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Establishing the presence and mitigations of perfluoro octane sulphonic acid (PFOS) in the Ugandan market

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Abstract

A study was conducted to determine the presence of perfluoro octane sulphonic acid (PFOS)-containing chemicals and products imported and used in Uganda's environment and to evaluate the performance of the legal and institutional frameworks used to reduce their presence in the environment. The study called for an interaction with public officials and private-sector business individuals, and the performance of a content analysis of the legal and institutional framework to govern the management at the source, movement and distribution, disposal at waste disposal sites, and management of waste products. Results indicate several PFOS-containing chemicals and products from countries that historically used PFOS for commercial and industrial processes. There are inadequacies observed in import management, waste collection, and waste disposal methods from sources to waste dumping sites. The weak legal and institutional frameworks and poor collection, handling, and disposal methods risk populations to exposure to PFOS. The results indicate poorly structured organization plans of the country, for the entry, movement, distribution, and disposal of emerging persistent organic pollutants (POPs) in the environment for low-income and developing countries like Uganda. There is a need to establish Public-Private Sector partnerships, structure specialized administrative units, and purchase specialized equipment for PFOS analysis.

Keywords: PFOS-containing chemicals and products, legal and institutional framework, mitigation measures, Ugandan environment.

Introduction

Perfluorooctane sulphonic acid (PFOS) and its related compounds are manufactured for use in the making of other products by imparting the desired characteristics such as stain resistance, oil/grease and dirt repellency, and fire retardation[1,2]. The production of PFOS and related compounds is of concern because of their toxicity, bio-accumulative potency in plants and animals, high mobility, long-range transport potential (LRTP), global warming potential, persistence in the environment, serious health effects on human health including causing cancers, birth defects, dysfunctional immune and reproductive systems, and greater susceptibility to diseases[3-8]. This prompted the inclusion of PFOS and its related compounds in Annex B of the Stockholm Convention[9] rules and regulations, as an international initiative to prohibit or restrict their production and use worldwide[10].

PFOS belongs to a large group of compounds called per- or poly-fluoroalkyl substances (PFASs), whose applications comprise uses in textiles, refrigerants, food (packaging), electronics, lubricants, pharmaceuticals, construction, and many others[11-15]. For instance, PFOS polymers are used as finishing agents at a substrate level of 1% in textiles, leather, and carpet; providing high-quality materials to impart water, oil, dirt, and stain resistance[11,13,15-17]. PFOS salts are used to synthesize firefighting foams[18]. Since 2002, most industrialized Western countries have limited or precluded the production and use of PFOS polymers, salts, and substances through national and regional regulations, and voluntary actions with the manufacturers[4,11]. This called for stringent management of PFOS-containing chemicals and products. China has remained the largest producer and exporter of PFOS-containing chemicals and products in the world[19-21]. In less industrialized countries (Uganda inclusive), there is still limited documentation as regards to control of imports, movement, disposal, and guiding the voluntary risk reduction such as proper management of suspected waste to minimize the discharge of PFOS to the environment[22]. The presence of PFOS and its related compounds is not documented in Uganda and is not perfectly regulated by the legal and institutional frameworks to mitigate their presence in the Ugandan environment. Yet the documentation of PFOS entry, use, and disposal in the country is critical to the implementation of the relevant provisions of the Stockholm, Rotterdam, and Basel Conventions on POPs and, the transboundary movement of the hazardous wastes and control of their disposal[14,22-26].

This paper provides insights and findings of the study that was conducted to exhaustively identify the suspected PFOS-containing chemicals and products and their related compounds in the Ugandan market, and investigate the management and processing of wastes of PFOS-containing products. The paper also analyses the applicable regulatory and voluntary approaches to reducing PFOS risks in Uganda. The proper knowledge of the production, distribution, storage, and disposal of PFOS and its related compounds, provides better planning for the entry, distribution, movement, and waste disposal of PFOS-containing chemicals and products in a country, state, or region[14].

Material and Methods

Study area: The study covered three areas in Uganda where conditions for the use and disposal of suspected PFOS-containing articles and products are prevalent. They included Kampala, the capital city of Uganda in the central region; Mbarara city, located in South Western Uganda; and Jinja city, located in the Eastern region of Uganda. The three cities are the major urban areas in Uganda where trading suspected PFOS-containing chemicals and products such as firefighting foams, insecticides/pesticides, textiles and apparel, leather, and carpets imported from countries that manufacture and export the products takes place.

Study design and sample size estimation: The study is a qualitative research design where the approach used one-on-one interviews and a content analysis of self-guided questions. The self-guided questions aimed at interrogating public officials and the business community about PFOS-containing chemicals and products sold on the market and used in the different segments of society, and evaluating the performance of legal and institutional frameworks being applied to mitigations of the potential threats to human health and the environment in Uganda respectively. The first approach constituted key informants on PFOS-containing chemicals and products in the Ugandan market, who were purposively sampled and interviewed. Snowball sampling was used to employ more respondents until no new information was obtained. A total of five hundred and thirty-two (n=532) respondents were contacted in the study. The second approach constituted a cross-sectional evaluation and analysis of the legal and institutional frameworks on the generation, movement, and waste disposal of PFOS-containing chemicals and products on the Ugandan market concerning the Stockholm Convention[9] and Basel Convention[27] as a benchmark for the control of PFOS, its salts, and PFOSF compounds and their respective wastes in an environment.

Study population: The study targeted public officials, large volume, and retail traders of suspected PFOS-containing chemicals and products. The study defines large-volume traders as a group of people involved in the import/re-export and trade of suspected PFOS-containing chemicals and products on a large scale. The large volume and retail traders were registered with a private-sector business organization. The public officials were policymakers in relevant government institutions that could identify key sector players in the importation, trade, and use of articles and products suspected to contain PFOS. The public officials would also report the generation, movement, and disposal of wastes for suspected PFOS-containing chemicals and products; guide on issues concerning the importation, trade, and use of the articles and products; and the generation, movement, and disposal of wastes in the Ugandan market.

Data collection: To undertake the study, a one-on-one interview checklist that adopted aspects from the standard questionnaires used in PFOS inventories as provided in the Guidance for Inventory of PFOS and related chemicals[10] developed with modifications to suit the chosen approaches to identify the suspected PFOS-containing chemicals and products on the Ugandan market. The checklist constituted open-ended questions to administer orally under different interview topics. The topics included the category of chemicals and products imported, traded, or used, the country of origin of the chemicals and products, knowledge of the existence of such chemicals and products in the market, kind of traders or users of the chemicals and products. Other topics of interest included description of physical characteristics of the PFOS-containing chemicals and products (stain-resistant, water-resistant/repellent, oil/grease-repellent, fire-retardant), and methods of collection, transfer, and disposal of PFOS-containing wastes.

In addition, a content analysis of self-guided questions was used to study Uganda's legal framework, institutional framework, and different stakeholder organizations (private sector and non-governmental organizations) relating to their effectiveness in reducing PFOS-related exposure to the environment and human health. To understand the effectiveness of the legal and institutional framework of Uganda on mitigation risks posed by the PFOS-containing chemicals and products, a standard benchmark checklist was drawn from elements and requirements of the Stockholm Convention[9] and Basel Convention[27]. This was to evaluate the performance of the administration and regulation relating to the control of the potential threats from PFOS chemicals and products. The study used an objective scoring system to evaluate the performances of the legal and institutional framework including administrative structures, regulations, laws, and policies against the provisions of the Stockholm Convention and the Basel Convention. Objective one (referred to as effective) describes in particular, the exclusive administrative structures and regulations of PFOS, its salts, and PFOSF compounds mentioned in fulfillment of the elements and requirements for those provisions in the Stockholm Convention and Basel Convention at different control stages including entry, trade, movement, use, and disposal in consideration of environmental sound management strategies. Objective two (referred to as less effective) is the general consideration of administrative structures and regulations based on the elements and requirements of POPs as described by the Stockholm Convention and Basel Convention.

Objective three (referred to as Passive), describes the administration and regulation which are not relevant and related to the control of POPs but provide administrative and regulation guidelines aimed at safeguarding human health and the environment. This concerns the control of chemicals and products constituting of, containing, or contaminated with hazardous chemicals that can be harmful to human health and the environment. Comparisons were made to international initiatives, consents and agreements, and regulations concerning the reduction of PFOS in global environments.

Identification and categorization of suspected PFOS-containing chemicals and products on the Ugandan market: The study exclusively defines PFOS-containing chemicals to contain PFOS, its salts, and PFOSF-related compounds as the major constituents in a given product. In addition, the study defines PFOS-containing products as those items, articles, or materials impregnated with small amounts of PFOS, its salts, and PFOSF-related compounds to impart characteristic properties such as stain/dirt-resistance, water/oil-repellent, and fire-retardation. The identification, characterization, and categorization of the chemicals and products suspected to contain PFOS and its related compounds were done according to OECD and UNEP[10,28].

The study categorizes PFOS-containing chemicals and products into i. articles such as textiles, apparel, leather, carpets, non-stick cookware, a certain type of medical equipment, and aviation hydraulic fluids and ii. PFOS-containing chemicals such as insecticides/pesticides products for agricultural use only, and firefighting foams for protection against class B fires. The study chooses these suspected PFOS-containing chemicals and products because of their anticipated use by the communities in Uganda.

Results and Discussion

Presence and sources of suspected PFOS-containing chemicals and products on the Ugandan market: The suspected PFOS-containing products traded by private business organization members include synthetic fabrics, cookware, upholstery, sports socks, sportswear such as socks and shoes, overalls, and jackets. Synthetic leather is traded as lady bags, belts, shoes, jackets/apparel, furniture, and sportswear shoes. The traders were unaware of the PFOS in the materials traded since had no labels to indicate the materials' ingredients. Table-1 represents a summary of results showing that most products came from China with significant characteristic properties of water-repellent, dirt/stain-resistant, and fire-retardants.

Most imports of PFOS-containing firefighting foams come from The United Arab Emirates as compared to other countries. The study found government security agencies and private-sector business-driven companies to import firefighting foams. In addition, the information provided by the stakeholders in the import, trade, use, and disposal of FFFs in Ugandan shows that there were significant amounts of stockpiles at a government security agency, oil industry facilities, airports, industrial premises, and storage facilities for chemical importers. In addition, a previous study on the subject indicated the presence of large stockpiles of FFFs[22]. The firefighting foams constituted aqueous firefighting foams (AQFFF 3% or 6%) and FFFP 3% (Figure-1). The FFFs data sheets confirm the presence of a mixture of ingredients such as hydrocarbon surfactants, propylene glycol, and fluoro surfactants[10]. No reports of aviation hydraulic fluids that contain PFOS substances imported to Uganda. Figure-1 presents pictures taken at the source for the suspected PFOS-containing chemicals and products imported into Uganda. There was no trading in the PFOS-containing chemicals used as baits for imported red ants in commercial agricultural plantations.

Table-1: Representation of the summary results showing the country of origin, product category, and the general characteristics of the products as reported by the respondents in the study.

Country of origin and sample size	Products	Percentage of respondents who indicated the sources of articles and products (%)	Responses by respondents regarding the characteristics of articles and products imported and traded on the Ugandan Market (%)			
			Oil/grease repellent	Stain resistant	Water repellent	Fire retardant
China (n=282)	Synthetic articles	53	41	57	59	6
UAE (n=43)	Synthetic articles	8	16	9	10	-
	Aviation fluids	-	-	-	-	-
	Insecticides/pesticides	-	-	-	-	-
	FFFs	6	-	-	-	94
Thailand (n=69)	Synthetic articles	13	18	11	15	-
Malaysia (n=106)	Synthetic articles	20	22	19	12	-
Kenya (n=32)	Synthetic articles	6	3	4	4	-

Figure-1: Pictures taken at source for some of the suspected PFOS-containing chemicals and products in Uganda. Note: (a) & (b) Stockpiles of firefighting foams; (c) synthetic lady bags; (d) synthetic textiles; (e) synthetic shoes; (f) synthetic carpets; (g) & (h) picture of labels on some of the containers containing firefighting foams.

Evaluation of the existing legal and institutional frameworks for controlling and regulating PFOS in Uganda: Three fundamental areas guided the qualitative review of the existing PFOS risk mitigation measures. First, the state of the legal framework to use in regulating the importation, trade, and use of PFOS-containing articles and products; and the generation, movement, and waste disposal of PFOS-containing chemicals and products and wastes. This is through registration of imports/ exports, import inspection and certification, monitoring, and surveilling of the PFOS-containing chemicals and products on the market through trade and use, waste management and disposal through handling at source, sorting, method of transfer for disposal, and disposal at the dumping site or landfill. Second, the institutional framework that could provide the conditions for proper enforcement of the existing regulations and issuance of permits to certify compliance with the regulations. Third, the voluntary approaches used by Public-Private Sector Partnerships in handling suspected PFOS-containing chemicals and products; ensure no exhibition of characteristic adverse effects of PFOS on human health and the environment when disposed of.

The legal framework: The National Constitution generally anchors the legal framework relating to regulating and controlling entry, trade, movement, use, and disposal of chemicals and products containing chemical hazards in Uganda. The Poverty Eradication Action Plan (PEAP) is an overarching national policy upon that anchors all other policies. Specifically, the control of pollution through environmental contaminants in Uganda is provisioned in policies, acts, and regulations[29-48]. The National Agriculture Chemical (Control) Act[39] regulates mainly agricultural chemicals including among others, agricultural insecticides/pesticides.

The Uganda National Bureau of Standards Act[47] requires that all manufactured products on the Ugandan market conform to national or international standards. In the analysis, the study finds provisions of several legislations, regulations, and policies in the Ugandan legal framework to provide general elements and requirements for the control of POPs, not particular to PFOS, its salts, and PFOSF compounds as regards the entry, movement, and disposal.

Specific provisions in the legal framework of Uganda required to regulate and control several aspects of PFOS-containing substances such as identification, notification, and communication about PFOS-containing chemicals and products; preclusion to trade in PFOS-containing chemicals and products except for certain specific exemptions or acceptable purposes for chemicals and products. In addition, includes other regulations for distribution, storage, transportation, and handling at different points in the market chain of the country; regulations for industrial and domestic usage of these chemicals and products to avoid exposure to human health and the environment. Others include regulation of handling of wastes of the PFOS-containing chemicals and products right from the collection points, transportation, to disposal sites, and processing of the wastes at the disposal sites; control of the movement of waste sludge and wastewater from wastewater treatment plants to areas of food production and water systems; are missing.

Table-2: Representation of the study analysis of the benchmark checklist as drawn from elements and requirements of the Stockholm Convention on POPs and the Basel Convention on control of the transboundary movement of toxic chemicals and their disposal.

Control stage for PFOS	Measures prescribed for control of PFOS-containing substances	Requirements for a state actor to control Annex B substances	Requirements for Non-State Actor (Business actor) to control Annex B substances
Entry	Import inspection and certification	Establish provisions for identification, notification, and communication about Annex B substances for imports. Establish administrative structures for inspection and certification of Annex B substances.	Exhibit an import certificate for a Party to import chemicals and products of Annex B substances. Exhibit permit of compliance as provisioned by the State as a Party to the Stockholm Convention.
Trade	Purchase, monitoring sales and offers for sale, and re-export	Establish provisions for the trade of Annex B chemicals and products. Establish provisions for administrative measures to monitor sales, and offers for sale; purchase, and re-export.	Exhibit permit to purchase and trade as provisioned by the State as a Party to Annex B. Take stock of quantity, number, and stockpiles of Annex B as required by the State as a Party to the Stockholm Convention.
Movement	Distribution, storage, transportation, and handling	Establish provisions to register for the transboundary movement of POPs as a Party under Annex B of the Stockholm Convention To establish an administrative structure to monitor the movement of Annex B substances.	To exercise transboundary movement limitations license as per State as a Party to the Stockholm Convention. Exhibit compliance to provisions in line with the Stockholm and Basel Conventions on the movement of hazardous chemicals and products.
Use	Industrial and domestic Use of chemicals and products	Establish provisions and register for a specific exemption or acceptable purposes for industrial and domestic use of chemicals and products.	Exhibit permits for industrial and domestic use as per State as a Party under Annex B of the Stockholm Convention.
Disposal	Collection, handling, processing, and treatment of waste, wastewater, disposal of treated wastewater to the natural water system, and Monitoring of PFOS at waste disposal sites	Establish administrative measures to ensure that stockpiles and wastes constituting, containing, or contaminated with annex B chemicals are managed safely and in an environmentally sound manner in line with the Basel Convention. Establish provisions for the collection of comparable monitoring data on the presence of POPs in the environment and human populations. Establish an administrative structure for monitoring the levels of the Annex B substances in commodity and environmental samples.	Exhibit a permit as per regulatory instruments, administrative, or policy guidelines on handling hazardous wastes. Exhibit a monitoring policy for compliance with provisions of handling and monitoring of chemical wastes. Exhibit competence in the disposal of chemical wastes in an environmentally sound manner according to the Basel Convention Take necessary measures to limit the release of Annex B substances from exposure to human health and the environment.

Table-3: Representation of the study evaluation of Uganda's policy and legal frameworks for PFOS risk control as contrasted to the provisions of Stockholm and Basel Conventions.

Control stage for PFOS	Control measures	Policy and relevant provisions to control Annex B substances such as PFOS	Legislations and relevant provisions	Effectiveness of policy and law to control PFOS as evaluated against the benchmark	Deficiencies in policies and laws to control PFOS as evaluated against the benchmark
Entry	Import inspection and certification	NEMP, NTP, NAP	NEA, ACCA UNBSA, AEA, NDPA, TCPCA, ETA, ICA	Less effective	No provisions for PFOS-containing chemicals and products including: Identification, notification, and communication. Categorization and certification
Trade	Purchase, monitoring sales and offers for sale, and re-export	NEMP, NTP, NAP	NEA, ACCA, UNBSA, AEA, NDPA, TCPCA, ETA, ICA	Less effective	No provisions to preclude as a non-registered Party to trading PFOS-containing chemicals and products including: provisions for trade-in-specific exemptions and acceptable purposes
Movement	Distribution, storage, transportation, and handling	NEMP, NAP	NEA, ACCA	Less effective	No provisions to monitor the movement, storage, transportation and handling of PFOS-containing chemicals and products
Use	Industrial and domestic Use of chemicals and products	NEMP, NAP	NEA, ACCA, UNBSA, AEA, NDPA, TCPCA, LA, WA	Less effective	No provisions for industrial and domestic use of PFOS-containing chemicals and products including: to minimize human exposure and release to the environment
Disposal	Collection, handling, processing, and treatment of water; disposal of treated wastewater to the natural water system monitoring of PFOS at waste disposal sites	NEMP, NAP, NDPA, NLP, NHP, NPISHCWM	NEA, ACCA, UNBSA, AEA, TCPCA, LA, PHA, OSHA, FDA, WA	Less effective	No provisions for disposal including: Identification and categorization of wastes of products and articles consisting, containing or contaminated with PFOS chemicals. Identification of stockpiles of wastes containing PFOS-containing chemicals. Identification of sites contaminated with PFOS-containing chemicals. Monitoring of PFOS at waste sites.

Note: NAP-National Agricultural Policy; NLP-National Land Policy; AEA-Atomic Energy Act; NDPA-National Drug Policy and Authority; NTP- National Trade Policy; NHP-National Health Policy; NPISHCWM- National Policy on Injection Safety & Health Care Waste Management; NESDoEWL- National Standards (Discharge of Effluent into Water or on Land) Regulations; ETA-External Trade Act; PHA-Public Health Act; FDA-Food and Drug Act; OSHA-Occupational Safety and Health Act; NACCA-National Agricultural Chemical (Control) Act; NEMP-National Environmental Management Policy; NEA-National Environment Act; WA-Water Act; UNBS-Uganda National Bureau of Standards Act; NEWM-National Environment (Waste Management) Regulation; LA-Land Act; ICA-Investment Code Act; TCPCA-Toxic Chemicals Prohibition Control Act.

The institutional framework: The design of the institutional framework supports the efficacy of the mitigation measures as described by the legal framework of Uganda. The National Environment Management Authority (NEMA) is the leading institution on environmental matters in the country. The ACB is a lead agency that regulates agrochemicals in Uganda. The UNBS is a lead agency that ensures the conformity of manufactured products to national and international standards. The NEMA as an institution has a hierarchy of administrative structures for the management of the environment, which stretches from the national level and runs to the local councils at the district and village levels. The National Environment Act[32] supported by the environmental protection police unit mandates these administrative structures to enforce laws on the environment. The administrative effectiveness of the institutions in the control of PFOS-containing chemicals and products faces a number of challenges and weaknesses at different stages of risk control.

Table-4: Representation of the study evaluation of the institutional framework on PFOS risk control in Uganda.

Control stage for PFOS.	Control Measures.	Institutions and relevant mandates.	Roles of institutions in implementing SC on PoPs (Annex B).	Effectiveness and achievements to control PFOS.	Challenges and weaknesses of institutions as evaluated against the benchmark and how it affect PFOS risk control.
Entry	Import inspection and certification.	UNBS, NEMA, ACB	Restrict imports of Annex B chemicals and products.	Less effective for non-agriculture chemicals. Effective for agricultural chemicals.	Lack of administrative structures as regards identification, notification, and communication on PFOS-containing chemicals and products. Lack of scientific knowledge on the identification, characterization, and categorization of PFOS chemicals and products.
Trade	Monitoring sales and offers for sale; purchase.	UNBS, NEMA, ACB	Register trade of all PFOS-containing chemicals and products.	Less effective	Lack of Public-Private Sector Partnership to streamline the trade of PFOS-containing chemicals and products.
Movement	Registration, storage, transportation, and re-export.	NEMA, ACB	Streamline the registration of all quantities, numbers, and stockpiles of PFOS-containing chemicals and products.	Less effective	Lack of administrative measures to monitor the movement of PFOS-containing chemicals and products.
Use	Industrial and domestic Use of chemicals and products.	NEMA, ACB	Restrict industrial and domestic use of PFOS-containing chemicals and products.	Less Effective	Lack of data on the Public-Private Sector usage of PFOS-containing chemicals and products.
Disposal	Collection, handling, processing, and treatment of wastewater. Disposal of treated wastewater to the natural water system. Monitoring of PFOS at waste disposal sites.	NEMA, ACB	Designate and inspect waste dumping sites and wastewater treatment plant. License waste handlers. Monitor and supervise waste disposal at different water systems and waste disposal sites.	Less effective	Lack of identification and classification of PFOS-containing wastes. Lack of scientific monitoring data to ascertain levels of PFOS at the wastewater treatment plants and waste disposal sites. Lack of certification and remedial procedure(s) for wastewater treatment plants, waste disposal sites, and fire training drill sites where PFOS substances are disposed of Lack of facilitation to monitor the levels of PFOS at different waste sites.

Note: NEMA: National Environment Management Authority; ACB: Agriculture Chemical Board; and UNBS: Uganda National Bureau of Standards.

These include among others: a lack of a special administrative structure of experts on per or polyfluoroalkyl substances (PFASs) within these institutions to identify, notify, and communicate about all PFAS-containing chemicals and products on their import status, registration, industrial and domestic usage, transportation, and disposal to designated waste dumping sites and/or landfills. There is also a lack of initiatives between different stakeholders and public institutions to form the Public-Private Sector Partnership to streamline the registration, purchasing, and re-export of all imports and stockpiles for PFOS-containing chemicals and products. In addition, there is a lack of scientific data on the toxicity of PFOS and its related compounds, and monitoring data on environmental levels of PFOS at firefighting training drill sites, wastewater treatment plants waste dumping sites, and/or landfills. Also noted were a lack of identification and certification of waste handlers, remedial procedures for wastewater treatment sites, training drill areas (where FFFs are

applied), and waste dumping sites. The study observed that the ACB is effective because they have software with a list of chemicals that detects imports of restricted or prohibited chemicals. Table-4 summarizes the evaluation of the institutional framework of PFOS control in Uganda as contrasted to the standard benchmark checklist drawn from the elements and requirements of the Stockholm Convention on POPs and the Basel Convention on the control of the transboundary movement of toxic chemicals and their disposal.

Waste management of PFOS-containing chemicals and products on the Ugandan market: Waste handlers in the Ugandan market report two categories of waste. Category 1 includes those chemical wastes defined by regulation to have strict monitoring since they produce hazardous wastes and are known to exhibit adverse effects on human life and the environment when disposed of and exposed to human health and the environment. Category 2 includes product wastes defined by regulation to have components of the chemical to low levels, to the extent that their wastes are referred to as non-hazardous wastes and their regulation do not have strict monitoring, since they require further study to qualify if they can exhibit adverse effects to human health and the environment when disposed of.

In the current study, the category 1 PFOS-containing chemical wastes included among others; firefighting foams and agricultural insecticides/pesticides, and the category 2 PFOS-containing product wastes were synthetic textiles, leather and carpets, hard plastic components (from bathroom tubs, medical types of equipment, and other), aviation hydraulic fluids and cookware products. The certified waste handlers collect and transfer PFOS-containing chemical wastes to designated waste disposal sites for incineration. In some instances, security agencies use FFFs for fire training drills and in areas where accidents involving factory fires and oil tanker accidents for extinguishing such class B fires. There were no remedial procedures for such circumstances to destroy, the presence of these contaminants to avoid the eventual exhibition of the characteristic adverse effects on the communities around and the environment.

Licensed waste handlers or urban council departments are responsible for the transfer of non-hazardous PFOS-containing wastes together with organic food wastes, scrap metals, broken glasses, debris, human fetuses, plastic bottles and bags, and many others referred to as municipal or solid wastes collected from the population to designated open waste dumping sites or landfills for disposal.

There is no sorting of wastes at source but transferred to landfills or open waste dumping sites for disposal. Therefore, the handling of municipal waste at the source, waste movement from the source, and waste disposal at dumping sites in Uganda is in its infancy as regards hazardous waste management.

Management of PFOS-containing chemicals and products on the Ugandan market: The results have shown the highest quantity of imports of chemicals and products suspected to contain PFOS came from a single country - China. The items traded on the Ugandan market significantly presented the physical characteristics of water-repellency, oil/grease-repellency, stain-resistance, dirt-resistance, and fire-retardant, which could be attributed to the presence of PFOS polymers such as perfluoro octane sulfonate ethanol (FOSE) derivatives[1,28,49]. The FFFs have been useful in extinguishing factory fires and incidents involving fuel tanker accidents in Uganda[22].

There is poor disposal of PFOS-containing chemicals and products since the administrative and regulative hierarchy of waste disposal as provided by the Basel Convention[27] and Stockholm Convention[9] is at its basic in terms of handling chemical and product wastes at the source, storage, use, movement, transportation, and disposal at wastewater treatment plants and waste disposal sites. The poor disposal of PFOS-containing wastes in open waste dumpsites, poor methods of destroying PFOS articles and products, and poor methods of remediation where PFOS direct disposal and exposure to communities neighboring the sites is a danger to human and the environment since PFOS substances can accumulate in food or directly expose humans and the environment[27,50].

Gaps in the mitigations of PFOS in the Ugandan Environment: First, the legal framework in Uganda has identified, notified, and communicated the presence of Annex B substances as specified in the Stockholm Convention[9] and other subsequent Conference of Party(s) (COPs) meetings; and the support comes by its submissions of the National Implementation Plan[51] to the Conference of Parties, Stockholm Convention. The policies, regulations, and laws provided in the legal framework align with the general elements and requirements of the Stockholm Convention for POPs regarding their elimination, restriction, or prohibition concerning production, use, storage, movement, and waste disposal to designated waste dumping sites. However, PFOS, its salts, and PFOSF-related compounds do not appear among a list of hazardous chemicals in the National Environment Act[32].

Before and after international initiatives such as the Stockholm Convention[9] that included these chemicals of human health and environmental concerns, many countries developed laws and took voluntary approaches toward their reduction in the environment. Developed countries with or without a history of manufacturing them, have provided specific laws that ensure not all PFASs phased out re-enter the marketplace without review[14]. China which is known to have increased production of PFOS-containing chemicals and products, since 2003, has banned the "production, transportation, application, imports, and exports of PFOS, its salts, and POSF-related compounds, except for specific exemptions and acceptable use" since 2014[21,52].

Second, the administrative structures of the institutions in Uganda do not have the capacity to enforce the laws, monitor the occurrence of PFOS at different stages including disposal sites, and carry out scientific research. This may be due to a lack of specific administrative units or technical committees of experts and institutional infrastructure development for the purpose. Most of the developed countries in the Western world have established institutions both at national and regional levels that enforce the regulations as developed by established regulatory agencies and national legislations. Several European Union countries use regional regulations such as EU regulations Number 757/2010 of 24 August 2010 and Directive 2008/105/EC specifically for PFOS reductions in their environments[53,54]. The US EPA is not only an environmental agency of the federal government of the USA but also a regulator, which is empowered by Congress to formulate regulations that specifically encounter PFOS, its salts, and PFOSF-related compounds for their reductions in the US environment. These institutions have been empowered through infrastructure development and research that can monitor PFOS substances in the environment by analyzing articles or items, monitoring soils near airports where there is application or use in training drills of FFFs, and issuance of certificates to waste disposal sites such as wastewater treatment and sewage plants[14,55,56].

Third, there is no Public-Private Sector approach for the reduction of PFOS and its salts in Uganda to regulate the importation, entry, registration, use, and waste disposal at landfills and open waste dumping sites. This would be a source of commitment to the reduction of PFASs in Uganda's environment by the different stakeholders. Uganda has not initiated cooperation between the industry (manufacturers of PFOS-containing chemicals and products) and the private sector that imports, uses, and disposes of the items in the environment. Through a multi-stakeholder initiative, developed countries in collaboration with product developers, industry (including manufacturers, importers/exporters), and research, have developed hazard and exposure information by consent agreements[14]. The voluntary actions include raising awareness of the industry on the hazardous chemicals and monitoring the manufacture, import, and use of PFASs, engaging with stakeholders to exchange information and signal to the industry concerns related to PFASs, and conveying information to the public[14].

Conclusion

This study has established that a significant number and quantity of suspected PFOS-containing chemicals and products imported from countries known to have manufactured PFOS, its salts, and PFOSF, and who have used these substances to impart characteristic properties to materials including water-repellency, water-resistance, oil/stain-resistance, and fire retardation. Most of the trade is done by private sector business operators, who are unaware of the existence of PFOS substances in these chemicals and products. The country's legal and institutional framework is inadequate in several ways to control the potential threats from PFOS substances.

The study recommends the following: i. A creation of a specific administrative unit or technical committee of experts on PFASs within the NEMA that will be responsible for identification, notification, and communication about the PFOS, its salts, and PFOSF-related compounds in imports, industrial and domestic usage, distribution, storage, and waste disposal at designated waste dumping sites. The administrative unit or technical committee of experts formed should be able to monitor the entry, distribution, storage, industrial and domestic usage, and waste handling from collection to disposal. This committee should provide methods for reduction and remediation of exposure to the communities around waste dumping sites and the environment according to the sound management as prescribed by the best available techniques and best environmental practice. ii. The NEMA should formulate regulations for PFOS, its salts, and PFOSF-related compounds. This includes among others: inspection and certification of the chemicals and products; preclusion of trade except for the specific derogation of PFOS-containing chemicals and products according to the Stockholm Convention; industrial and domestic usage; movement including distribution, storage, stockpiles, and transboundary movement of wastes as according to the Basel Convention. In addition, include disposal of sludge waste and wastewater from waste treatment plants, including regulations on wastes handling; direct application and disposal of chemicals such as firefighting foams at firefighting training drill sites, and waste disposal sites where there is suspected incineration taking place. Other regulations should include leachate and sludge wastes, and processing of the wastes at the waste dumping site and/or landfills to prevent exposure of contaminants to the surrounding communities and the environment. iii. The NEMA should establish the Public-Private Sector Partnerships as a multistakeholder partnership between the government and all other stakeholders including the industry, academia, private business membership, and governmental and non-governmental organizations. The partnerships should include among others: signatories to an environmental performance agreement where different stakeholders agree to provide annual performance reports about steps taken to reduce PFOS, its salts, and PFOSF-related compounds. Also, the provision of scientific data about the toxicity of the available PFOS-related chemicals; and monitoring data of PFOS and its related compounds in different media including air, water, sediment, aquatic and terrestrial biota, wastewater, and bio-solids. Finally yet importantly, make awareness campaigns through media campaigns and available means to reach the public that is the immediate beneficiary in the reductions of the contaminants. iv. Increase the enforcement of the laws and regulations; utilize specialized equipment for analysis of PFASs in different materials, biomonitoring, testing and analysis of environmental samples, administration, and scientific research.

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