CHALLENGES FOR THE INDIAN MILITARY: MANAGING OZONE DEPLETING SUBSTANCES

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One of the last vestiges of Ozone Depleting Substances (ODS) usage happen to be the military organisations due to the known efficiency of these chemicals. After the international agreement (Montreal Protocol) amongst nations on phasing out these chemicals, they were no longer to be produced and their availability would be drastically reduced. This has the potential to adversely impact upon military operations. The present article attempts an overview of some of the approaches that could be adopted by defence organisations to successfully phase out ODS and introduce their alternatives, where feasible. The legacy military equipment designed to work with ODS-based technology would have to be carefully managed so as not to allow accidental discharges which would harm the ozone layer adversely. Due to these reasons, the military organisations would now have to take leadership decisions and manage their operations without ODS in the long run and by optimum inventory management in the interim, till their replacements are in place.

THE OZONE LAYER: BACKGROUND

The ozone layer had formed millions of years ago to safeguard life on the planet. High in the atmosphere, some oxygen (O_2) molecules absorbed energy

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from the sun's ultra-violet (UV) rays and split to form single oxygen atoms. These atoms combined with O_2 to form ozone (O_3) molecules, which are very effective at absorbing UV rays. The thin layer of ozone that surrounds the earth acts as a shield, protecting the planet from UV radiations. Nature had provided for the sun to be an abundant source of energy for the earth and was benign enough to provide for the ozone layer so that the associated UV rays do not harm the living organisms on the planet.

The amount of ozone required to shield the earth from biologically lethal UV radiation wavelengths from 200 to 320 nanometers (nm), is believed to have been in existence 600 million years ago. Prior to this period, life was restricted to the ocean. The presence of ozone enabled organisms to develop and live on the land. The formation of the ozone layer and its maintenance has been so pristinely planned by nature that its despoilment by the human race is a tragedy beyond comprehension.

Ozone molecules in the stratosphere absorb UV light from the sun, providing a filter that prevents this radiation from passing to the earth's surface. While both oxygen and ozone together absorb 95 to 99.9 per cent of the sun's UV radiation, only ozone effectively absorbs the most energetic UV light, known as UV-C (220-290 nm) and UV-B (290-320 nm). Energetic UV radiation at the earth's surface is a health concern because it causes biological damage in the form of skin cancer (malignant melanoma), tissue damage to the eyes, plant tissue damage and destruction of plankton populations in the ocean.

The overall amount of ozone in the stratosphere is determined by a balance between photochemical production and recombination. The whole process was in a state of equilibrium till anthropogenic actions ensured placing ODS in the stratosphere, namely, the halogenated carbons. Some of these compounds are chlorofluorocarbons (CFCs), methyl bromide and bromochloro/fluoromethane, namely, halons, amongst others. The halogen atoms of chlorine and bromine act as catalysts to destroy the ozone molecules. Each of these compounds has a different Ozone Depleting Potential (ODP).[1]

History of Research

- In the 1950s, David Bates and Marcel Nicolet presented evidence that various free radicals, in particular hydroxyl (OH) and nitric oxide (NO), could cause a disassociation reaction, reducing the overall amount of ozone.
- In 1970, Prof. Paul Crutzen showed how NO affects the ozone layer. In the following year, Crutzen and (independently) Harold Johnston suggested that NO emissions from supersonic aircraft, which fly in the lower stratosphere, could also deplete the ozone layer.
- In 1973, Chemists Frank Sherwood Rowland and Mario Molina, then at the University of California, began studying the impacts of CFCs in the earth's atmosphere. They discovered that CFC molecules were stable enough to remain in the atmosphere until they got up into the stratosphere where they would be broken down by UV radiation, releasing chlorine atoms. They then proposed that these chlorine atoms would cause the breakdown of large amounts of ozone in the stratosphere. Their argument was based upon an analogy to contemporary work by Crutzen and Johnston mentioned above. Later, two more scientists, McElroy and Wofsy, extended the work of Rowland and Molina by showing that bromine atoms were even more effective catalysts for ozone loss than chlorine atoms and argued that the brominated organic compounds known as halons, widely used in fire extinguishers, were a potentially large source of stratospheric bromine. Crutzen, Molina, and Rowland were awarded the 1995 Nobel Prize in Chemistry for their work on stratospheric ozone.
- In 1985, British Antarctic Survey scientists Farman, Gardiner and Shanklin shocked the scientific community when they published the results of a study in the journal *Nature* showing an ozone "hole"— showing a decline in polar ozone far larger than anyone had anticipated.

1. The ODP is a number that refers to the amount of ozone depletion caused by a substance. It is the ratio of the impact on ozone of a chemical compared to the impact of a similar mass of CFC-11. Thus, the ODP of CFC-11 is defined to be 1.0.

- The same year, 20 nations, convinced of the problem of ozone depletion, signed the Vienna Convention which established a framework for negotiating international regulations (Montreal Protocol) on ozone-depleting substances. However, the CFC industry, led by DuPont, still took some more convincing before they actively started working on its replacement.

IMPACT OF OZONE DEPLETION

A brief recap of the impact of ozone layer depletion would enforce the rationale behind urgent international action for phasing out the ODS. As already mentioned, depletion of the ozone layer allows dangerous UV radiations to pass through to the earth surface. This, in turn, harms all living organisms in the following manner:

- **Skin Cancer:** The most common forms of skin cancer in humans have been strongly linked to UV-B exposure. A study of people in Punta Arenas, at the southern tip of Chile, showed a 56 per cent increase in melanoma and a 46 per cent increase in non-melanoma skin cancer over a period of seven years, along with decreased ozone and increased UV-B levels.[2]
- **Cataracts:** Studies are suggestive of a direct association of UV-B exposure and ocular cataract.[3]
- **Increased Tropospheric Ozone:** Increased surface UV radiation leads to increased tropospheric ozone. Ground-level ozone is a health risk, as it is toxic due to its strong oxidant properties.
- **Effects on Crops:** An increase in UV radiation would affect the bacteria responsible for retention of nitrogen in plant roots, thereby affecting their growth and productivity.
- **Effects on Marine Ecosystem:** Planktons are susceptible to the effects of UV light. They are vitally important to marine food webs.[4]

2. Jaime F. Abarca, and Claudio C. Casiccia, "Skin Cancer and Ultraviolet-B Radiation Under the Antarctic Ozone Hole: Southern Chile, 1987-2000," *Journal of Photo-dermatology, Photoimmunology & Photomedicine* (ISSN 0905-4383).
3. West et al., Sunlight Exposure and Risk of Lens Opacities in a Population-Based Study: The Salisbury Eye Evaluation Project, August 26, 1998.
4. NewsFactor Network.

USE OF ODS

The US Environment Protection Agency (EPA) has divided ODS into two groups as per their ODP range. Class 1 ODS are those in which the ODP is 0.2 or higher. Class 2 ODS are those in which the ODP is less than 0.2. Their impacts can be gauged when the wide array of their usage is analysed. A list of some of these ODS is compiled (from the US EPA Internet sites) below in a tabular form for ease of understanding.

Table 1: Class I Ozone-Depleting Substances

Chemical Name	ODP (Montreal Protocol)	GWP[5] (TAR)	Usage
CFC-11 (CCl3F) Trichlorofluoromethane	1	4600	CFCs are/were commonly used as refrigerants, solvents, Metered Dose Inhalers (MDI) and foam blowing agents.
CFC-12 (CCl2F2) Dichlorodifluoromethane	1	10600	
CFC-113 (C2F3Cl3) 1,1,2-Trichlorotrifluoroethane	0.8	6000	
CFC-114 (C2F4Cl2) Dichlorotetrafluoroethane	1	9800	
CFC-115 (C2F5Cl) Monochloropentafluoroethane	0.6	7200	
CFC-13 (CF3Cl) Chlorotrifluoromethane	1	14000	
Halon 1211 (CF2ClBr) Bromochlorodifluoromethane	3	1300	Halons are used as fire extinguishing agents, both in built-in systems and in hand-held portable fire extinguishers. Widest use is in defence establishments.
Halon 1301 (CF3Br) Bromotrifluoromethane	10	6900	
Halon 2402 (C2F4Br2) Dibromotetrafluoroethane	6		
Methyl Bromide (CH3Br)	0.6	5	Methyl bromide is an effective pesticide used to fumigate soil and many agricultural products.

5. The GWP is the ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide. Thus, the GWP of CO2 is defined to be 1.0. TAR is the Third Assessment Report of an international body of scientists studying the climate, called the Intergovernmental Panel on Climate Change (IPCC).

Table 2: Class II Ozone-Depleting Substances

Chemical Name	ODP (Montreal Protocol)	GWP (TAR)	Usage
HCFC-133a (C2H2F3Cl) Monochlorotrifluoroethane	0.02 - 0.06		These are transitory alternatives of CFCs in the refrigeration industry. Their ODP is much less than the CFCs but still with a high GWP.
HCFC-141b (C2H3FCl2) Dichlorofluoroethane	0.11	700	
HCFC-142b (C2H3F2Cl) Monochlorodifluoroethane	0.065	2400	
HCFC-221 (C3HFCl6) Hexachlorofluoropropane	0.015-0.07	Not Mentioned	
HCFC-222 (C3HF2Cl5) Pentachlorodifluoropropane	0.01-0.09	-do-	
HCFC-223 (C3HF3Cl4) Tetrachlorotrifluoropropane	0.01-0.08	-do-	
HCFC-224 (C3HF4Cl3) Trichlorotetrafluoropropane	0.01-0.09	-do-	
HCFC-225ca (C3HF5Cl2) Dichloropentafluoropropane	0.025	180	
HCFC-225cb (C3HF5Cl2) Dichloropentafluoropropane	0.033	620	
HCFC-226 (C3HF6Cl) Monochlorohexafluoropropane	0.02 - 0.1	Not Mentioned	
HCFC-231 (C3H2FCl5) Pentachlorofluoropropane	0.05 - 0.09	Not Mentioned	

HFCs are considered better replacements for CFCs for refrigeration purposes as well as in MDI for asthma patients. Their ODP is 0 but their GWP is very high. Some examples are given below.

Table 3: Examples of HFCs

Chemical Name	ODP	GWP
HFC-134a CF3CFH2	**All zero**	1300
HFC-143a C2H3F3		3800
HFC-152a CF2HCH3		140
HFC-227 C3HF7 and blends	Now being considered for defence applications	2900

These ODS are used in many applications in military establishments. In the Indian Air Force (IAF), halons are used for fire-fighting in the Crash Fire Tenders (CFTs) as well as on every aircraft (for the engine, auxiliary power unit and cargo compartment) as a fire suppressant. In the Navy, they are used for fire-fighting operations in ships and submarines at almost all vulnerable places of these platforms. In the Army, all motorised armoured carriers utilise them for fire-fighting operations. As refrigerants, these ODS are used in all central air-conditioning plants, mobile communication hubs, missile batteries, armoured carriers, and cockpits/cabins (for certain aircraft only). The use of carbon tetrachloride (CTC) as solvents for cleaning and degreasing as well as precision cleaning of electronic components was also carried out in a few defence applications.

THE MONTREAL PROTOCOL: AN IMPACT ANALYSIS

Life on the planet was in jeopardy. The international community acted in concert to halt production and consumption of these ODS, through an agreement called the Montreal Protocol under the aegis of the United Nations. The treaty was opened for signature on September 16, 1987, and entered into force on January 1, 1989. Since then, it has undergone seven revisions, in 1990 (London), 1991 (Nairobi), 1992 (Copenhagen), 1993 (Bangkok), 1995 (Vienna), 1997 (Montreal), and 1999 (Beijing). The successive revisions expanded the list of regulated substances, accelerated control measures and set time-lines for phasing out the use and production of some of the regulated substances. Scientists had claimed that if the international agreement is adhered to, the ozone layer would recover by 2050. However,

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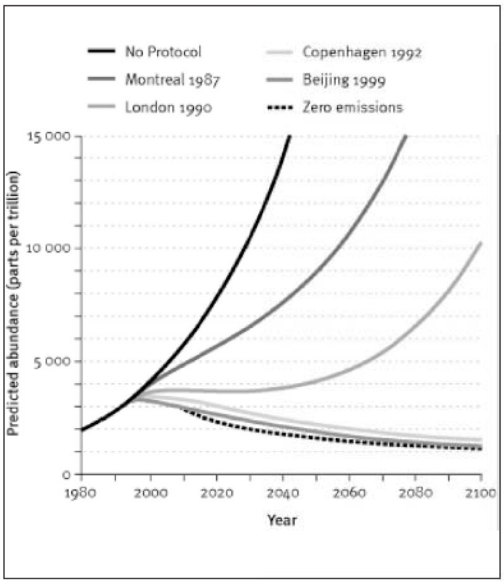
now it is being said that due to the impact of global warming, a more realistic time-frame of recovery would be 2060 due to the reported impact of Green House Gas (GHG) emissions on the ozone layer. As reported by the scientific assessment panel, the United Nations Environment Programme (UNEP) 2006, (Nairobi), due to its widespread adoption and implementation, the Montreal Protocol has been hailed as an example of exceptional international cooperation.

Fig 1 shows the effect that the Protocol and its various amendments have had and are expected to have in reducing effective stratospheric chlorine (combined effect of chlorine and bromine) throughout the coming decades. The reduction is a result of restrictions on the production and consumption of synthetic ozone depleting substances.

Fig 1: Effect of Montreal Protocol in Reducing Halogens in the Atmosphere



Source: (Modified by the Australian Government) from WMO 2007.

The Protocol and its revisions have many features which directly affect the functioning of India's military establishment. These features are explained in the succeeding paragraphs. Their impact on the Indian military establishment would be analysed thereafter. The Protocol has 20 Articles in all. Brief details[6] of the salient points of the relevant Articles are mentioned below.

Article 1 states the definitions of the terms used in the Protocol. The relevant definition to note is that of production and consumption of ODS.

- "Production" means the amount of controlled substances produced, minus the amount destroyed. The amount recycled and reused is not to be considered as "production".
- "Consumption" means production plus imports minus exports of controlled substances.

Article 2 defines the production control measures that need to be adopted for various ODS. These control measures are defined in Articles 2A to 2I, for different groups of ODS and with respect to 1986 consumption figures. A brief summary of these control measures is tabulated below.

Table 4: ODS Control Measures as Stipulated in Montreal Protocol

Substance	Developed countries	Developing countries (Article 5 countries)
Chlorofluorocarbons	Phased-out end of 1995	Phase-out 2010
Halons	Phased-out end of 1993	Phase-out 2010. Accelerated phase-out 2008.
Carbon tetrachloride	Phased-out end of 1995	Phase-out 2010
Methyl chloroform	Phased-out end of 1995	Phase-out 2015
Hydrochlorofluorocarbons	Frozen in 1996 Phase-out 2020	19^{th} MOP Freeze 2013 level, 100% reduction in 2030 with a service trail up to 2040.

6. The Montreal Protocol: www.unep.org/ozone/Montreal-Protocol

Methyl bromide	Frozen in 1995 Phased-out 2005 (Essential Use Exemption exists for some countries)	Frozen at 2002 level Phase-out 2015
Bromochloromethane	Phased-out 2002	Phased-out 2002

Article 3 mentions the method of calculating the control levels, till the phase-out. Article 4 talks of trade issues related to ODS and the introduction of the licence system. These are relevant to India's context as the national ODS imports would have to conform to these stipulations.

Article 5 is very relevant to the Indian context. It states, "Any Party that is a developing country and whose annual calculated level of consumption of the controlled substances in Annex A is less than 0.3 kilograms per capita on the date of the entry into force of the Protocol for it, or any time thereafter until 1 January 1999, shall, in order to meet its basic domestic needs, be entitled to delay for ten years in its compliance with the control measures set out in Articles 2A to 2E, provided that any further amendments to the adjustments or amendment adopted at the Second Meeting of the Parties in London, 29 June 1990, shall apply to the Parties operating under this paragraph after the review provided for in paragraph 8 of this Article has taken place and shall be based on the conclusions of that review." It is clear that special provisions have been made for the developing countries as per the principle of "common but differentiated responsibility."

Article 6 talks of assessment and review of control measures on the "basis of available scientific, environmental, technical and economic information. At least one year before each assessment, the Parties shall convene appropriate panels of experts…." Article 7 is concerned about reporting of data on the production, imports and exports of each of the controlled substances by the countries within three months of becoming a party.

Article 8 speaks of procedures and institutional mechanisms for determining non-compliance and their treatment thereof. Article 9 is regarding research, development, public awareness and exchange of information "taking into account in particular the needs of developing countries."

Article 10 is regarding establishing a financial mechanism "for the purposes of providing financial and technical cooperation, including the transfer of technologies" to the developing countries (Article 5). The multilateral fund has been established under this provision under the London Amendment. Articles 11 and 12 are on administration of the Protocol. Other Articles (13 to 20) are regarding the provisos mandated by international agreements.

The parties to the Montreal Protocol have defined recovery, recycling and reclamation as follows:

- Recovery relates to the collection and storage of controlled substances from machinery, equipment, container vessels, etc., during servicing or prior to disposal.
- Recycling refers to reuse of recovered controlled substances following a basic cleaning process such as filtering and/or drying.
- Reclamation is about reprocessing and upgrading of a recovered controlled substance through such mechanisms as filtering, drying, distilling, and chemical treatment, in order to ensure that the substance once again meets specified performance standards. Such processing often takes place offsite at some central facility.

MULTILATERAL FUND

With a view to assist the developing countries in their ODS phase-out efforts, a Multilateral Fund (MLF) has been established. It has various functions like financing various incremental costs of ODS phase-out, including cost of technology transfer, purchase of capital equipment and operational cost of switching over to non-ODS technologies. Enterprises using ODS technology prior to July 25, 1995, are eligible for funding to convert to non-ODS technology. India, being an Article 5 country, is eligible for this funding.

IMPACT ANALYSIS

India became a signatory to the Montreal Protocol in 1992. Since then, it has played an active role in meeting its obligations under the agreement. It has displayed a matured leadership in the international arena with regard to shaping the world policies on the issue. These issues are spearheaded under the aegis of the Ministry of Environment and Forests (MoEF), with the National Ozone Unit (NOU – Ozone Cell) having been set up in Delhi. The Ozone Cell is the nodal agency which oversees the implementation of Montreal Protocol stipulations in India and also reports on the status as required vide the relevant Article of the Protocol. India has prepared a detailed Country Programme (CP) to phase out ODS in accordance with its National Industrial Development Strategy. This strategy primarily took into consideration the economic considerations of the consumer and the industry. Defence sector considerations were left to the concerned stakeholders.

Major users of ODS have been the civil industrial sectors of Refrigeration and Air-Conditioning (RAC), fire-fighting, solvent industry, MDI, and foam manufacturers, besides some others. Oil, space and nuclear plants are essential or critical users of ODS, especially in the RAC and fire-fighting applications. The military establishment – the three Services as well as the defence production Public Sector Undertakings (PSUs)—are also major and strategic consumers of ODS, as already explained above. Parties to the Montreal Protocol decide, at their annual meeting, which uses of ODS are to be granted an "Essential Use Nomination" (EUN). This exemption is with respect to the regulatory provisions that set the phase-out dates for the production and import of ODS. Thus, it allows the production or import of **new or virgin** ODS after their respective phase-out dates. The EUN is not granted by the national government. No such EUN has been granted for any military use till date. The EUN has only been given to non-Article 5 countries primarily for health purposes (MDI – asthma patients), methyl bromide as fumigant due to lack of alternatives, and other ODS for laboratory use only. For all other usages, the EUN has either not been sought or not granted by the Meeting of Parties (MOP) to the Protocol.

The military establishments have not been kept out of the ambit of the Protocol stipulations and India cannot specifically ask for an EUN for them for any ODS production unless it can justify that human lives are at stake owing to their unavailability. In such a scenario, it is obvious that the Indian civil and military establishments will have to take care of this requirement by either planning for their alternatives or stockpiling (banking) their inventory for use in the legacy equipment. Just to provide the right perspective to the readers, aviation majors like Boeing and Airbus Industries have stockpiled halons to the amount of thousands of metric tonnes so that their business interests are taken care of in the near future – 40 years or so — by which time a technology change either of the system or environmentally friendly alternatives would have been invented. All developed military powers have sufficient inventories of these chemicals so that their operations are not adversely affected. In contrast, India has developed the Light Combat Aircraft (LCA) which would now enter service – and presumably stay in service for the next four decades — but it uses halons for inbuilt fire-fighting applications. New or virgin halon is not being produced within India or elsewhere in the world. India has met the 2002 freeze in consumption and production of halons, a 50 per cent reduction by 2005, and has to now meet total phase-out by 2010. Therefore, the military establishment has to be totally geared for it in terms of policies and procedures.

The RAC applications, whether in civil or defence organisations are not very different from each other in terms of usage and system requirements. So if the replacements are fine-tuned for the civil organisations, it would be a matter of time before they find their way in defence applications also. However, drop-in replacements are hard to find for any defence application because of having to satisfy the military standards. The developing countries have already passed an important milestone: the 1999 freeze in consumption and production of CFCs. In 2005, CFC use had to be reduced by 50 per cent and they are now to be completely phased out by January 1, 2010. As part of the accelerated phase-out of CFCs, India had completely phased-out CFCs by August 1, 2008, ahead of the agreed phase-out schedule.[7] Clearly, the quantity of ODS permitted in the manufacture, operation and maintenance of critical military weapons systems will be restricted in the near future.

So the moot question is: why were halon production facilities within the country closed before catering for the requirements of the military

7. "The Montreal Protocol: India's Success Story", Ozone Cell MoEF GOI 2008 Journal.

establishments? There are many answers to this question, depending upon whom the question has been posed to. The MoEF, the Defence Research and Development (DRDO) body (Centre for Fire, Explosive and Environment Safety – CFEES) and the military establishments themselves have different takes on the problem. To be fair, the military establishments have only recently started to realise the implications of the Montreal Protocol on their functioning. The need of the hour is to institute ground level bodies within the military establishments that are aware of their responsibility with regard to the ODS that they are handling. UNEP and a few individuals within and outside the organisations who see the complete picture are already spearheading the capacity building within the defence sector.

The ostensible 'disconnect' between the MoEF and the military establishment would have to become a thing of the past. Concerted effort would have to be mounted within the military in studying the implications of the absence of ODS on their functioning – at the present and in the future, – and ways and means to ameliorate the situation both in terms of mitigation and adaptation. The 'national halon bank' that has been established with CFEES (DRDO) in Delhi has no military inventory of halons which are banked with them. This situation has to be addressed on a war-footing and the inventory level needs to be built up wherever required. It can well be understood that in the absence of halons, no military hardware utilising them can be put into operation. Similarly, for RAC applications, military hardware may not be readily compatible for utilisation with alternatives. Different types of military hardware use different ODS, mostly depending upon the origin of the hardware – Western or Russian. Therefore, the requirement becomes still more complex as these ODS are not drop-in replacements for each other. This is another facet of the problem.

IS IGNORANCE BLISS?

The impact of non-availability of ODS or their replacement on military operations described above is too parochial an approach. The larger picture emerges when one considers the following scenario. Due to lack of information, the defence sector could not react in time to ensure that there was no interruption in supply due to phase-out of ODS. Therefore, it is entirely possible that their personnel even now do not comprehend the damage potential of the ODS usage, and the ways and means to avoid their accidental release. The ODS are being utilised by the personnel working on the military hardware at the manufacturing/ overhaul agency such as defence PSUs or the repair workshops/ depots/docks, ordnance factories, and even by the field level operators. The refrigerants are also utilised by the Military Engineering Services (MES) for the air-conditioning of defence buildings which they are supposed to maintain. Lack of policy, knowledge or Standard Operating Procedures (SOPs) on safe use of the ODS inventory of refrigerants (CFCs/HCFCs) and fire suppressants (halons) at any of these nodal points can cause comprehensive damage. On the one hand, the inventory level of the ODS may get depleted due to accidental or careless release and, on the other, the impact of their release into the environment will be prohibitive.

A centralised data repository in India within the MoEF or any other ministry needs to be set up which can provide regularly updated information on the amount of ODS being stocked or held by all users.

The data on the requirement of these ODS by the three military Services in India was last compiled in 2002/03 with the help of CFEES. This happens to be the only authentic but outdated source of such information till date. With so much of military hardware having changed in the three Services in the last five years, the requirement of these substances would have changed in both quantity and type. The overhaul agencies like Hindustan Aeronautics Limited (HAL) and Heavy Vehicles Factory (HVF), etc. and in-house organisations like base repair depots in the Indian Air Force (IAF) and repair docks and workshops in the Indian Navy (IN) and Army respectively should by now have a fair idea of knowing their ODS requirements, and need to compile these for the next two to three decades at least.

A centralised data repository in India within the MoEF or any other ministry needs to be set up which can provide regularly updated information on the amount of ODS – halons and refrigerants — being stocked or held by all users – private and government departments, within the country. In its absence, there may be cases wherein private halon holders (from erstwhile stocks of fire appliances) may find it difficult to dispose of their stocks within the country. In the absence of this information, the defence sector also would not know the amount of halons that it can procure/ exchange from within and the amount it needs to import. Such rudimentary information is a must if the Indian military establishment is to become self-sufficient in ODS management.

Banking of halons along with recycling and work on alternatives to the refrigerants is required to gather sufficient momentum in the Indian military establishment. The Indian Navy has set up two halon recycling plants. The IAF and Army are as it is at different stages of setting up their own halon banks with sufficient inventories to remove their dependency upon the national halon bank at CFEES in Delhi. From January 1, 2010, onwards, pressure would start building on Article 5 countries for progressively reducing their ODS inventory. Since there are very few users left of halons, the defence sector would definitely be exposed to this pressure.

The race for finding alternative refrigerants – with lower ODP and GWP—is presently on in the civil sector. Military systems would also need to be modified as per these alternatives. This is likely to pose a challenge as modification of systems cannot be allowed to cause a disruption in the operational capability of the armed Services. The military establishment cannot afford to be ignorant of these changes taking place around them as there is the potential of again missing the bus if it does not voice its requirements. It might result in Indian policy-makers taking decisions akin to closing of halon production in the country without understanding the needs of the military establishment.

Scarcity of this vital chemical has the potential to disrupt military operations. If the variables involved in managing ODS in the military are not thought out, a possibility exists wherein the Indian military establishment, through the government, might be constrained to ask for the EUN from the parties to the Montreal Protocol. Such an eventuality does not bode well for an emerging superpower like India. It is, thus, essential that an elaborate

ODS management policy and action plan be put in place by the Indian military Services. An in-depth policy and action plan has been drafted here to help the Indian military establishment draw its own customised solutions. The same is explained in the succeeding paragraphs.

RECOMMENDED POLICY FOR ODS MANAGEMENT AND ACTION PLAN FOR THE INDIAN MILITARY

ODS Utilisation in Various Applications Pertaining to Military Equipment

The Indian military would have to take urgent action even if it is a late entrant on the ODS management scene. From fire-fighting agents to refrigeration, air-conditioning, some metal cleaning and medical equipment sterilisation applications, ODS have been widely utilised in military equipment due to their properties such as low toxicity, stability, corrosion resistance and very fast fire sequestering action relative to volume and weight proportions. Finding alternatives to ODS like halons used for fire-fighting in military applications is not going to be easy, even though considerable efforts are on in this direction. Therefore, it would be prudent for the military establishment to draw a comprehensive policy on how to cope with the situation, in terms of adaptation to their non-availability, mitigation so that they do not harm the environment while utilising ODS, and, finally, adoption of technology that would enable phase-out of ODS from defence applications. The latter is especially relevant for ODS refrigerants utilised in RAC applications, for which a wide variety of alternatives is available, which require sustained efforts in terms of implementation of technology to phase them out.

An adaptation and mitigation policy supported by an action plan is presented here so that it may be used as a blueprint to develop a more comprehensive individual plan with respect to formations under a particular branch of an organisation. For example, this blueprint may be used on a template for an operational wing/ station under any air force. It could also be applied, albeit with minor modifications, to the defence PSUs and defence estate organisation. This plan takes the Air Force as a template for assumptions of certain ground features. These features may not match exactly with a particular air force but are generic, for ease of understanding and implementation of policy in any military establishment.

Air Force (AF) Policy on Ozone Depleting Substances

Background

The Government of India (GoI) has signed the Montreal Protocol, an international agreement for phasing out ODS to protect the ozone layer. The Ministry of Environment and Forest (MoEF), GoI, has issued a Gazette notification Ozone Depleting Substances (Regulations and Control) Rules 2000 under the Environment Protection Act, 1986, on control of production and consumption of ODS in India within the laid down time span.

Aim

The aim of the policy on ODS management and its action plan would be to reduce the use of ODS to levels absolutely necessary and promote use of alternative substances and processes, whenever possible. This will limit the use of environmentally non-friendly substances. It is equally important to ensure that while doing all this, degeneration of the operational capability of the military forces is not allowed. Finally, it is also important to demonstrate leadership in the control and phase-out of ODS procurement and use in the military organisation to strengthen the government's actions on this front.

Scope of Policy: (May be issued as an AF Order/ Instructions)

The policy would apply to all formations of the Air Force – operational, maintenance or purely administrative in nature, equipment, systems and products purchased by the Air Force. All relevant Air Force policy directives, issued under any authority, would be read in the context of this policy. The policy statement would include the following ODS.

- Halons: Halons 1211,1301 and 2402 are used primarily as fire-fighting agents.
- Chlorofluorocarbons (CFCs): 11, -12, -113, -114, -115, -13, -111, -112, -211,

-212, -213, -214, -215, -216, and -217 are used primarily as refrigerants and cleaning solvents.

- Other controlled substances: Carbon tetrachloride (CTC) and methyl chloroform (MCF), are used primarily as cleaning agents and methyl bromide is used as a pesticide and fumigant.

Contours of the Action Plan

An ODS Management Plan would have to be put in place by the Air Force to support the government's initiative and minimise the effects of ODS phase-out on its operations. The contours of the plan would have to include the following broad three focus points:

- **Assessment of ODS use pattern and future needs, including the phase-out strategy.** *As part of this initiative, the Air Force needs to*
    - Develop a comprehensive inventory of ODS, processes, systems, and management practices at installations that use these chemicals.
    - Standardise processes and management practices.
    - Stop purchase of halons-based fire extinguishing equipment and ODS containing air-conditioning and refrigeration equipment for ground applications; stop award of contracts for equipment that requires the use of ODS; cease use of solvents / cleaning agents containing CFCs.
    - Focus research on converting mission-critical systems to non-ODS as far as possible.

- **Operations/ practices and procedures for minimising ODS demand and emission reduction.** *These would include:*
    - Instituting operations, maintenance and administrative procedures to minimise or eliminate the use of ODSs.
    - Developing refrigerant and halon management plans at each installation. Use of conservation practices such as banking, recycling, reuse, and substitution where applicable. Specifically, this should include a recovery plan while decommissioning ODS-based equipment.

  - Preventing intentional release of ODS into the environment even in training or during validation of maintenance procedures.

- **Institutional structure for management of ODS.** ***This would include:***
  - Establishing a base/ formation focal point (under the maintenance/ logistics/ administrative head) to track and control requisitions, receipts, and issues of all ODS, including refrigerants. A reporting chain till the Service HQ needs to be set up from the formation ODS manager upwards, to provide organisation-wide focus to the subject.
  - The use of ODS in construction of air-conditioned buildings, chiller plants for hospitals and other uses, and similar uses for existing utilities would be tracked by the designated focal point through adequate reporting procedures put in place by the formation head.
  - Managing ODS to meet mission critical needs, including operational requirements (war reserves), while systems are being converted to non-ODS alternatives.
  - Information exchange on ODS-free alternatives to relevant authorities from national, regional and international resources.
  - Interaction with the National Ozone Unit on specific ODS phase-out issues such as preparation of the HCFC phase-out management plan, implementation of phase-out and substitution tasks, participation in study tours/programmes organised in the military, etc.

Defence research labs should consider identifying substitutes as per applicable Military Specifications (MILSPECs) and standards. Till the time alternatives are in place, such ODS as halons for fire-fighting operations would continue to be utilised. Their effective management is thus an imperative.

Action Plan: The ODS action plan would take into account the ground features of the organisation for which it is intended. In fact, wherever the ground features do not include an established organisation hierarchy catering to environment related issues, it would be imperative for the top echelon to first set up a formal structure which would manage the ODS and other environmental related issues in the entire organisation. This formal structure would manage both intrinsic and extrinsic communication channels on all environment issues.

Whatever be the type of ODS being utilised, a military organisation would first have to ensure that at no stage are its operations compromised. Therefore, ensuring their availability is imperative. For this purpose, inventory management of the ODS should be the primary focus of the organisation. Inventory management would include optimum utilisation of the existing ODS with recycling; their procurement and banking – for both peace and war applications; supply to each formation – transportation to and from the bank; and, ensuring that discharges, accidental or intentional, are kept to the barest minimum. Even the non-utilisable ODS being banked would have to be safely maintained till they are destroyed in an environmentally safe manner.

Whatever be the type of ODS being utilised, a military organisation would first have to ensure that at no stage are its operations compromised.

It would also have to take the lead in changing over all non-critical application from ODS-based to non-ODS. Defining what constitutes a critical application is another criterion that each organisation would have to institute. However, a broad definition of mission critical applications would be those ODS applications which have the potential of adversely impacting on operational training during peace; combat missions during operations; and for which no alternative has yet been identified, developed, or implemented. They include applications integral to military hardware systems, absence of which would directly degrade their operational capability.

Halon Policy: Use Pattern, Future Needs Assessment and Purchases

The purchase of newly produced or virgin halons is to be prohibited as per the existing regulations. Halon needed to meet mission critical applications will be recycled from existing stocks at an ODS bank that would need to be set up.

Mission critical halon applications in the Air Force may be defined as these used on board aircraft which are required to meet flight safety and flight survivability requirements. In the event the ODS bank is unable to meet the requirements, recycled halons may be purchased from commercial sources. However, it is to be ensured that all aircraft in development at the defence PSUs or being contracted for do not use ODS-based systems. In the event they do use halons for fire-fighting, ensuring its supply for the entire duration of the aircraft life should be the responsibility of the aircraft supplier and this should be incorporated in the initial contract.

Aircraft halon systems such as fuel tank inserting systems tend to discharge into the atmosphere for other than actual fire situations. Therefore, this shall be used only in actual operations. Correcting fire warning systems and operational procedures that result in false alarms and discharges shall be a top priority of system engineers at the respective production/overhaul facility. The halon fire-fighting system in the flight line or Crash Fire Tenders (CFTs) has to be disabled or replaced with non-halon alternatives which are widely available and used at many civil airfields across the globe. Halon so retrieved may be used for mission critical operations after recycling, where possible, or returned to the bank. It is evident that the twin focus of halon policy should be on its inventory management and banking strategy. Both these are now explained in some detail.

Inventory Management

A major user of halon is the system maintenance group. Therefore, it would be the responsibility of the maintenance group head at the Service HQ to identify total annualised halon requirement needed for mission critical applications by its quantity, type and application system, until its requirement is no longer felt. The operational/administrative group would identify the same for the ground-based fire-fighting system, which in any case, needs to be replaced with alternatives identified. Total Air Force requirement should then be matched against the availability in the halon bank. The halon bank manager would verify the inventory level of each type of halon projected. The requirement would have to take into consideration the halon lost during recycling, minimal losses due to accidental discharge plus an amount that may actually be required for fire-fighting. A typical halon inventory management instruction from the Service HQ should ensure that:

The Air Force bank should have the complete details of the inventory of halon being used at each operational base.

- halons be removed from aircraft being retired and be redeployed or added to the Air Force bank;
- all servicing of aircraft halon systems should capture the filled halon for recycling;
- there is no atmospheric discharge during servicing, other than the bare minimum;
- halon captured by base/ major repair organisations shall be recycled for reuse by returning to the bank or recycling plant if co-located;
- halon removed from non-mission critical applications which have been declared excess, be added to the Air Force halon bank;
- banking of halon which is not fit for use till its destruction; and
- the halon bank itself does not discharge halon into the atmosphere for any reason.

Halon filling operations are mostly carried out at system repair/ overhaul workshops. The operations of filling, removal and testing and transportation of halons – from the aircraft bottle as well as the source tank/ bottle – should be standardised for all workshops, including the defence industry, by an internal standardisation body already existing in India. It should be ensured that nitrogen used for pressurising halons in the aircraft bottle should be pure so as not to contaminate it lest it requires changes often. Annualised losses while undertaking these operations should be calculated as a percentage of the total quantity handled and measured against a benchmark (theoretically established with the help of system consultants). System operations would then be improved for meeting these standards. Halon not restorable/ recyclable to usable condition shall be stored in the bank until approved destruction facilities are made available.

The Air Force bank should have the complete details of the inventory of halon being used at each operational base as well as base/ major repair depots through effective communication between them. This inventory should include halon filled in the aircraft. The net figures should be easily accessible between the Service HQ of each sister Service for ease of transfer in case of excesses and shortages. These figures could also be shared with the defence production/overhaul agencies that may also be involved in mutual sharing of the resources in case of shortages. (At the national level, this information bank would have to be handled by the MoEF – National Ozone Unit)

Banking Strategy

Since the production of halons has stopped the world over, two courses of action are open to the users. The first and the best course of action would be to use this opportunity to change the technology requiring the use of halons. However, in most military applications where legacy equipment is being used, this is presently not economically and operationally feasible. Therefore, the next course of action is to set up halon banks where stocking is feasible for some time to come, till alternatives are in place. Working out the exact requirement is very important as excess quantity would lead to the requirement of its disposal in the future. A good estimate would take into account the Total Technical Life (TTL) of the equipment using this type of fire suppressant and then working out the requirements considering the overhaul life, servicing discharges, actual usage and minor amounts of accidental discharges. Some amount of war reserves would also have to be catered for, taking into account discharges and fast supply cycle required during operations. Setting up recycling plants along with the banks as well as at the hardware servicing facilities or repair depots would be essential so that halons can be retrieved if the purity is observed to have deteriorated. If the repair depots do not have the facility to check the purity level of the gas, there would be no alternative but to blindly charge new gas in the system hardware and return the old usable gas to the bank. Additionally, the bank should also have the facility to check the purity level of the gas being received/despatched and, thus, being able to decide which is recyclable and which is not.

CFC Policy

Refrigerants: Use and Purchase

As per the local legislations, new ODS-based RAC equipment cannot be manufactured in almost all member countries, including India. Therefore, the need of the hour is to conserve CFCs for use in legacy equipment and, where possible, use replacements. Refrigerants are used in the military establishments for various types of air-conditioning – in buildings and for automotive usage, chiller plants and food service refrigeration units in the Officers' and the Other Ranks' (OR) Messes, etc. Various types of CFC and its blends are used for the purpose.

The ODS manager in each formation would have to coordinate with the controlling manager of each of these assets to ensure that adequate CFC refrigerants are available for RAC applications till the replacements are in place. The acquisition of new air-conditioning systems, Ground Equipment (GE) and other refrigeration and support equipment using ODS will have to be prohibited in any military establishment as per the local legislation. This aspect would have to be built into procurement of both administrative and maintenance assets, including buildings and vehicles.

This policy would, in most cases, be drafted and implemented at the Service HQ level. The existing equipment using ODS refrigerants may be used till the end of its economic life or if the retrofitment with the new refrigerant is not cost-effective, considering the years of life left. However, any equipment having more than 75 per cent of its TTL left should be retrofit with an alternative refrigerant system, provided the same is available. Retrofitment would be the responsibility of the maintenance staff at the Service HQ along with the concerned defence research labs.

Refrigerant Leakage Rate, Leak Detection and Training Issues

A good maintenance and repair programme of the equipment using ODS refrigerants should be in place to avoid accidental discharge in the atmosphere. Purchase of recycled ODS should only be permitted to charge such equipment whenever required.

For example, the US EPA does not permit discharge of more than 15 per cent for comfort cooling and 35 per cent for refrigeration and process cooling applications, on an annualised consumption rate. This maintenance benchmark would ensure reduced release of ODS into the atmosphere as well as maintain the inventory level for future uses. All technicians who work with refrigerants should be trained to reduce accidental emissions, and be certified. Training includes improved maintenance practices and refrigerant conservation measures. This training should be inclusive and has to cater to stakeholders such as the Military Engineering Services (MES) in charge of the construction and maintenance of buildings. Further, to conserve and properly manage the base refrigerant resource, a routine inspection programme and record keeping of the RAC applications needs to be drawn up by the base commander.

Inventory Management

As in the case of halons, inventory management of refrigerants till they are in service is very important. The Service HQ would have to designate the concerned Administrative/Maintenance Directorates to identify total annual ODS refrigerant required to meet mission critical applications, by quantity, type, and application for Service-managed systems until their requirement no longer exists. The CE Directorate/Branch should identify requirements for the buildings being managed by them. Correcting leaking systems shall be a top priority for system managers.

Banking and recycling of refrigerants would be simpler as the time spans involved would be much less than in the case of halons due to availability of alternatives. However, till the time ODS refrigerants are in use, the standard maintenance processes outlined above need to be implemented to prevent their escape into the atmosphere.

Purchase of recycled ODS refrigerants from commercial sources may be permitted to maintain this equipment. However, this approach shall not be seen as a substitute for effective management and recycling of the existing refrigerant inventory, and proper repair and maintenance of equipment. ODS refrigerants would have to be recovered from equipment being retired at the end of their economic life, and utilised to service the remaining ODS systems in the inventory.

For the military hardware utilising CFC-based air-conditioning, it may now be feasible to develop in-house alternatives by suitable redesigning as the available alternatives are as efficient.

Refrigerants needed to meet mission critical applications will be obtained by using existing stocks from the ODS bank till the alternative/retrofitment takes place. The ODS bank would be responsible for mapping the entire inventory of ODS refrigerants of the Service as without this information, no serious and measurable efforts can be mounted for their phase-out. Such information is to be shared within the Ministry of Defence establishments for ease of transfer of ODS on the demand and supply principle. The underlying idea would be to avoid procurement of these ODS from an outside source without exhausting the sources within.

Refrigerant Phase-out Strategy: Alternatives

Research on alternatives to the refrigerants would include refrigerant containment and conservation options, equipment retrofit options, equipment replacement options and/or refrigerant replacement options. The defence research labs would have to work in conjunction with civil consultants for designing the retrofitment. The individual Service HQ may consider hiring a civil consultant for undertaking this retrofitment design change till it meets the MILSPEC requirements. The long-term ramifications of using HCFC-based alternatives must be carefully evaluated. These chlorine-based refrigerants (such as R-22), although with less ODP than CFCs, have also recently been subject to a phase-out. For this reason, Air Force policy may allow their use only as a last resort after all other alternatives for a particular application have been evaluated and ruled out.

Screening and Selection

A feasibility-and-cost screening analysis is essential for each alternative and for each piece of equipment. Each identified option should be rated based on engineering, environmental and economic factors, including: age and reliability of existing equipment, efficiency, maintenance, effect on the environment, safety, cost, and likely sources of availability. For the military hardware utilising CFC-based air-conditioning, it may now be feasible to develop in-house alternatives by suitable redesigning as the available alternatives are as efficient. Retrofitting existing equipment is less expensive than total replacement. However, incompatibilities between replacement refrigerants and lubrication oil, age and reliability of existing equipment, and complexity of the retrofit all play a major part in the decision to retrofit or not. Therefore, this option needs to be exercised with due diligence.

Natural Refrigerants: As discussed above, refrigerant choice is normally a function of several considerations – economic and property compatibility. The property-based factors include the GWP and ODP of the alternative, flammability, and efficiency (thermo-physical properties), etc. Natural refrigerants are most beneficial due to their least impact on the environment with less GWP and nil ODP . These refrigerants include ammonia (NH_3, R-717), carbon dioxide (CO_2, R-744), and hydrocarbons (iso-butane R-600a, propane R-290, propylene R-1270, and a mixture thereof). These are the three most commonly used natural refrigerants in the compression system.[8] In view of the accelerated HCFC phase-out programme, this aspect needs to be a part of the Air Force policy.

ODS Solvents: Policy

The existing legislation on ODS in any country would normally specify a ban on ODS solvents. Sufficient advancements have taken place wherein ODS

8. Natural Refrigerants Sustainable Ozone and Climate-Friendly Alternatives to HCFCs by gtz, Proklima German Federal Minstry for Economic Cooperation and Development.

solvents utilised for cleaning avionics and micronic filters, lubricating compounds and preservation of parts in the past, may be replaced with available alternatives. No solvent use should be considered mission critical. Most of these solvents are CFC-based or methyl chloroform. For their replacement, the standards are to be specified by the central standardisation body of each military establishment. Sharing this information may be very useful in this context. However, for this to happen, an inventory of usage in different applications should be drawn up by the logistics maintenance managers at the Service HQ level.

Specifications and standards laid down by the Maintenance and Administrative Directorates for systems/processes that require ODS should be revised.

The USEPA, for instance, has a Significant New Alternatives Policy (SNAP) programme to evaluate and regulate substitutes for the ozone-depleting chemicals that are being phased out under the stratospheric ozone protection provisions of the US legislation — the Clean Air Act (CAA). They have identified many alternatives to aerosol-based solvents and the details are available on the site http://www.epa.gov/ozone/snap/aerosol/list.html. With so much of international effort already having been undertaken on this front, phasing out the use of ODS solvents should be a priority of the system managers at field and production levels.

General Policy Provisions

In addition to the above, Service HQ would need to lay down certain policy provisions in the various facets of their working so as to meet the objectives of the Montreal Protocol. These provisions cover the entire gamut of military operations and are cross-linked. Thus, it is best not to group them under different headings but apply them as per each organisation's processes.

- Specifications and standards laid down by the Maintenance and Administrative Directorates for systems/processes that require ODS should be revised to change over to non-ODS alternatives. The concerned stakeholders (hardware maintenance engineers and estate managers) at the field formation level should be asked to forward a request for revision of these specifications and standards. This bottom-up approach would result in a microscopic examination of ODS usage at the field level, thus, ensuring no details are missed out. This would be a one-time exercise which would purge the organisation of standards mandating ODS use.

- The hardware servicing schedules development department of the military establishments would examine all servicing schedules to undertake a similar exercise as outlined above. It should also be ensured that in case substitute chemicals are being proposed for an ODS, the same should not contradict the accelerated phase-out schedule of HCFCs or be Kyoto Protocol-controlled substances. The alternative strategies outlined for refrigerants can be used for such evaluation.
- After standards have been changed, certain processes would be observed wherein only ODS usage is possible. These processes should be compared between each Service HQ to ensure that there are actually no alternatives to the use of ODS for the same. These usages/processes would need to be compared internationally for economically feasible alternatives and in the event no such alternatives are found, the Service HQ should then ensure that adequate provisions are made for the availability of that ODS through internal or external sources of recycled chemicals. In the event retrofitment is an economically viable option, the same may be considered, provided it does not degrade the combat potential of the equipment and also that of the organisation. These iterative processes are essential to ensure that there is no need to prematurely phase-out costly military hardware due to non-availability of an essential ODS or its alternatives.
- The Service HQ shall implement procedures whereby the use of non-ODS alternatives should be a technical Qualitative Requirement (QR) in all future Air Force procurements. If the Service HQ determines that a feasible alternative is available for use in a contract under evaluation, the appropriate directorate shall enter into negotiations to modify the contract so as to mandate the use of the alternative.

- Supplies out of the ODS bank should be a controlled and properly monitored exercise. An external audit of the ODS bank by the central audit team of the Service HQ should be an annual exercise as per the SOP laid down for an operational formation. This would ensure that no emissions from the bank are taking place.
- A nodal agency on the ODS and other environment matters should be formed at the level of Service HQ and Regional/ Command HQ. An information flow on ODS inventories within the defence production industries and military Services should be formalised by the Ministry of Defence (MoD).
- Reporting relationships are required to be set up for effectively controlling the ODS management in military organisations. Since the military cannot work in isolation on this vital issue, the reporting relationship would be required to be established both externally and internally.

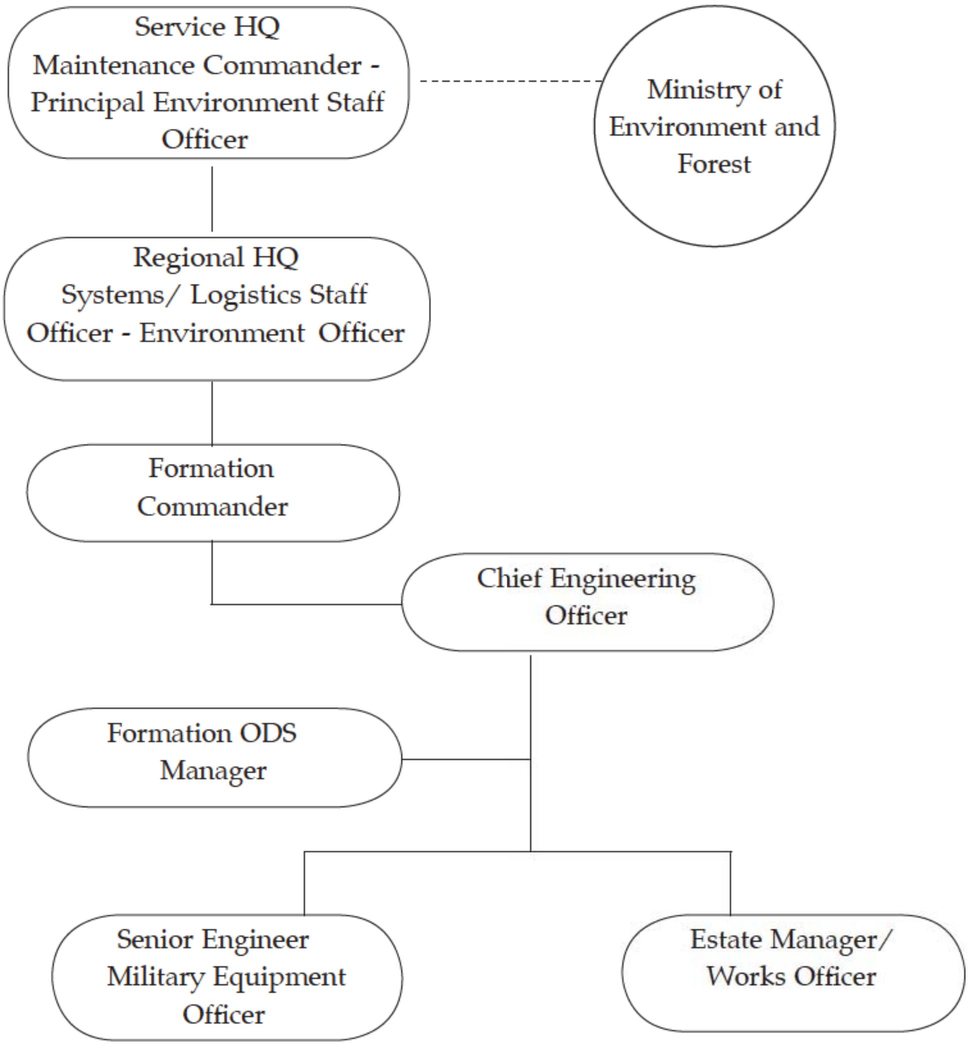
A nodal agency on the ODS and other environment matters should be formed at the level of Service HQ and Regional / Command HQ.

CONCLUSION

An attempt has been made in this article to engage the military organisations on the ODS management issues. A brief sketch of how this could be implemented has also been added. However, this does not in any way make this a comprehensive plan which would have to be developed by organisations considering their ground realities. The purpose would be well served if it provokes the readers into thinking on these lines.

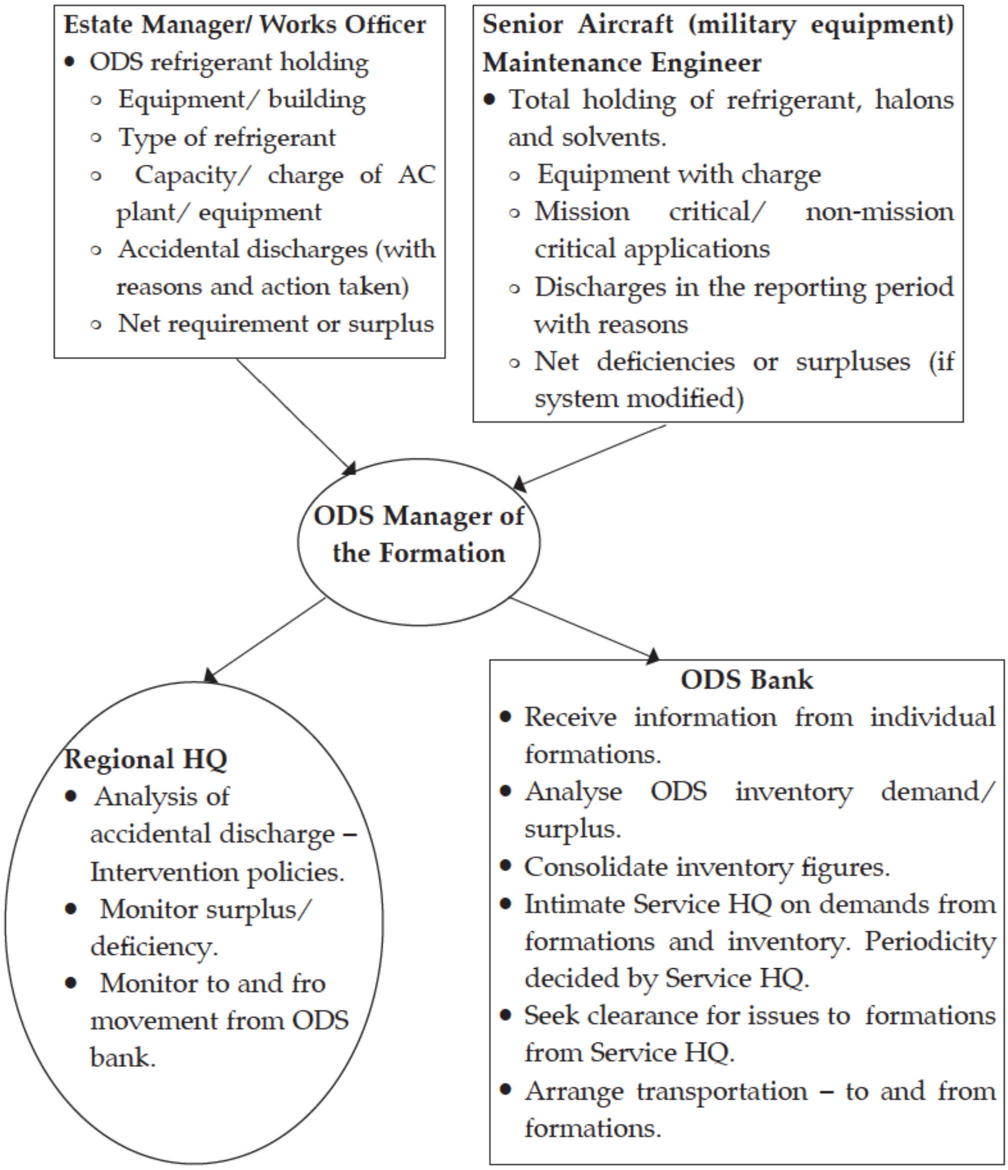
Appendix 'A'

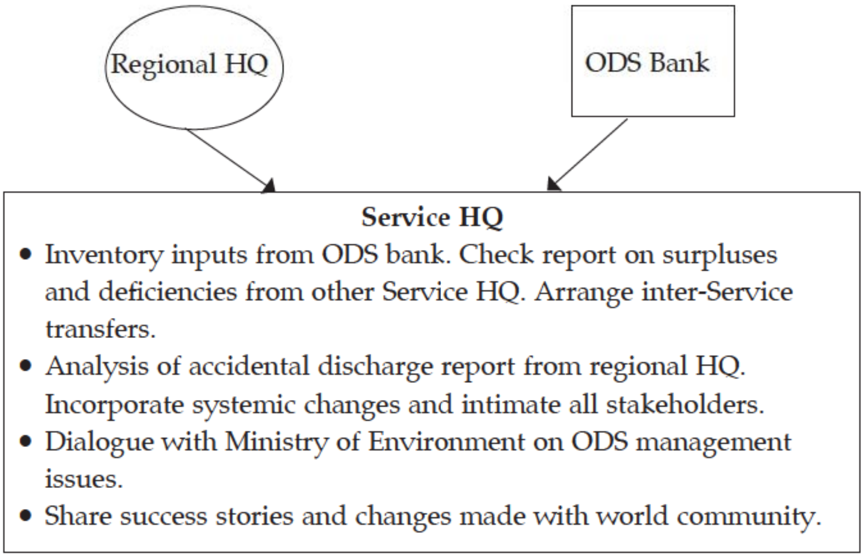
Suggested Environment Management Organisation Structure in the Military Organisation



Appendix 'B'

Recommended Reporting Relationships/Communication Channels for Effective ODS Management in a Military Establishment




Regional HQ
ODS Bank
Service HQ
• Inventory inputs from ODS bank. Check report on surpluses and deficiencies from other Service HQ. Arrange inter-Service transfers.
• Analysis of accidental discharge report from regional HQ. Incorporate systemic changes and intimate all stakeholders.
• Dialogue with Ministry of Environment on ODS management issues.
• Share success stories and changes made with world community.