Characterization of Persistent Organic Pollutants (POPs) and its adverse effects on environment and public health in Rwanda

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Abstract— *There is a low awareness level among the general populace and relevant stakeholders on Persistent Organic Pollutants (POPs) and their adverse effects on human health and the environment. This often results in the continued use of POPs in agriculture as pesticides, industrial chemicals, and production of unintentional POPs from incineration, open burning, and other practices that add to the POPs level in Rwanda. Thus, all stakeholders have a responsibility in the process but due to the lack of awareness about the issue they are not able to fulfill this role. With increased awareness, concrete steps can be taken towards the elimination of POPs in Rwanda. The identification of the stakeholders and their roles in the waste management in Rwanda, tool kit for POPs identification and quantification, Desk Review and Field visits have been used to characterize and assess the management of POPs in Rwanda. The most commonly encountered POPs in Rwanda, are organochlorine pesticides, industrial chemicals, most notably polychlorinated biphenyls (PCB), as well as unintentional by-products of many industrial processes, especially polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF). The POP pesticides are temporarily stored in the Nyanza-Kicukiro dumpsite. These POPs pesticides are Endosulfan 3% dust (1,748 kg) and Lindane (mixed with Thiram (Fernasan 45%WP): 1,280 kg. The country contains around 1,905.9 kg of PBDEs and both transport sector and electronic sector have almost the same contribution as their contents are around 935.9kg and 966.1 kg respectively. The production of iron and steel from metallic wastes (scraps) are producing the UPOP releases of 4000 g TEQ/a in air and 6000 g TEQ/a in residues and waste incineration of medical wastes released 42.1 g TEQ/a in air and 104.6 g TEQ/a in residue. And other sources are producing UPOP releases at low level. The contaminated sites are Nyanza, Nduba landfill, Nyabugogo wetland and Gikondo industrial Park. The workers who recycle and dispose of POPs are exposed to dangerous materials and the environment suffers from them. This paper is intended to characterize the POPs and waste management in Rwanda in order to characterize the persistent organic pollutants (POPs) and build capacities of vulnerable communities for the sound environmentally management of chemicals and wastes and transforming waste into resources of greater value for reuse. This paper can be considered as one of primary form of intervention related to persistent organic pollutants and waste management in Rwanda.*

Keywords— Persistent Organic Pollutants (POPs), PCB.

I. INTRODUCTION

1.1 Background

The Republic of Rwanda became a Party to the Stockholm Convention in order to work in liaison with the International Community in order to tackle problems arising from the Persistent Organic Pollutants (POPs). The Stockholm convention covers the management of POPs harmful to human and environmental health. The release of POPs is a factor of aggravation of poverty in developing countries and hinders the governments' efforts for a sustainable development (Stockholm Convention, 2009). Persistent Organic Pollutants (POPs) are chemical substances that persist in the environment, bio accumulate through the food web, and pose a risk of causing adverse effects to human health and the environment (Maren Mellendorf, UNIDO). This group of priority pollutants consists of pesticides, industrial chemicals (such as PCBs) and unintentional by-products of industrial processes like dioxins and furans (UNEP, 2011).

In addition to their toxicity, POPs are Persistent chemicals in the environment, and do not easily degrade in the environment (that resist rapid degradation); undergo or travelling long distance globally (transport through air, water and migratory species across international boundaries far from their place of release); are bio accumulating in people and wildlife; They are

usually fat soluble and build up in higher trophic levels; they accumulate in terrestrial, marine and aquatic ecosystems far from their origin; as semi-volatile compounds, POPs undergo a series of evaporations and condensations in the environment, making them mobile.

The national challenge posed by chemicals in agriculture (pesticides & fertilizers) and waste management in Rwanda is multifaceted, with human health risks associated with it being a key area of concern. The general concern is that Rwanda might suffer from air, water and soil pollution, food contamination, soil microorganisms decline, vector-borne diseases for animals and plants/crops, diseases, insect pests and diseases of grains, seeds and crops with higher frequency and greater intensity. The sound management of chemicals and wastes is an important component of Rwanda's efforts to achieve sustainable, inclusive and resilient human development in Rwanda. It's imperative to advocate for integrating chemicals management priorities into national environmental and poverty reduction planning frameworks, helps access financial and technical resources, and provides assistance and implementation support to improve the holistic management of chemicals and waste at national level.

1.2 Problem justification

There is a low awareness level among the general populace and relevant stakeholders on Persistent Organic Pollutants (POPs) and their adverse effects on human health and the environment. This often results in the continued use of POPs in agriculture as pesticides, industrial chemicals, and production of unintentional POPs from incineration, open burning, and other practices that add to the POPs level in Rwanda. Thus, all stakeholders have a responsibility in the process but due to the lack of awareness about the issue they are not able to fulfill this role. With increased awareness, concrete steps can be taken towards the elimination of POPs in Rwanda. The locally generated domestic waste such as municipal wastes, kitchen waste, medical waste and industrial waste and unintentionally produced chemicals continue to be generated. Also, the capacity is still limited under both public and private sectors in terms of technology as well as human skills to properly handle and reduce discharge and/or transfer of waste into more useful resources. However, without sound management practices, chemicals and their hazardous wastes can pose significant risks to human health and the environment especially for the poorest members of the local community.

Further, at present, various activities relative to waste management such as waste collection, waste selection and recycling, and waste dumping are conducted by various entities without having knowledge or skills, techniques and any harmonized institutional framework. Some activities are done inefficiently and it is missing the chance to maximize reusing and recycling, and minimize landfill site discharge (Basel Convention, 2003). If left unchecked, this will have adverse impacts on environment in general and on human health in particular. Therefore, Sound waste management is one of the serious and pressing environmental issues that the urban areas in Rwanda are now facing. It's in this framework that this study was conducted to characterize the persistent organic pollutants (POPs) and build capacities of vulnerable communities through CBOs to address chemicals and waste management in Rwanda. The public awareness on POPs effects to human health and the environment will be raised. Safe and proper handling of chemicals and waste management promoted and therefore the production, use, and/or release of POPs should be reduced or eliminated.

II. MATERIALS AND METHODS

To get the current status of POPs management present in Rwanda different methodological approaches were used: identification of the stakeholders and their roles in the waste management in Rwanda; tool kit for POPs identification and quantification; desk Review and field visits.

2.1 Identification of the stakeholders and their roles in the waste management in Rwanda

The identification and analysis of stakeholders was an important step as it allowed to the team to draw out the opportunities and relationships that can be built on during the implementation of POPs management in Rwanda. The analysis of collected data also helped to identify who, where and when each group (stakeholders) intervenes.

TABLE 1
STAKEHOLDERS INVOLVED IN THE USE OF POPS MANAGEMENT

Use	Stakeholders	Their interventions
Electrical and electronic equipment (EEE) and waste electrical and electronic equipment (WEEE)	MoE/REMA	Coordination of wastes management activities Setup an education or a sensitization mechanism Monitoring, regulations Ensure the proper managements of EEE-wastes as well as the contaminated sites
	Basel Convention focal point (and stakeholders in Basel activities on e-waste)	Collaboration with the focal point of Stockholm convention for an harmonized EEE-wastes managements
	Importers of electronics	Comply with the Standards of EEE Contribute in their wastes management, generate wastes
	Users (private sector, NGOs, governmental institutions)	Contribute in EEE-wastes management Comply with the regulations, generate wastes
	Private sector: Retailers of electronics and second-hand electronics	Contribute in EEE-wastes management Comply with the regulations, generate wastes
	MINALOC (Provinces, Kigali City, districts and sectors)	Ensure the proper managements of EEE-wastes as well as the contaminated sites
	Refurbishes	Collect and repair WEEE
	MINICOM / RSB	Set up regulations as well as standards
	MININFRA	Set up regulations as well as standards
Transportation and end-of-life vehicles	MoE / REMA	Set up regulations and coordination of wastes management activities Setup an education or a sensitization mechanism Monitoring, regulations Ensure the proper managements of –wastes from vehicles as well as the contaminated sites
	Retailers of vehicles (in particular, second-hand vehicles):	Ensure the compliance with the required standards for vehicles
	RRA	Ensure appropriate coding of items and consolidation of statistics data into their data base
	Scraps recycler: SteelRwa, garages	Ensure a proper sorting of scraps
	Transport agencies: Virunga, KBS,Volcano express, Horizon express, Sotra tours, Kigali safaris, etc.	Ensure the compliance with the required standards by the convention
	RNP	Cooperate with RRA, RSB and REMA in combating and controlling the entry of unauthorized chemicals in the country.
	RURA	Regulate certain public Utilities, namely: telecommunications network and/or Telecommunications services, electricity, water, removal of waste products from residential or business premises, extraction and distribution of gas and transport of goods and persons.
	MoE / REMA	Set up regulations and coordination of wastes management activities
Other uses: Furniture Textiles Mattresses Construction materials	NIP coordinator and steering committee	Coordinate both NIP elaboration and implementation
	Importers of furniture, textiles, mattresses, and construction materials Transport agencies	Ensure the compliance of with the required standards Proper management of their wastes
	Retailers of furniture, mattresses and textiles and related second-hand articles GAKINJIRO, Mutara enterprise, etc.	Sorting of wastes, compliance with the environmental requirements
	Wastes collection companies	Collect, sort, transport and dump the collected wastes
	MoE/REMA	Set up regulations, guidelines, monitoring and evaluation
Contaminated sites	MINALOC (Provinces, Kigali city, districts, sectors)	Follow up, management and awareness campaign
	MoH	Rising the public awareness, follow of wastes managements provide the wastes management infrastructure and guidelines,
	Universities (UR, ICK, INES, UNIK, ULK, etc.)	Technical guidance, research on the contaminated sites and awareness campaign
	Importers and distributors	Generate wastes.
	NGOs	Generation of land filled wastes, provide funds for their disposal
	Users	Generation of land filled wastes, provide funds for their disposal.

2.2 Tool kit for POPs identification and quantification

POPs have been analyzed according to the source categories provided by the toolkit for identification and quantification of releases of dioxins, furans and other unintentional POPs, under article 5 of the Stockholm convention. The toolkit was used to calculate all relevant PCDD/PCDF sources.

2.3 Desk Review

A desk review of the available reports and documents on POPs management was carried out to assess the status of the POPs management in Rwanda. One of the key documents reviewed among others is the "National Implementation Plan of the Stockholm Convention on Persistent Organic Pollutants (POPs) in Rwanda: 2007-2025. Important reports on pesticides inventory and management have been reviewed. The review of literature also covered reports, publications, the legal, policy and institutional framework related to POPs management.

2.4 Field visits

The field visits targeted mainly the following key players: Institutions members of the POP steering committee where appropriate, REMA, Rwanda Revenue Authority, pesticides and veterinary products agro-dealers. The visits were performed at the stockholders' workplaces and discussions conducted with the main technician or the owner of the company according to a short indicative interview guide and the questionnaires have been used to collect data.

III. STUDY AREA

The study covered the sites of Rwanda including the landfills, dumpsites, hospitals located in 30 Districts, 4 provinces and the City of Kigali. The site visits have been conducted to assess the status of POPs management and wastes in general and how these affect the waste collectors and local communities.

IV. RESULTS AND DISCUSSIONS

4.1 The case of Rwanda for POPs management

The case of Rwanda considered in this study has shown some of the observations of POP issues including wastes from hospitals and industries, waste from septic tanks, latrines, manure and animal waste, refuse infest water, electronic waste, air and soil pollution are the most serious issues that Rwanda is dealing with in order to keep green environment. The workers collecting waste are extremely vulnerable to POPs accumulation due to the collection, transport, separation and treatment of wastes without appropriate protection equipment. These people are highly exposed to the POPs releases during waste incineration. In the cities of Rwanda, waste management is conducted by private corporations. At present, 13 companies (AGRUNI, COPED, UBUMWE, INZIRA NZIZA, ROAD ENVIRONMENT PROTECTION (REP), CESCO, COCEN, COVAGAYING, ISUKU KINYINYA, UMURIMO MWIZA, INDATWA, and BAHEZA) are operating in Kigali City. These companies take care of the collection and transport to the landfill of waste.

4.1.1 POP Pesticides in Rwanda

The analysis of the situation revealed that except dioxins and furans which are unintentional POPs, Rwanda never produced or reformulated the POP pesticides or industrial products. Pesticides can be found in large amounts on commercial farms. Some of pesticides may have expired or are no longer used by the farmer and could possibly leak out of their old containers and drums in which they are stored. It was revealed that in Rwanda, pesticides are used on crops such as coffee, rice, maize, Irish potatoes and vegetables, against insects that invade crops. Nearly 75% of imported fungicides (Mancozeb + copper oxychloride) are used on Irish potatoes and coffee and 75% of imported insecticides are applied to coffee and almost all of herbicides are used in tea plantations (Twagiramungu F., (2009), Environmental, health and safety management of disposing of unused and expired pesticides and fertilizers on behalf of RSSP / MINAGRI). The ministry of agriculture (MINAGRI) has banned a number of pesticides including POPs pesticides prohibited on national territory. The unlawful entry of obsolete pesticides banned can be observed on the borders with Uganda as Thiodan (Endosulfan).

Currently the POP pesticides are temporarily stored in the Nyanza-Kicukiro dumpsite. These POPs pesticides are Endosulfan 3% dust (1,748 kg) and Lindane (mixed with Thiram (Fernasan 45%WP): 1,280 kg (REMA, (2005), National inventory). Lindane and Endosulfan are mentioned as Toxic Pollutants Substances, and later on they have been listed as POPs by conference of parties of the Stockholm Convention respectively in May 2009 and May 2011.

4.1.2 POP-PBDEs

The POP-PBDEs in electrical and electronic equipment (EEE) and related waste (WEEE) were founded on the recent inventory that was conducted by the MINISTRY of ICT that put out the combined mass of EEE in use and WEEE generated yearly in Rwanda (REMA 2015, National inventory of POPs in Rwanda). The Sources of EEE/WEE observed in Rwanda are essentially the following: IT & Telecom Equipment, Large Household Appliances, Small Household Appliances, Consumer & Lighting Equipment, Electrical & Electronic Tools, Toys, Leisure & Sports Equipment, Medical Devices and Monitoring & Control Instruments. It is considered only the POP-PBDEs in transport sector (cars, jeeps, pickups, trucks and buses) and in EEE/WEEE as other uses of POP-PBDEs (e.g. furniture, mattresses, textiles, construction materials, rubber, and drilling operations) are thought to be of minor relevance. The non-relevance in this case of Rwanda is supported by the fact that most of the industries of this sector started after the ban of the production of PBDEs. In this context, the country contains around 1,905.9 kg of PBDEs and both transport sector and electronic sector have almost the same contribution as their contents are around 935.9kg and 966.1 kg respectively.

TABLE 2
AMOUNT OF POP-PBDES-C-OCTA BDE IN ELECTRICAL AND ELECTRONIC EQUIPMENT

Relevant EEE	Quantity of EEE present 2014(in use and in stock)	Total polymer fraction (mean)	c-OctaBDE content (mean) in plastics	Amount of POP-PBDEs-$_{c\text{-}OctaBDE}$
		$f_{Polymer}$ [in % by weight]	$C_{OctaBDE;Polymer}$ in [kg/ metric ton]	In [kg]
WEEE category 3 (without CRTs=Printer, Mobile, photocopying machine)	1,026,507.86+523,889.124	42%	0.225	97.0
CRT computer monitors	2095556.6	30%	2.54	1,596.8
WEEE category 4 (without CRTs=Radios)	2,150,239.53	24%	0.15	77.41
CRT-TVs	10,934,167.94	30%	0.87	2853.8
Total (kg)				*4,625.01*

Finally, the results were translated into Hexa BDE and hepta BDE mass using their respective proportions.

TABLE 3
HEXA BDE AND HEPTA BDE PRESENT IN EEE, WEEE AND IN POLYMERS IN RECYCLING

Homologues	Distribution homologues c-OctaBDE	POP-PBDEs in import for inventory year 2014(kg)	POP-PBDEs in stocks for inventory year 2014(kg)	POP-PBDEs entering the waste stream 2014(Kg)	POP-PBDEs in recycled polymers for inventory year 2014(kg)
Inventoried c-OctaBDE		Σc-OctaBDE= *4,625.01*	NA*	Σc-OctaBDE *=966.1*	NA*
HexaBDE	11%	508.75	NA*	106.3	NA*
HeptaBDE	43%	1,988.8	NA*	415.4	NA*
OctaBDE	35%	*1,618.8*	*NA**	*338.1*	*NA**

**** There is not a facility recycling polymers containing POP-PBDEs. Only PE is recycled.***

From the table above it is very important to note that, category 2 that concerns the small household appliances EEE or their wastes is missing as the data were not available during the inventory.

Although the absence of data is a gap in the inventory, even the POP-PBDEs inventory guideline recognizes the non-relevancy of POP-PBDEs of this category particularly when it arrives at the recalculation of c-Octa BDE concentrations. However, the management of wastes related to category 2 as well as other wastes is described in a specific chapter. The estimation of the quantity of POP-PBDEs-$_{c\text{-}Octa\ BDE}$ was done applying the formula earlier given in the previous paragraph. As the available data show only the quantity of EEE present in Rwanda and the quantity of WEE entering in waste stream yearly, only these two parameters were considered.

4.1.3 PFOS

Although PFOS and its derivatives are used in numerous manufacturing processes such electronics industries, Semiconductor industry, Photographic industry, Metal plating industry, chemically driven oil and gas production, mining industry, mining industry, and in Manufacture of plastic and rubber product; these industries are yet developed in Rwanda. Examples of PFOS or related substances applied to different consumer articles and products: Textiles and upholstery, synthetic carpets, leather, paper and paper board, industrial and household cleaning products, surface coating, paint and varnishes, medical devices, toner and printing inks, cleaning agents, waxes and polishes for cars and floors… The next two tables are showing recent importation of EEE and E-wastes discharge by 2014.

TABLE 4
EEE IMPORTATION (KG) TO RWANDA

Type	2010	2011	2012	2013	2014
Computers	358,186.00	227,351.00	410,629.42	295,975.62	261,063.74
PC printers	9,455.00	21,011.00	33,894.00	33,322.06	21,721.00
Mobile phones	0	168,015.00	318,231.60	0	963,922.86
Copying machines	55,956.00	74,588.00	88,010.00	48,248.20	40,858.00
Refrigerators	655,648.00	529,209.00	494,127.00	364,048.00	408,785.60
Air conditioners	23,966.00	39,320.00	163,922.40	82,839.15	146,673.05
Televisions	457,710.00	695,216.00	480,978.25	339,269.66	205,297.75
Washing machines	29,869.00	33,996.00		38,681.00	0
Stabilizers			184,789.26	172,513.07	169,616.40
Electric cooking stoves	78,434.00	103,061.00	126,386.50	156,109.00	186,969.60
Electric water heating systems	69,581.00	56,598.00	84,076.00	64,092.00	91,997.00

TABLE 5
TOTAL EEE (KG) AND POTENTIAL E-WASTE DISCHARGE (KG)

	Total usage weight (kg)	Potential E-waste per year (kg)
PCs (both laptops and desktops	2,619,445.62	599,725.68
PC printers	876,564.03	269,961.69
Mobile phones	668,024.96	115,489.54
Copying machines	793,893.10	192,930.27
Refrigerators	2,832,275.80	517,041.39
Air conditioners	1,596,692.16	1,121,062.30
Televisions	10,934,167.94	1,981,198.24
Washing machines	208,238.39	54,300.87
Stabilizers	2,140,652.74	421,873.85
Electric cooking stoves	4,754,262.86	1,285,046.49
Electric water heating systems	1,525,687.77	506,184.63

TABLE 6
CATEGORY OF EEE AND WEE

Category	Articles	Mass in Kg of materials	Potential E-waste per year (kg)
1	Fridges	2,832,275.80	517,041.39
	Air conditioners	1,596,692.16	1,121,062.30
	Washing machine	208,238.39	54,300.87
	Total	**4,637,206.35**	**1,692,404.56**
3	Desktop PC	2,619,445.62	599,725.68
	Laptop		
	Printer	876,564.03	269,961.69
	Photocopying machine	793,893.10	192,930.27
	Mobile phone	668,024.96	115,489.54
	Total	**142,32,340.41**	**45,62,916.30**
	CRT-TV	10,934,167.94	1,981,198.24
	Flat panel TV		
	Radio	2,150,239.53	483,852.96
	Total	**130,84,407.47**	**24,65,051.20**

POP-PBDEs were used in electrical and electronic equipment. The mass flow of these equipment, involves different stakeholders starting from their manufacturers, importers, users (government and private institutions), refurbishes, wastes collection companies, regulation institutions, local government, etc. Like in other developing countries the E-wastes managements in Rwanda needs more works as the lack of the recycling companies as well as appropriate technology hinder their Environmental Sound Management (ESM).

Old EE collected from governmental institutions are stored at GIKONDO under the supervision of Rwanda Housing Authority (RHA) which will plan how to auction them. Others are still in store of those institutions. All those e-wastes stored at GIKONDO are mixed with other waste including waste from office furniture. The visit to different institution either public or private revealed that E-wastes are stored in specific stores waiting to be auctioned, the practice that end up by handing the E-wastes and old E-equipment to the refurbishes. The same management practice is found in private sector. According to COPED, sometimes the e-wastes generated at household are included in other wastes in the wastes collection sites.

4.1.4 Vehicles Wastes from garages and households

Vehicles are concerned as they contain PBDEs and PFOS as mentioned previously. The wastes from vehicles are generally found in private garages and institutions garages. In different garages across the country, the scraps metals and replaced spare parts are collected and stored. When the stock is big, Steel Rwanda scraps dealers buy and take them to the plant for recycling. However, sometimes the clients like to take the replaced spare parts to their homes. Furthermore, in Kigali City wastes which are not taken to Steel Rwanda Ltd are collected by COPED and end up also by entering in Nduba dumpsite. Even metals are not containing POPs, the poor sorting of scraps from other parts with plastics as well as their contact with hydraulic oil make them to be part of items concerned by Stockholm convention.

4.1.5 PCB

4.1.5.1 PCBs in Rwanda

The field visit of equipment was conducted in REG/EUCL and private energy producers' hydro power plants, transmission and distribution network, and major industries based on information of equipment. The disposal options were assessed. A datasheet was used for the identification of the PCB-containing equipment were appropriately filled so that every transformer can be identified, location, company name or the user, name of the manufacturer, etc. It was carried out for the identification of the PCB-containing equipment based on information available and collected on the nameplate.

TABLE 7
MATERIALS CONTAINING PCBS

Branch	Inventoried equipment	Equipment supposed with PCB	%	Equipment leaking		Quantity of PCBs		Without nameplate or non-readable	
				PCB	Non PCB	Liquid	Waste	Total	Dielectric
Remera	118	20	17	0	0	118.893	20.419	139.402	6
Kacyiru	96	15	16	0	0	102.376	2.0439	104.420	3
Kanombe	97	15	15	0	0	95.175	6.5405	101.716	3
Gikondo	102	11	11	0	0	132.816	9.973	142.789	1
Muhima	119	11	9	1	0	178.448	12.445	190.893	1
Nyarugenge	75	18	24	0	0	34.935	59.715	94.650	4
Nyamirambo	39	3	8	0	0	30.937	13.914	44.851	1
Ngoma	252	5	2	0	2	144.979	32.310	177.289	7
Nyagatare	335	7	2	0	11	44.081	76.081	120.162	3
Bugesera	79	2	3	0	0	39.202	14.999	54.201	1
Rwamagana	106	1	1	0	0	37.725	13.914	51.639	1
Nyamagabe	127	1	1	0	0	56.25	20.634	76.884	1
Huye	88	11	13	2	0	57.837	20.439	78.276	1
Nyanza	45	6	13	0	0	3.619	6.5405	10.160	0
Ruhango	48	3	6	0	0	24.064	9.973	34.037	1
Muhanga	72	2	3	0	0	49.149	12.445	61.594	4
Karongi	58	18	31	1	1	150.46	59.715	210.175	3
Ngorero	60	9	15	0	0	33.46	13.914	47.374	3
Rubavu	85	26	31	2	0	76.045	32.310	108.355	4
Rusizi	102	18	18	0	0	182.638	76.081	258.719	3
Musanze	108	17	16	0	0	151.901	75.245	227.146	4
Rulindo	86	6	7	0	0	33.46	13.914	47.374	3
Gicumbi	46	4	9	0	0	43.807	20.634	64.441	1
Total	**2344**	**229**	**10**	**6**	**14**	**1780.907**	**665.64**	**2446.547**	**59**

4.1.6 Unintentional –POPs (UPOPs) in Rwanda

The data collected from human activities such as waste incineration of medical, municipal wastes, cement kilns and thermal processes have been analyzed according to the source categories provided by the toolkit for identification and quantification of releases of dioxins, furans and other unintentional POPs, under article 5 of the Stockholm convention. The toolkit was used to calculate all relevant PCDD/PCDF sources. The municipal solid wastes are not incinerated. Some are burned openly and they release PCDD/PCDF in flue gas, fly ash, bottom ash and wastewater. The municipal solid wastes are generated by household during normal daily life and it also commonly includes wastes produced in industrial, commercial and agricultural activities. They are composed of paper and cardboard, plastics, food and kitchen residues, cloth and leather, wood, glass and metal as well as dirt and other inert materials. Small quantities of hazardous materials, such as batteries, paints, drugs. According to information gathered from technical services encountered on land, these wastes contain infectious material, secretions, blood, safety boxes of (syringes, needles, cotton), gloves, saddle pots, buffers, dressing waste, packaging and chemicals. The incineration of medical wastes is operated in small and poorly controlled incinerator in health centres; this is a major source of PCDD/PCDF. Currently medical wastes are incinerated at hospital incinerators with two types of furnaces (main furnace and after burner). The current situation shows that the quantities of medical wastes from hospitals of Rwanda are 2,911,422 kg per years.

TABLE 8
THE QUANTITIES OF INCINERATED WASTES IN HOSPITALS (ESTIMATED ANNUAL AMOUNT IN KG)

No	Hospitals	Kg/year	Hospitals	Kg/year	Hospitals	Kg/year
1	Kigeme	1,769	CHUK	208,176	Kanombe	42,350
2	Ngoma	12,776	KING Faisal	38,900	Musanze	39,933
3	Munini	20,800	Kibagabaga	26,780	Nemba	6,948
4	Byumba	14,400	Huhima	144,357	Kinihira	37,960
5	Kibuye	47,830	Medico center/Biryogo	3,600	Ruli	7,300
6	Kibogora	109,500	Masaka	43,600	Health centers	768,325
7	Kirehe	36,700	Kalisimbi	138,047	Rutongo	12,775
8	Gihundwe	18,437	ADPER Nyamata	12,168	Muhororo	65,700
9	Kabaya	36,400	Remera/ Rukoma	29,200	Gitwe	13,900
10	Murunda/Rutsiro	31,200	Kabgayi	44,200	Nyagatare	8,473
11	Rubavu	39,600	Nyanza	58,800	Kiziguro	18,250
12	Shyira/nyabihu	26,000	Kinazi	3,100	Gahini	166,400
13	Rwamagana	78,000	Musha	455,000	Butaro	43,768
	Total	473,412		1,205,928		1,232,082
Overall total: 2,911,422						

4.2 Production of ferrous and non-ferrous metals

The sub category of Iron and steel production plants is produced in two plants located at Rwamagana (SteelRwa) and IMANA Steel located at Bugesera/Gashora. Annual production is 400,000,000 tones / year of iron and steel. This activity can be potential source of PCDD / PCDF as thermal processes contaminated non-ferrous metal scrap influenced by the degree of using scrap metal contamination and also retention and treatment of gas flow.

TABLE 9
QUANTITIES OF UPOPS RELEASES IN AIR, WATER, LAND, PRODUCT AND RESIDUES

Group	Source Groups	Air	Water	Land	Product	Residue
1	Waste Incineration	42.1	0.0	0.0	0.0	104.6
2	Ferrous and Non-Ferrous Metal Production	4000.0	0.0	0.0	0.0	6000.0
3	Heat and Power Generation	0.0	0.0	0.0	0.0	0.0
4	Production of Mineral Products	0.1	0.0	0.0	0.0	0.0
5	Transportation	0.0	0.0	0.0	0.0	0.0
6	Open Burning Processes	0.5	0.0	0.0	0.0	0.0
7	Production of Chemicals and Consumer Goods	0.0	0.0	0.0	0.0	0.0
8	Miscellaneous	0.0	0.0	0.0	0.0	0.0
9	Disposal	0.0	0.0	0.0	0.0	0.0
10	Identification of Potential Hot-Spots				0.0	0.0
	Total	**4,042.7**	**0.0**	**0.0**	**0.0**	**6,104.6**
	Grand Total	**10,147**				

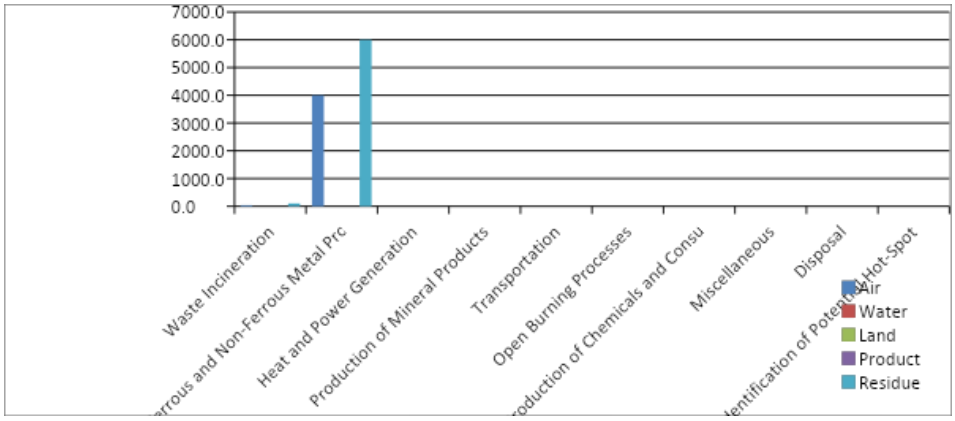

FIGURE 1: Production of iron and steel from metallic wastes (scraps)

According to the graphs above the production of iron and steel from metallic wastes (scraps) are producing the UPOP releases and the second production is waste incineration of medical wastes. And other sources are producing UPOP releases at low level.

V. THE CONTAMINATED SITES (HOTSPOTS)

5.1 Former public waste dumpsite of Nyanza- Kicukiro

This waste dumpsite is located at the top of the hill called Nyanza Kicukiro, in Kagarama Sector, District of Kicukiro. The site contains all kind of waste from Kigali town for long time ago up May 2012, the time the town's wastes were relocated to the Nduba dumpsite.

5.2 Public waste dumpsite of Nduba

This public waste dumpsite located in Nduba Sector, Gasabo District; has replaced the Nyanza-Kicukiro site in May 2012. The site receives all kind of urban waste without a prior sorting. The dumpsite receives an average of 70 trucks (5 tones / truck) per day. Nduba dumpsite was initially designed for receiving in general all kinds of wastes segregated at the origin in order to allow an easy recycling process for some of them. Since this site was opened, no infrastructure development is going on as planned. While the wastes collection practices require wastes to be sorted at generation site, wastes in Nduba are mixed and good variety of hazardous wastes are dumped. Currently, the site employs 90 workers who separate plastic wastes to be recycled from other wastes and dump the latter in appropriate pits. Among these workers who are daily dealing with these wastes, are 23 women (25%). Furthermore, companies involved in wastes collection and their transport, around 500 persons are involved.

5.3 Nyabugogo wetland and River

Nyabugogo wetland is also another place that is required to be subjected to laboratory test as it has been acting as the sink of all categories of wastes collected by the runoff either from the city, surrounding areas as well as the former industrial area of Gikondo.

FIGURE 2: Contaminated site of Gikondo/Industrial Park

The latter also makes another potential contaminated site. In fact, the former GIKONDO industrial park was located upstream of Nyabugogo wetland that gives the name to the river that drain surface water from upstream areas. Many industries, that were in that area lacked the on-site waste treatment, which sometimes results in illegally sending untreated discharge into rivers and wetlands. The next map is showing the interconnection between Nyabugogo wetland and Nyabugogo River with some key pollution hot spots.

5.4 Other Potential contaminated sites

Besides the enumerated dumpsites their other places such where activities that involved articles containing the new POPs took place for long period that need to be subjected to laboratory test for confusion removing. These include for example Agakiriro and other places in Kigali where furniture manufacturing took place in the past years.

VI. RECOMMENDATIONS

The limited knowledge and skills on POPs, lack of information access and analytical capacity of POPs are considered as crucial issues for waste collectors and local communities who are vulnerable to POPs and wastes to fulfill the obligations of the Stockholm Convention. In order to reduce or eliminate the POPs, the capacity building of vulnerable communities is needed in Rwanda to save their lives, public health and environment in general. Therefore, the following recommendations are formulated to an opportunity for waste collectors and local communities to become familiar with POPs information and environmentally sound management of chemicals and wastes:

- It should be better to organize the permanent training of waste collectors and local communities to apply Best Available Techniques/Best Environmental Practices needed to reduce the production of POPs and waste management and implement technical environmentally sound management of wastes. Capacity building of waste collectors and various stakeholders intervening in waste management should be effective and efficient in the management of chemicals and wastes
- Awareness promotion should be organized separately in Hospitals, industries, local communities… and various stakeholders including CBOs, NGOs and local communities should participate actively and play key role in chemicals and waste management
- Introducing the measures of alternative technologies to improve the incineration systems (eradication lowly incineration furnaces, low technological condition) and enforce the use of gas tributaries of control systems.
- The use of approved incinerator designs that can achieve appropriate combustion conditions (e.g., minimum temperature of 800^{o} C, maximum temperature 1500 ^{o} C. currently the medical wastes are burned on the temperature between 800-900 ^{o} C
- The location for the incinerator should be considered to minimize potential risks to public health and the environment (Minimizing the number of people potentially exposed)
- Further studies should be conducted on assessment of POPs management and analytical analysis of POPs potential in Rwanda and other POPs related researches.

VII. CONCLUSION

In general, in Rwanda, there are the releases of POPs/chemicals and wastes. This affects the environment and public health negatively according to the frequency and period of exposure. The vulnerable communities (waste collectors and local communities) should be trained on chemicals and waste management, Best Available Techniques/Best Environmental Practices and proposed together the way forward to apply with BAT/BEP measures needed to reduce or eliminate the releases of POPs and technical guidelines of environmentally sound management of wastes including chemicals. The study proposed the recommendations to be put into action for the efficient results to adapt Best Available Techniques/Best Environmental Practices (BAT/ BEP) to reduce the emissions of POPs/chemicals and waste management for protecting the environment and public health.

Therefore, the collaboration and ownership of various stakeholders including local authorities, communities, Civil Based Organizations, Private Sector and academic institutions should be important for effective and efficient management towards POPs free environment and waste management for sustainable development. Without environmentally sound management of wastes; public health can lead to significant environmental degradation and pollution. The contribution of local communities,

especially the waste collectors in cooperatives and companies should be more effective to achieve the management of chemicals and wastes and pollution control thus save the environment.

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