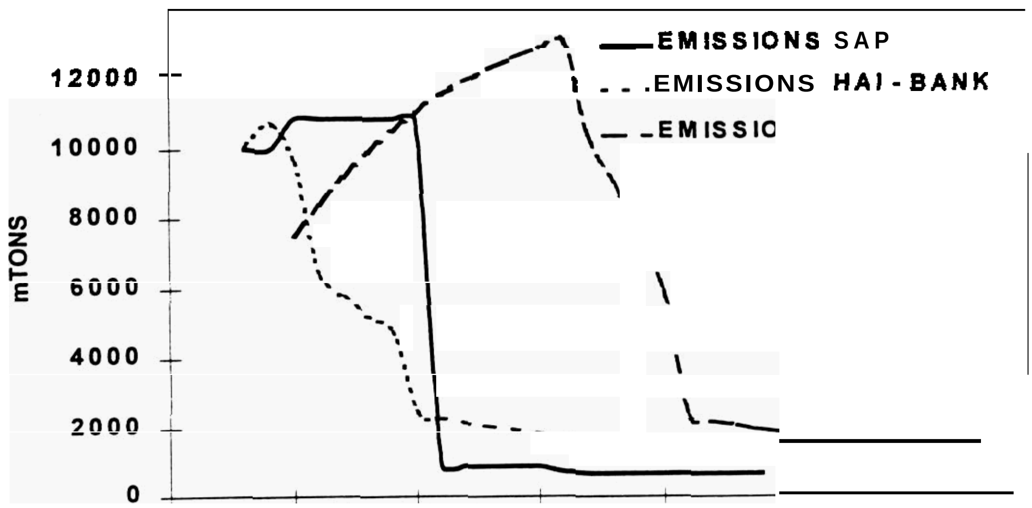

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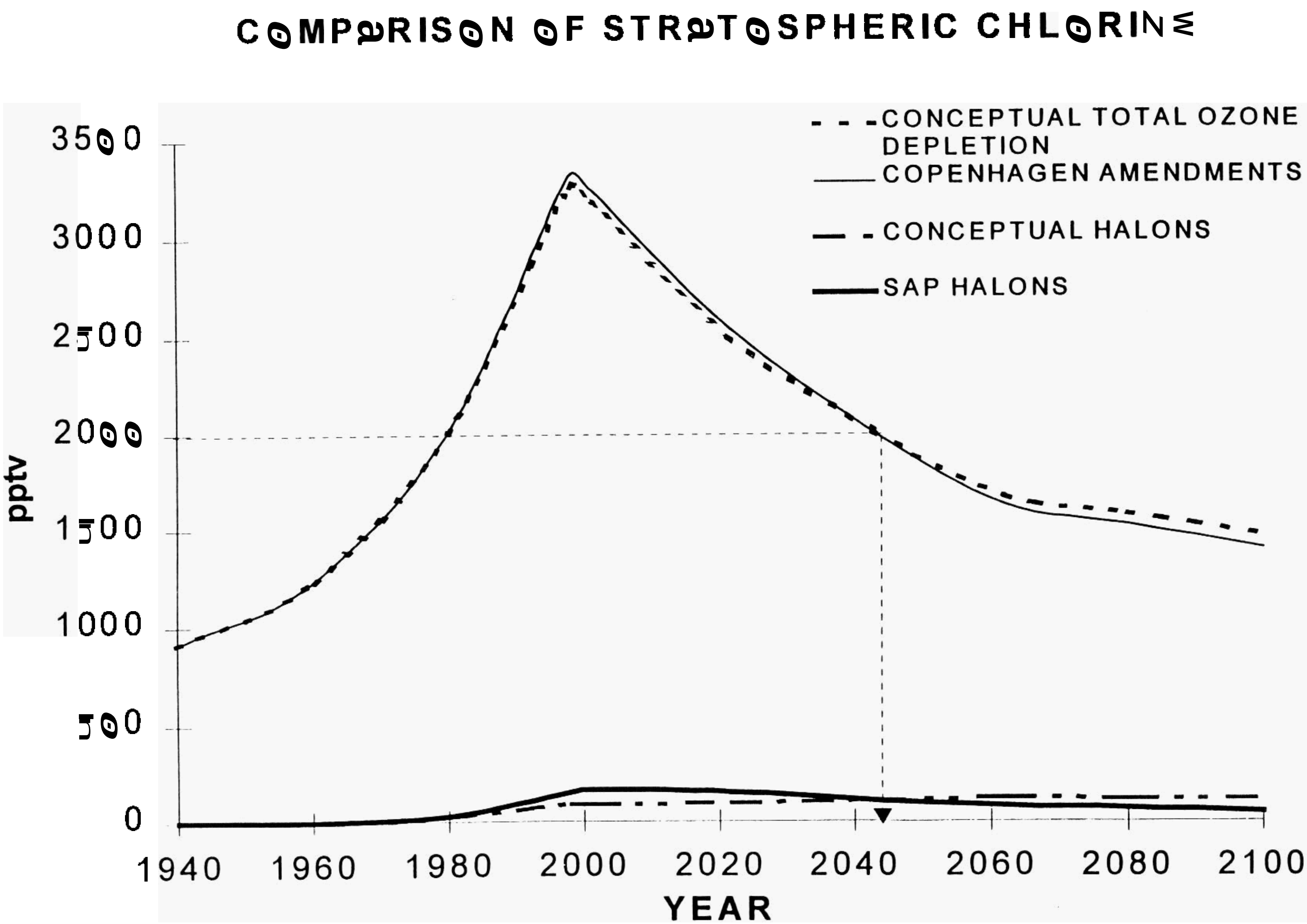
Figure 4


COMPARISON OF STRATOSPHERIC CHLORINE
CONCEPTUAL TOTAL OZONE DEPLETION
COPENHAGEN AMENDMENTS
CONCEPTUAL HALONS
SAP HALONS
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