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ORIGINAL PAPER

Halon management and ozone-depleting substances control in Jordan

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Abstract The Montreal Protocol's Multilateral Fund is often hailed as a key component of strategies aimed at reducing the amount of ozone-depleting substances in the less-developed countries. Yet, while there are studies that exemplify how the fund has been implemented as well as the strategies that individual countries adopt, there is still a lack of academic literature about the steps taken and implemented to devise successful alternative production strategies. In this case study, we analyze Jordon's current strategy to reduce ozone-depleting Halon 1211 and 1301, two fully halogenated hydrocarbons that are extensively used in Jordan for their exceptional fire-extinguishing characteristics. In response to the Montreal Protocol, an international treaty to phase out halon use, Jordan adopted a halon management program to manage the use of halons, build strategic reserves for "essential uses," and limit the amount of these substances that are released into the atmosphere. This study presents the actual inventory data of halons in Jordan in addition to the challenges and obstacles in the halon bank management system in Jordan. Moreover, this research covers the prospects of Jordan halons banking to achieve the goal of meeting Jordan's halons demand for essential uses up to the year 2030. To this end as well as to fulfill Jordan's commitment to the Montreal Protocol, the research recommends finding the balance between effectively enforcing regulations against the use of ozone-depleting substances while being able to meet halons demand for the essential uses until alternatives are comparably affordable and available on the national market. The research recommends that regulations should be supported with effective governance measures to minimize the

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occurrences of ozone-depleting substances escaping into the atmosphere as well as to meet halons demand.

Keywords Halon · Ozone · Ozone-depleting substances · Jordan · Halogenated hydrocarbons · Montreal Protocol

1 Introduction

Stratospheric ozone depletion poses significant threats to human health and the global environment. Concern about the destructive impact of the emission of ozone-depleting substances (ODSs) on the atmospheric ozone was predicted as early as 1974 (Molina and Rowland 1974; Anderson and Sarma 2002). It was observed in 1975 that stratospheric ozone had declined 60–70% from pre-1975 levels (Fahey 2006). The ODSs include chlorofluorocarbons (CFCs), halons, and a number of other chlorinated and brominated compounds. The chain reactions of the ODSs and their destruction of stratospheric ozone have been already identified. Halons alone are ozone-depleting substances with 6% responsibility of the ozone layer depletion of all ODSs (Rowland and Molina 1975; Ramaswamy et al. 2001; Stemmler et al. 2007; WMO 2007). Moreover, ODSs are potent greenhouse gases (GHGs) "with global warming potentials thousands of times greater than carbon dioxide" (Gonzalez et al. 2015) that influence the climate of the earth by trapping terrestrial infrared radiation (Canan et al. 2015). The ODSs contribution to global warming and climate change is estimated to be about 20% (Dekant 1996; Molina et al. 2009; IPCC 2007).

To confront these threats, the international community took action by creating and agreeing to the Montreal Protocol in 1987, which sets binding reduction goals as countries phase out products and organic chemicals that cause rapid ozone depletion. The Montreal Protocol was opened for signature on September 16, 1987, and entered into force on January 1, 1989, followed by a first meeting in Helsinki, May 1989. Since then, the original protocol has achieved universal adoption, and it has undergone seven revisions where additional requirements have been added through amendments adopted in London (1990), Copenhagen (1992), Montreal (1997), and Beijing (1999) (Gonzalez et al. 2015). Since then, the international agreement has been successful in reducing global environmental harm and has opened up the possibility that the ozone layer could return to its 1980 levels by mid-century (Gao 2015), "provided that humans soon take fast action to reduce greenhouse gas (GHG) emissions" (Andersen 2015). Due to its widespread adoption and implementation, it has been represented as an example of exceptional international cooperation (World Bank 2010).

While the Protocol calls for all nations to take action, it takes into consideration that not all countries have the same capacities to implement the provisions. The Montreal Protocol has been hailed a tremendous success not least due to the implementation of common but differentiated responsibility, which provides less-developed countries that fall into the Article 5(1) category with a deferral in the implementation of obligations to reduce consumption of ozone-depleting substances as well as assistance with the incremental costs of compliance (Matsui 2002). In some cases, Article 5 parties (including Jordan and 146 other countries) have ten years to comply with control measures, and in other cases, they have more time. Overall, the responsibility of so-called Article 5 nations (developing countries) was to start controlling the production of CFCs before 2003 and ultimately phase out their use completely by 2010 (UNEP 2000). Reductions goals are accompanied by a series of targets for incremental reductions, such as those established with Decision IX/6 (adopted in 2007), wherein Article 5 parties implemented a freeze on HCFC consumption in 2013, a 10% reduction in 2015, and would implement a full phase-out in 2030, a full 15 years after the initial reduction (Zaelke and Borgford-Parnell 2015). This establishment of common but differentiated responsibility is widely praised as being key to assuring that all less-developed countries comply with the phaseout schedules established by all the countries (Andersen 2015; Canan et al. 2015). Other ODSs, such as methyl bromide, have different phaseout schedules for Article 5 nations, and exemptions to the phaseout schedule as defined by "essential uses" (in the case of CFCs) or "critical uses" (in the cases of methyl bromide) remain important considerations under Montreal Protocol deliberations (Gareau 2013, 2015).

In terms of funding the phaseout, the ability to finance the incremental costs of transition via the Montreal Protocol's own Multilateral Fund, as opposed to using the World Bank "or another entrenched finance institution, where environmental investment was a secondary priority," was critical to successful implementation (Andersen 2015: fn 9). Crucially, the Multilateral Fund was housed in a multilateral agreement in which it has been shown that actors trusted one another and the process by which environmental improvements were to be made (Canan and Reichman 2002; Gareau 2010). Consequently, the Protocol "demonstrated that the Multilateral Fund (MLF) can invest well over US $3 billion cost-effectively—and often with more technical capabilities—than much larger financial institutions" (Andersen 2015). As reported in 2003, by parties in accordance with Article 7 of the Montreal Protocol, implementation of the Protocol produced tangible results in terms of reductions in ODSs by more than 90% (UNEP/OS 2004).

Indeed, the Multilateral Fund is often hailed as one of the foundational keys to the entire ozone protection story (Canan et al. 2015; Parson 2003; Benedick 1998). Unlike the Kyoto Protocol, where climate change funds were created that are voluntary—or are mandatory but allocated for adaptation, not mitigation—the Montreal Protocol's Multilateral Fund is mandatorily filled by the industrialized countries to compensate Article 5 countries for incremental costs associated with transitioning to ozone-friendly alternatives. As such, the Montreal Protocol does not only encourage countries to make emissions reductions, it encourages "industrialized countries to pay developing countries to reduce their emissions" (Barrett and Stavins 2003: 361). As a result, "in lowering the cost to the industrialized countries of reducing emissions in developing countries more of the latter emissions are actually reduced" (Barrett and Stavins 2003: 361). To be sure, the Multilateral Fund has not been implemented without controversy, with criticism focused on the levels of assistance provided to less-developed countries (DeSombre and Kauffman 1996), the allocation of funds across countries (Swanson 2001), and whether the strategy would actually lead to a reduction in ozone-depleting substance consumption (DeSombre and Kauffman 1996; Swanson 2001). Nevertheless, it "was the element that allowed for universal participation in the agreement, and facilitated the process of moving away from ozone-depleting substances in developing countries. It is a generally well-designed instrument for bringing developing states into the Montreal Protocol and helping their implementation of the agreement." (DeSombre 2002: 70; see also Andersen and Sherman 2015).

In this context, it is surprising that few studies of the actual implementation of Multilateral Fund projects can be found in the academic literature on global environmental politics, not least in this very journal. Discussions of the Multilateral Fund, albeit vastly important inquiries in themselves, tend to remain at the global scale of discussion (Schreurs 2005), focusing on negotiations surrounding its implementation (Anderson et al. 2013; Kamigawara 2015); on policymaking debates on how its funds have been distributed (Heggelund and Backer 2007); on how the Fund may provide ways of assisting with climate change efforts (Oberthür 2001, 2002; Oberthür and Gerhing 2004; Kemp 2016; Ladly 2012), or remain on the fringes of studies as an example of how financial incentives to parties may be put into effect (Andresen and Hey 2005; McEvoy 2013).[1] It is important to unpack the barriers to successful implementation via a case study approach so that such barriers may be removed. For instance (and a notable exception), Gray (2003) finds that a major barrier to successful implementation of multilateral agreements in African countries is oftentimes a lack of an "institutional foundation" and inefficiencies in government outreach, as well as corruption.

1.1 Introducing the case study

Our case study on Jordan's halon phaseout strategy is designed to provide such a focus. We have carried out this study by demonstrating how the MLF works on the ground to make ODS reductions possible for an Article 5 party that most people know very little about. There are sometimes unforeseen costs that make it difficult to implement phaseout strategies, but without the MLF, these reductions would never happen in Jordan or similar Article 5 countries. The approach presented in this paper uses Jordan-based calculations to determine halon bank estimates on a country-level and make projections for the future.

Jordan falls into the category of a developing country as defined in Article 5 of the Montreal Protocol. ODS management and coordination in Jordan is the responsibility of its Ministry of Environment's (MoE) National Ozone Unit (NOU). In accordance with the Montreal Protocol guidelines, MoE/NOU adopted a national ODS phaseout plan in 2002 in cooperation with the World Bank. So far, no scientific studies related to ODS management in Jordan, or the Middle East in general, have been reported. In Jordan, halons are widely used to extinguish fires because they are clean extinguishing agents, they have no secondary damage effects, and they are cheap and technically easy to handle (UNEP 2011). However, halon management is needed in order to: (1) facilitate the transfer of available halon from one user to satisfy the needs of another; (2) control for emissions to the atmosphere; and (3) mitigate the need for consumption and production exemptions for essential uses. Consequently, halon management supports Jordan's phaseout plan to comply with international agreements, especially the Montreal Protocol and its amendments.

1.2 Halons

There are three types of halons in general use in the world today, which are fully halogenated chemicals with relatively long life spans in the atmosphere: halons 1211, 1301, and 2402 (UNEP 1994a). Each chemical compound has a specific impact on the level of degradation on the ozone layer. Therefore, this degradation can be described as the ozone depletion potential (ODP). The ODP of a given substance is defined as the ratio of global loss of ozone due to a given substance over the global loss of ozone due to CFC-11 of the same

[1] The journal Global Environmental Politics has given more attention to the specific implementation of projects funded by the Multilateral Fund. In these cases, however, focus remains relatively centered on the efficacy of the global regime itself, its secretariats, its use as a model for other agreements to follow, and much less on the specific context in which such projects are situated: See Bauer (2006), Gutner (2005), Sanwal (2007), Selin (2014), Streck (2001), Young (2001) and Zhao (2005). For an exception, see Bauhr and Nasiritousi (2012).

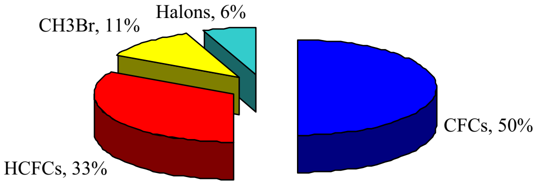

Fig. 1 Weighted ozone depletion potential (Montzka et al. 2008)

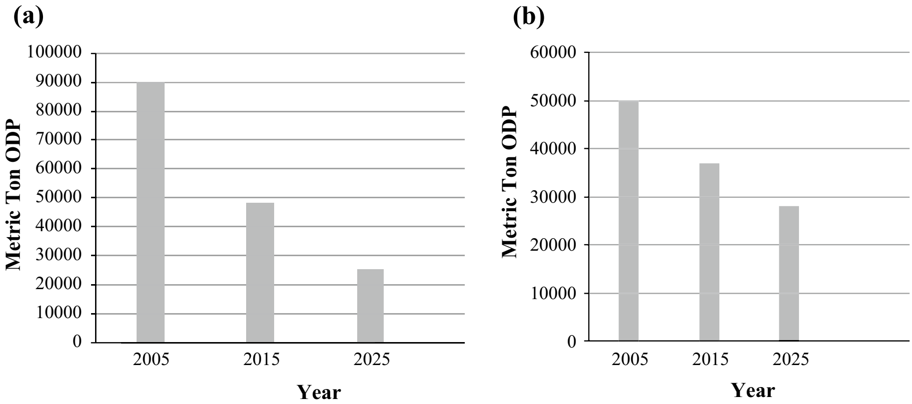

Fig. 2 Global inventories of **a** halon 1211 and **b** halon 1301 (UNEP 2011)

mass. For instance, trichlorofluoromethane (R-11 or CFC-11) has been fixed at an ODP of 1.0, and chlorodifluoromethane (R-22), has an ODP of 0.05. The CFC-11 or R-11 has the maximum potential for depletion among chlorocarbons because of the presence of three chlorine atoms in the molecule (Pyle et al. 1992). The ODP factors of the three halons 1211, 1301, and 2402 are 6, 10, and 4, respectively (UNEP 1994b). The contribution of different ODS classes or compounds to the ODP-weighted total global production based on UNEP for regulated uses for 2005 is shown in Fig. 1.

Halon banking is a critical part of the management strategy, making this resource accessible to all halon users and stakeholders. It can thus be argued that any plan to phase out halons cannot be accomplished without implementing national and regional halon bank management programs to collect, reclaim/recycle, store, and redistribute the agents halon 1301 and halon 1211. For the purposes of this study, "banking" refers to all functions both physical (contained in fire-extinguishing cylinders and storage cylinders) and virtual (in the context of a clearinghouse whereby halon transfer is facilitated between users), which involve the use, recovery, reclamation, transfer, storage, and disposal of all halons used to extinguish fires. On the global level, the Halon Technical Options Committee (HTOC) of the Montreal Protocol provides the most current estimates of inventories for halon 1211 and halon 1301 and their projections for 2025, as shown in Fig. 2a and b, based on the modeling of known production and estimated emissions (UNEP 2011).

With this background, the rest of the paper is organized in the following way. First, we provide an overview to evaluate the present halons systems status in Jordan, then we assess several prospects for halon recovery and recycling, and follow this by shedding light on the specific challenges associated with halon banking and Jordan's ODS facility program. As a result, we will be able to ascertain how a project located in an Article 5 country and supported by the Multilateral Fund unfolds vis-à-vis the specific condition in which it is embedded.

2 Halon management in Jordan

Jordan is an upper-middle income and non-oil producing country with a population of 9.53 million inhabitants (Saidan 2012). Forty-two percent of the population is under 15 years of age; 30% are non-Jordanians, and 30% are registered as refugees (Hararah et al. 2016; Saidan et al. 2016, 2017; Al-Hamamre et al. 2017). Jordan is ranked second in the world in water scarcity and is drastically influenced by climate change (Saidan et al. 2015; Al-Weshah et al. 2016). As a signatory to the Vienna Declaration and the Montreal Protocol, Jordan is committed to the complete phasing out of regulated substances under the MP and its amendments. Table 1 shows the timeline of Jordan's ratification and accession of the Montreal Protocol and its concomitant amendments.

In 2003, MoE/NOU signed an agreement with the Montreal Protocol's Multilateral Fund and the World Bank to initiate a halon hank management project to control usage of halons in Jordan. The bulk of the project funding was exhausted in the purchase of halon recovery and recycling equipment (UNEP 2014), and no funds were granted to the project since initiating operation in 2005. As a developing country, Jordan, whose annual per capita ODS consumption is less than 0.3 kg, operates under different phaseout schedules. It has a grace period before phaseout measures would apply in recognition of its specific needs (i.e., firefighting applications). Figure 3 shows the main stakeholders involved in halon activities in Jordan.

In 1999, a proposal was submitted by Jordan to the Multilateral Fund to finance a project of halon recovery, recycling, and banking in Jordan. Accordingly, a country program update and national ODS phaseout plan were issued by the MoE/NOU in cooperation with the World Bank in 2002. A year later, in 2003, the MoE/NOU submitted a halon bank project feasibility report based on the physical completion and successful operation of the new bank. As a result, the MoE has issued legislation number 4597 in 2003 for controlling ODSs in Jordan called "Instructions for controlling usage of ozone-depleting substance for the year 2003." Article 7 in this legislation states that a suitable instruction for the operation of a halon bank project would be issued by the MoE in cooperation with Civil Defense Directorate.

Starting in 2002, the MoE has launched a series of awareness campaigns and workshops targeting the industry, consultancies, companies, nongovernmental organizations, and the wider public. These campaigns and workshops aimed at discussing halons availability, the suggested phaseout plan, the introduction of a halon bank and its operations in addition to the role of the firefighting sector to the stakeholders in Jordan. The MoE subsequently enacted a de facto ban on halons and CFCs in 2007 and 2009, respectively, by nonissuance of import permits after having gradually decreased quotas for both substances based on Montreal Protocol interim targets. In 2012, MoE prepared a draft bylaw to formalize the ban on CFC and halon while establishing the phased HCFC consumption (import) ceilings through a quota system.

3 Halon banking

The halon banking program was officially implemented in 2002 in Jordan, under the auspices of the Jordan Armed Forces and the General Corporation for Environment Protection

Table 1 Status of Jordan agreements on the protection of the ozone layer

Country	Vienna convention	Montreal Protocol	London amendment	Copenhagen amendment	Montreal amendment	Beijing amendment
Jordan	13-05-1989 Accession	13-05-1989 Accession	12-11-1993 Ratification	30-06-1995 Ratification	03-02-1999 Ratification	01-02-2001 Ratification

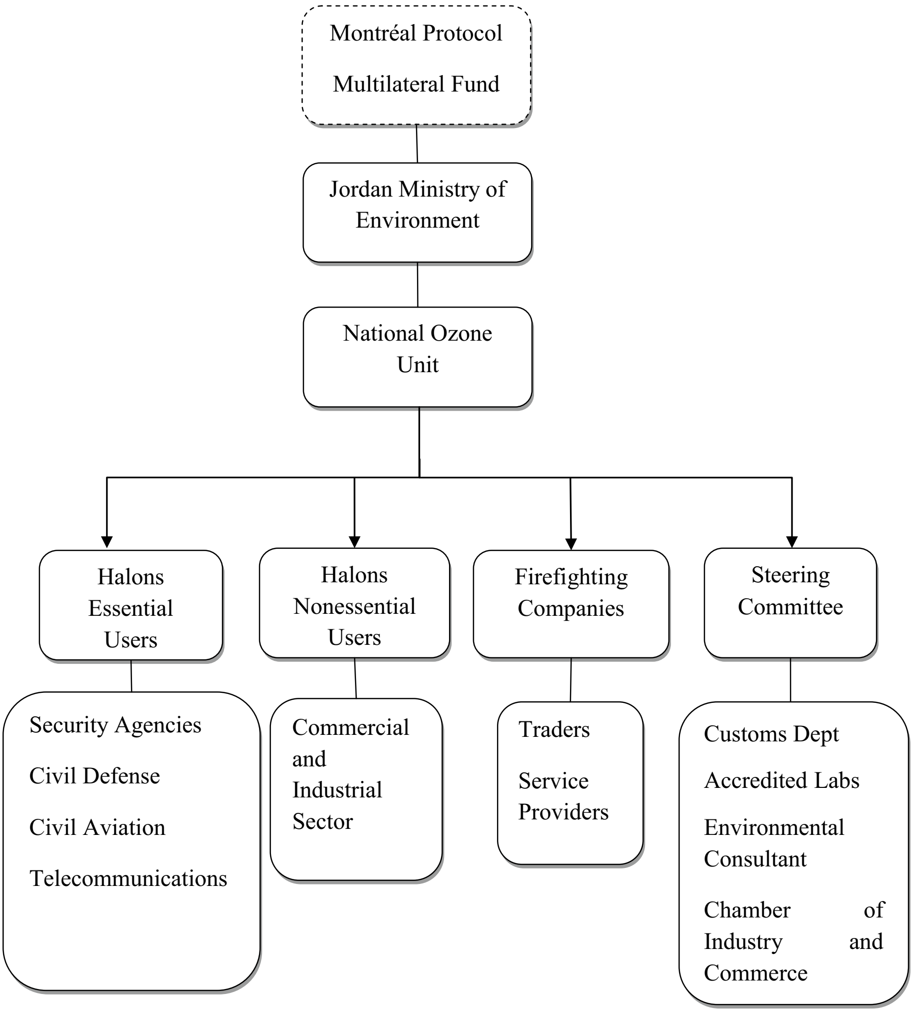

Fig. 3 Halons stakeholders in Jordan

(The official name of MoE before 2003). The halon bank of Jordan completed the Multilateral Fund project in 2005. The bank is now a self-sustaining organization, and it is run by a management committee led by King Abdullah II Design and Development Bureau (KADDB). No legislation has been proposed or implemented by the bank. Control of import or export of halons is regulated by the Customs Department and in cooperation with the MoE. The management of the halon bank program relies on the MoE by following the intention of the Montreal Protocol and amendments. The quality of the halon is tested in the certified laboratory for samples before and after recovery and recycling in the Royal Scientific Society (RSS) in Jordan, to determine the degree of purity.

The halon bank facility consists of recovery, recycling, and reclamation machines for two kinds of halons (1211 and 1301). The halon bank is located at the Jordan Industrial Estate Corporation, Abdullah II Ibn Al Hussain Industrial City in Amman. The

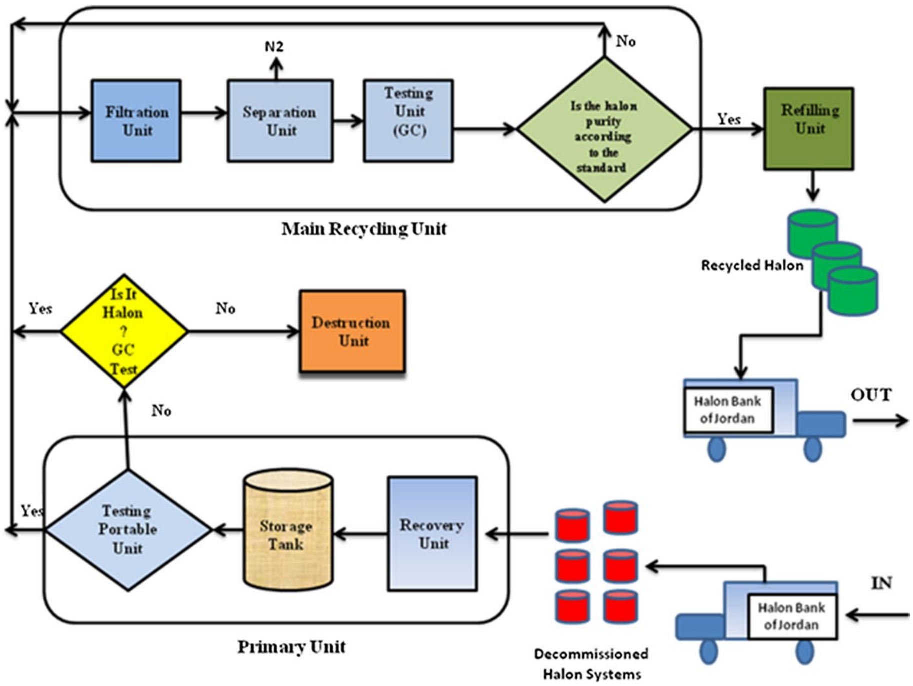

Fig. 4 Halon bank facility process flow sheet (KADDB 2012)

bank facility has been officially operational since May 2005. Recycling is provided as a charged service to users (of which many are governmental organizations). The halon bank stockpiles halons to be provided to users for future uses which are considered essential to Jordon.

The process flow sheet of the Jordan halon bank, as shown in Fig. 4, starts at the collection and transportation stage, when the end user decides to comply with the safety procedures. Halons are received in their original containers via cylinders or fire extinguishers. The halons are then recovered from its original containers using a recovery unit (pneumatic piston pump assembly) and stored in high-capacity storage tanks. Random samples are taken for primary testing to identify the halon type. After this, it is decided whether to accept or reject the recovered unknown material and subsequently deal with it as either an item to be recycled or as hazardous waste.

Recovered halons are introduced to the recycling unit, which consists of a set of filters to remove all rust and impurities that may have accumulated while it was stored. The cleared halon is then fed to a separation unit to isolate the halon from its inert gas carrier typically pure nitrogen (N_2). The final step in the process is analyzing the recycled halon to determine the purity percentage. However, if the purity result does not meet the assigned target, then the halon is filtered again. The test is cross-checked by a third independent party laboratory (Royal Scientific Society, Jordan) to insure credibility to the end users.

All the steps in the operating procedures are conducted in a batch system with no continuous closed system operation, which means that there is a quantity of unavoidable

Table 2 Jordan halon bank inventory quantities

Year	Quantities (metric tons)						
	2004	2005	2006	2007	2008	2009	2010
Halon 1211	3.20	1.80	9.30	4.60	7.18	4.22	4.62
Halon 1301	2.00	2.00	1.80	4.20	4.20	3.27	2.56

halon that is lost or discharged to the atmosphere during ventilation and while dismantling hoses and pipelines. Internationally, a total of 5% (weight basis) loss of the original quantity is acceptable. However, the Jordan halon bank developed an in-house method by using the steps of clean production measures to reduce the loss to 2–3% (weight basis) of halons during the recycling process. A waste stream that is generated from the process is controlled and collected in specially marked storage tanks within the storage area at the halon bank facility's premises for further treatment or destruction under MoE Hazardous Waste Management regulations.

3.1 Halon bank inventory and halon consumption

Halon bank programs must be accessible to all halon users and stakeholders (i.e., nongovernmental organizations, scientific agencies, monitoring bodies, etc.). If a country has no halon bank program, it will run the risk of accelerated atmospheric emissions. A national banking scheme should maintain good records to offer the opportunity to minimize uncertainty in stored inventory and stock availability (Al-Awad 2012; Saidan and Tarawneh 2015). In Jordan, the halon bank inventory is fed by many sources including: the import of halons from the international market, both newly produced (authorization issued by MoE) and certified recycled halons; the direct trade of non-recycled halon with the local maintenance of firefighting workshops and companies; and decommissioned firefighting halon systems. The inventory quantities of the halon bank for the two types of halons used in firefighting systems in Jordan since the year 2004 are shown in Table 2. It is worth mentioning that no information exists on any halon inventory in Jordan prior to 2004.

The inventory quantities are normalized and calculated in weighted ODP tons unit to show the total number of the bank inventory, as shown in Fig. 5.

Halon consumption as defined by the Montreal Protocol is the production of halon in addition to imports, and excluding exports of controlled substances. The MoE/NOU annually reports Jordan's halons consumption data to the Ozone Secretariat in ODP tons up to the year 2010 (MoE 2011).

Figure 6 shows the consumption of new halons which are imported into Jordan (new halons as defined by Montreal Protocol). The recycled halons line represents the total yearly actual consumption of recycled halons from the halon bank's inventory, and the data are reported to the MoE/NOU as internal statistical information and as part of follow-up progress reports. As is clearly shown in Fig. 6, the consumption of the new halons imports dropped sharply to zero starting from the year 2006, following the signing and ratification of the Montreal Protocol by the Jordanian government. However, the MoE shows its compliance with the Montreal Protocol through the national ozone-depleting substances control program and phaseout plan which, after being adopted in 2007, eventually led to banning the import of new halons. Without studying the growth and market demand, a sharp drop in consumption was adopted by the MoE in a very relatively short period of time before the

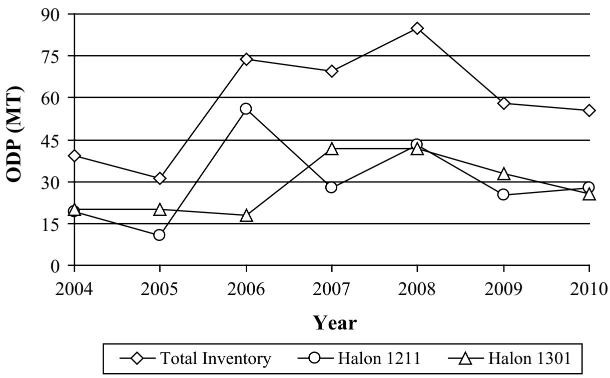

Fig. 5 Jordan halon bank inventory in weighted ODP tons unit (KADDB 2012)

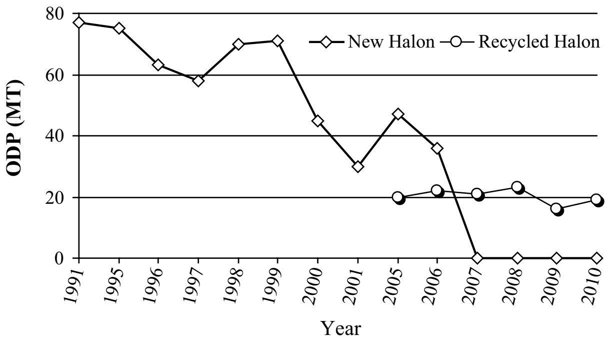

Fig. 6 Jordan halons consumption in weighted ODP tons unit

year 2010, and subsequently Jordan halon consumption was officially reported at zero ODP metric tons in 2010.

However, the Multilateral Fund's support to help with the transition to post-halon production practices has encountered an important wrinkle in this case: Jordan remains dependent on halons to meet demand for its essential uses. This has created imbalances in the firefighting market sector in Jordan. At this point, the halon bank facility introduces its recycled halon inventory to the market and encourages the end users to use the recycled halon to meet their needs and demands for essential uses. Moreover, the halon bank has succeeded in stabilizing the local market by supplying recycled halons consumption by 20 ODP metric tons per year on an average basis as shown in Fig. 6.

4 Halon recovery and recycling prospects in Jordan

Jordan's halons consumption for firefighting applications is expected to be steady at about 20 MT ODP (KADDB 2012), as shown in Fig. 6. The halon bank program is considered to be the only entity in Jordan that is performing halons recovery and recycling processes to meet the local market demand on halon consumption, without relying on imported halons (UNEP 2010). As a result, no halon imports have been needed since the local market demand will be met by recycled halons supplies. This in return will ensure sustainable halon bank activities and achieve emissions reductions. On the other hand, in 2010 the reserved inventory of the recycled halons amount generated alarm as it became clear that it would not be able to sustain increasing demand in the future (Al-Awad 2012). Moreover, the increasing costs of recycled halons due to their unavailability in the international market would run the risk of drying up the financial revenues of the halon bank.

Some of the halons owners are willing to hand over their decommissioned halons systems to the halon bank facility, driven either by environmental responsibility or by the enforcement of the MoE's developed regulations (World Bank 2013). For instance, in 2003 the MoE issued regulation number 4597 for controlling the ozone-depleting substances use in Jordan. Article number 16 of the same regulation prohibits all stakeholders from emitting/venting any ODSs into the atmosphere; moreover, it encourages the recover/reuse of the ODSs through proper recycling process (MoE 2003).

In light of the MoE's strategic national plan to reduce the ODSs inventory by 20% in 2016, and 75% in 2021 (MoE 2014, 2017), the quantity of halons received at the halon bank facility is expected to increase by, for instance, 10–15% of the recycled halon, and in line with the strategic plan of the MoE. However, this increase of the received halons might not continue to rise; in fact, halons quantities have decreased in the years 2015–2017 because of halons quantities that are becoming more difficult to find and because the international committee has downsized their production (Al-Awad 2012). However, the driving force for the halons owners to switch to halon alternatives is either because they are complying with international regulations or they are seeking an international certificate, such as the ISO 14000 series, in order to find an international market for their products and services (Al-Awad 2012). Therefore, by way of institutionalizing mechanisms that mandate halons owners to turn in their decommissioned stocks to the halon bank, no halons will need to be imported and this will increase the accumulated halons inventory up to the year 2030 (Al-Awad 2012).

However, there are cases in which halons owners in Jordan are unwilling to submit their decommissioned halons systems to the halon bank, mainly if higher selling prices are offered to them by local companies other than the local halon bank (UNEP 2010). This encourages uncontrolled halons collection because of the high prices offered in the market due to the high demand and the shortage in the available quantities. Consequently, private, small halon banks, other than the national halon bank, might appear in the local market, causing a decrease in business-as-usual recycled halons quantities in Jordan halon bank (UNEP 2014). The disadvantages of this prospect are an increase in the cost of the final products or services provided to the end user due to the high cost of the halons alternative because of the shortage of halons quantities. Additionally, the unavailability of halons quantities might lead to job losses. Eventually, halons emissions would increase, and halon bank operation might be hindered. For instance, in 2013 the halon bank operation was occasionally shut down due to the high prices that recycled halon reached in the international market, and as well as the cost of running the halon bank had become unaffordable (UNEP 2014).

All of the aforementioned prospects are subject to the challenges that the implementation of the Jordan halon bank has encountered and which have hindered its operations. These are discussed below. The challenges highlighted in this paper have been identified in existing literature and through a series of semi-structured interviews carried out throughout 2012–2014 with key stakeholders and organizations in Jordan (i.e., MoE/NOU; National Halons Company; Customs Department; Jordan Armed Forces; Arab Potash Company; Department of Civil Defense; Civil Aviation Regulatory Commission; Jordan Telecommunication Company; and firefighting companies) who deal with halon management and practices. The criterion for identifying those stakeholders was based on the principle of the "all-affected" principle as it is commonly used in these kinds of studies (Marchetti 2012: 31; Kuchler 2017).

To strengthen the textual analysis and provide assessment insights into implications of the present case study, the gathered data and information from the open-ended interviews were cross-checked with published reports (i.e., World Bank reports, UNEP reports, MoE annual reports, halon bank-KADDB internal reports, etc.). Additionally, on-site observations and walk-through assessments in the halon bank recycling facility have supported the analysis. All of these different types of sources and methodological approaches have focused on information addressing halon bank management obstacles, challenges, threats, lessons learnt, and future perspectives.

The competition within the local firefighting protection companies in Jordan and the promotion of halons systems instead of halon alternatives resulted in a lack of general support for halon banking (UNEP 2014). Moreover, the increase in halon alternatives systems imports has remarkably increased the total cost for consumers since these systems typically cost more than using the recycled halons systems, as it was stated in the interviews by key persons in the halon bank management in KADDB. Hence, it has eventually increased the final cost of the services and final products for the end users. Therefore, the supply of recycled halons inventory is no longer consumed due to the insufficient business strategies to sustain the operation (Al-Awad 2012).

The import or export control of halons is regulated by the Customs Department with an authorization by the halon bank and with full coordination with the MoE's Ozone Unit. The MoE's strategy for reducing halon consumption has relied on the intention to follow the Montreal Protocol and amendment by way of the halon bank (UNEP 2014). However, based on the data gathered from the stakeholders (excluding the MoE/NOU, Civil Aviation Regulatory Commission, and Customs Department) who were interviewed, it was stated that the physical halon banking concept is difficult to implement because the transportation of halon and recycling equipment is severely problematic. The agreement signed with the MoE does not contain any articles outlining transportation issues while many international halon banks projects have taken into consideration the transportation of recycling equipment or decommissioned halon systems to or from the location of the Jordan halon bank, as stated by firefighting companies' managers and National Halons Company's director. Therefore, this situation has led to an increased burden on present-day halon users to deliver their quantities to the halon bank at their expense.

Recycled halons in regional and international markets to supply the existing systems in Jordan are relatively nonexistent and have led to high costs for recycled halon. This in turn has caused financial burdens on the halon bank of Jordan (UNEP 2014). The bulk of the project funding was exhausted when purchasing halon recovery and recycling equipment; $< 15\%$ of the total halon bank fund was allocated to cover the overhead expenses and other daily operations. Therefore, no funding was available to sustain the operation and overhead expenses to meet the project plan's objectives, as stated by the National Halons Company's director and MoE/NOU's director. Data on the installed base and stored inventories of halon of the essential users are poor. Thus, the future business plan of the bank is unclear and needs to be reviewed annually to sustain the recovery and recycling operations (Al-Awad 2012).

5 Case study implications

The absence of regulations required to sustain the program in addition to the lack of enforcement mechanisms of existing regulations in support of halon banking and phaseout is a significant challenge. For example, the MoE issued a regulation for all nonessential users to hand over all halons in use to the halon bank, but there are no clear implementation steps or a detailed phaseout plan to meet this intent (Al-Awad 2012; MoE 2014). Instead, the MoE has just set the baseline of phaseout and deadline for reaching that baseline to fulfill the international agreement obligations (Al-Awad 2012; MoE 2017). A modest awareness campaign conducted in covering the spectrum of all stakeholders was implemented in 2006. Tracking the evolution of the halon bank in Jordan, it has been reported that at the stage of developing the halon bank project, there was an insufficient number of workshops and trainings (UNEP 2010). Additionally, not all stakeholders were involved in those workshops (Al-Awad 2012; Tarawneh and Saidan 2013). As it is the case in other developed countries, i.e., Australia, a continuous and comprehensive awareness program should be kept running throughout the life cycle of the halon bank program to make sure that most of the people are involved in the decision making.

Despite the fact that halon recycling was provided as a charged service to users (of which, many are governmental departments), the cost of running the halon bank was unsustainable. Moreover, there was no way to increase the service charge of halon recycling since the halon bank project was originally established to be a nonprofit environmental program. Therefore, to ensure achieving a halon-free Jordan, a successful ODS bank management in Jordan needs a sound understanding of the existing ODS bank, the technical feasibility of ODS recovery and destruction, the identification of associated costs as well as barriers and appropriate policy measures.

Hence, it is worth emphasizing that that World Bank funds no longer support operations and thus alternative mechanisms need to be secured in order to sustain the operations of the halon bank. The MoE's environmental protection fund established in 2009 can help to overcome the mentioned barriers by facilitating the mandatory recovery of ODS during servicing and at the end-of-life of equipment. Moreover, vitalizing the Extended Producer Responsibility scheme (EPR)[2] in the electrical waste sector will shift the financial responsibility from municipalities to producers who then have the responsibility for handling all waste components of the product. Therefore, this EPR scheme promotes the producer to deliver the appliances containing halon and pay a fee for the halon bank (GIZ 2015).

6 Conclusions

This paper has explored the halon bank management system in Jordan that was initiated as a way to regulate substances that deplete the ozone layer. As noted in the introduction, very few studies explore how Multilateral Fund funded projects are implemented on the ground. It is important to explore the particular cases in which the principle of common but differentiated responsibilities is implemented in order to discover how project implementation can be improved. It is widely agreed the Multilateral Fund has been critical to the success of widespread compliance of the Montreal Protocol, yet the project assessment has been compartmentalized in the fields of practitioners and government agencies. This case study opens the particulars of a rather obscure case (Jordan halons) to the international

[2] The Extended Producer Responsibility (EPR) is defined as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle," i.e., after end-of-life (OECD 2001).

community of scholars interested in international environmental agreements and the implementation of the Montreal Protocol's Multilateral Fund projects in particular.

In light of our findings, the Jordan halon bank is considered one of the most proactive programs in the region by effectively using recycled halon. Despite global turmoil, changing political parties, and the lack of infrastructure, the progress of halon recovery and recycling in Jordan is quite steady, and with continued support, that has significantly ensured its financial stability. The Montreal Protocol processes will allow for the utilization of halons in the remaining essential uses while minimizing unnecessary emissions to the atmosphere.

Halon banking operations can play a significant role in ensuring the quality and availability of recycled halon by bringing consumption down to zero. The national banking scheme maintains good records and offers the opportunity to minimize the uncertainty in stored inventory and stock availability. The Jordan halon bank facility introduced its recycled halon inventory to the market and encourages end users to use the recycled halon to meet their needs and demands for essential uses. It succeeded in stabilizing the local market by supplying recycled halons for consumption by 20 ODP metric tons per year on average basis. By using recycled halons, no halons are needed to be imported and this will increase the accumulated halons inventory up to year 2030. Eventually, the sustainable halons activities lead to the reduction in halons emissions to the atmosphere.

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