Estimation of Persistent Organic Pollutants releases and emission levels from Healthcare Waste in Mwananyamala and Temeke Regional Hospitals in Tanzania

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ABSTRACT
This study estimated the amount of polychlorinated dibenzodioxin (PCDDs) and polychlorinated dibenzofurans (PCDFs) from healthcare wastes generated in Mwananyamala and Temeke regional hospitals located in Dar es Salaam using Standardized Toolkit for sources of persistent organic pollutant (POPs) developed by UNEP. Healthcare wastes were collected in different categories and measured for fourteen (14) consecutive days. By using a weighing scale machine, the assessment of the healthcare waste generation rate in each hospital was measured. The average amount of healthcare wastes were 67.12 Tons/year and 105.34 Tons/year at Mwananyamala and Temeke hospitals respectively. The recommended tolerable daily intake (TDI) of dioxin/furans for an adult is 1.75 x 10-10 g I-TEQ/day. The value obtained in this study (2.38 x 10-4 g 1-TEQ/day) at Mwananyamala hospital and 3.62 x 10-4 g 1-TEQ/day at Temeke is about 1.36 x 106 and 2.07 x 106 times higher than the recommended value for adults respectively. It is hereby recommended the emission of dioxin/furan from hospitals must be controlled and if possible, reduced to below the recommended limit. More detailed studies and the permanent monitoring of air quality around different healthcare facilities would be appropriate.

Keywords: *Dioxin, healthcare waste, health risks, furans, infectious, incinerator*

INTRODUCTION
Dioxins and furans are common names for toxic chemicals that are found in very small amounts in the environment, including air, water and soil. As a result of their presence in the environment, they are also present in some foods. There are 210 different dioxins and furans. All dioxins have the same basic chemical skeleton, and they all have chlorine atoms as part of their make-up. Furans are similar, but have a different skeleton.

The name dioxins are often used for the family of structurally and chemically related *polychlorinated dibenzoparadioxins (PCDDs)* and *polychlorinateddibenzofurans (PCDFs)*. Certain dioxin like polychlorinated biphenyls (PCBs) with similar toxic properties are also included under the term dioxins (Figure 1 and 2). These polychlorinated biphenyls (PCBs) are industrial made organic compound with the general formula $C_{12}H10_{-x}Cl_x$.

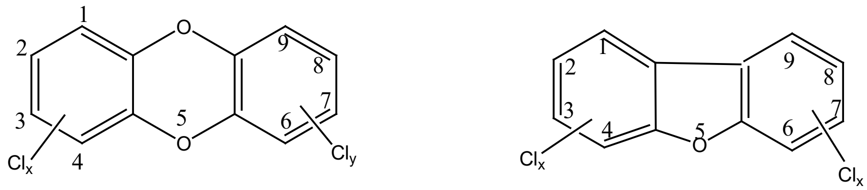

Fig. 1 General Structures of PCDDs (left) and PCDFs (right)

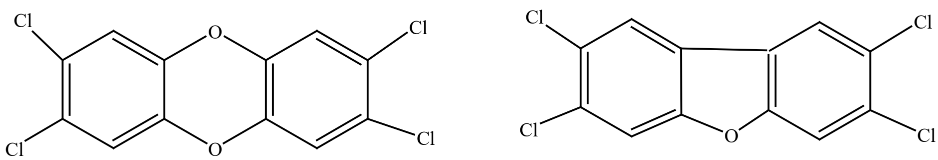

Fig. 2: 2,3,7,8-Tetrachlorodibenzo-p-dioxin (left) and 2,3,7,8-tetrachlorobenzofuran (right)

Among these PCBs, the compound 2,3,7,8-Tetrachlorodibenzo-p-dioxin referred as dioxin is the most toxic synthetic compound known (Harnly *et al.,* 2000) and chlorinated dibenzofurans (PCDF) which is tricyclic ethers having up to eight chlorine atoms attached at carbon atoms 1 to 4 and 6 to 9 (Fiedler, 1998). These chemical compounds may be created during burning of forests or household trash; medical waste, chlorine bleaching of pulp and paper; or manufacturing or processing of certain types of chemicals, such as pesticides (Zhang, *et al.,* 2015).

There has been great concern about dioxins-polychlorinated dibenzo dioxins (PCDDs), polychlorinated dibenzo furans (PCDFs), and polychlorinated biphenyls (PCBs) causing contamination in the environment because the adverse effects of these chemicals on human health have been known for many years (Shibamoto *et al.,* 2007). According to ATSDR (1998), it has been estimated that about 40% of 2,3,7,8-TCDD in the air can be found in vapor phase. However, the sunlight can break down these 2,3,7,8-TCDD into a very small portion of the CDDs which later deposited on land or water. In this study dioxins/furans refers to all polychlorinated dibenzo-p-dioxins and dibenzofurans considered toxic, namely, the 17 congeners chlorinated in the 2,3,7 and 8 positions.

According to Fiedler *et al.,* (2000) the main source of dioxins and furans in the health sector is combustion of healthcare waste and combustion related processes (open burning, different kinds of incineration, gasification, rotary kiln furnaces, plasma pyrolysis, etc). According to Dopico and Gomez (2015), the PCDD/PCDF are emitted unintentionally with about 75% being discharged to waste and only about 25% emitted to air. Air emissions are dominated by residential combustion in small combustion installations and open burning of waste like healthcare waste (UNEP, 2011).

The health effects associated with human exposure to dioxins and furans include skin disorders such as chloracne, immune system impairments, endocrine disorders, reproductive problems, and developing nervous system and certain types of cancer (Ma *et al.,* 2020). An occupational health study has shown the carcinogenic nature of these chemicals, confirmed in 96.5% effect in exposed workers (Dopico and Gomez, 2015). Dioxins and Furans can also affect humans and animals through skin contact or ingestion of fatty food and breathing contaminated air. The health problems associated with these toxic chemicals include cancers, immune problems and skin disease.

The biggest source of dioxins and furans in developed countries is the large-scale burning of municipal and medical waste. The healthcare waste can be categorized to be non-infectious waste or infectious (waste from patients with infections like swabs, bandages and disposable medical devices), sharps (needles and syringes), pathological waste (human tissues, organs or fluids, body parts and contaminated animal carcasses), pharmaceutical (expired, unused and contaminated drugs and vaccines including cytotoxic waste, hazardous chemical waste, radioactive waste, and general (non-risk) waste. Other major sources of dioxins and furans can be burning of household waste, especially plastics, fuel burning wood burning, if the wood has been chemically treated (UNEP, 2011).

In Tanzania different scholars (Manyele and Anicetus, 2006; Anicetus *et al.,* 2020) indicated management of healthcare waste is poor hence can be a major source of dioxins and furans. There is poor segregation of waste in acceptable categories and hazardous wastes are mixed with general waste during incineration (Kagonji and Manyele, 2016). Also, majority of the healthcare facilities has no specific sites for medical wastes disposal, the disposal methods is not safe (wastes are burnt in open areas due to unavailability of working incinerators (Figure 1a & b).

Most of the existing incinerators are not equipped with Air Pollution Control (APC) systems. The cost involved in procuring and running APC equipment discourages its use (Manyele and Anicetus, 2006). As a result, lots of noxious organic and inorganic pollutants are released in the flue gas.

Figure 1a: Broken burning structure

Figure 1b: Open burning space

Under the Stockholm Convention in which Tanzania is a member signed in 2001 and was adopted and ratified it on 30 April 2004 on Persistent Organic Pollutants requires parties to adopt measures that reduce sources of these chemicals (IPEN, 2018). Tanzania developed its National Implementation Plan (NIP) in 2006 (URT, 2006), in compliance with this requirement. However, no known further steps have been taken, particularly at community level. It is known that the main source of dioxins and furans in the health sector is combustion of healthcare waste and combustion-related processes open burning, which is common combustion method used by healthcare facilities in Tanzania.

The objective of this study was to estimate amount of persistent organic compounds (Dioxins and Furans) released in a year in two different hospitals of Dar es Salaam City (Temeke and Mwananyamala) from different categories of healthcare waste generated from these hospitals. Results of this study hopefully inform replication at other potential hotspot areas the country.

METHODOLOGY

The study area

The study was conducted in the city of Dar es Salaam assessing healthcare waste generation rate and its management system in two hospitals: Mwananyamala District Hospital and Temeke Regional Referral Hospital.

Study design

Observational checklist and weighting scale were used to assess the healthcare waste generated in each hospital. A cross-sectional study was conducted by weighing of healthcare waste for 14 consecutive days in two hospitals. Weighing of healthcare waste was done over two shifts. During the night shift healthcare waste was weighed in the morning, likewise, all the waste generated during the day was weighed in the evening and recorded before the end of days shift. A walk-through inspection in all hospitals was done by the investigator in order to identify what type of waste generated in relation to the working section.

Data collection procedures

To determine the weight of waste generated, the WHO guideline was followed (WHO, 2014). Each hospital was provided with 25 kg storage container with appropriate bin liners. The number of containers provided for each hospital depended on the number of functional units. All containers were well labeled as per Healthcare waste guidelines (URT, 2017).

Field investigators placed designated bin-liners in each Healthcare waste (HCW) generation unit at the start of a shift and collected the liners at the end of the shift, replacing it with a new one to continue the exercise. Waste generated were segregated and stored in appropriate color coded containers with appropriate polyethylene bag liners as per Tanzania Healthcare Waste Management (HCWM) guidelines (URT, 2017).

Frequent follow up on segregation practices as well as measurement of HCW was done by assigned supervisor in each hospital. All safety precautions including Infection Prevention and Control (IPC) were followed by both healthcare practitioners and investigators (HCW handlers).

The UNEP's standardized toolkit for dioxin estimation

The Toolkit (UNEP, 2013) focuses on activities under direct anthropogenic activity. Generally, an air release of POPs (PCDD/PCDF) is of concern at the local level especially in healthcare centers. It is usually an issue of workplace design, occupational exposure/worker hygiene and provision of suitable protective clothes–eventually including filter masks-to potentially exposed workers.

At both hospitals they have diesel burner operated incinerator with combustion design of Horizontal Double Chamber with capacity of 100 kg/h and maximum temperature 721ºC and 150 kg/h and maximum temperature 841ºC for Mwananyamala and Temeke regional referral hospitals respectively (Figure 2). The waste is inserted into two small openings of a bore hole that is paved, and then put on fire to burn.

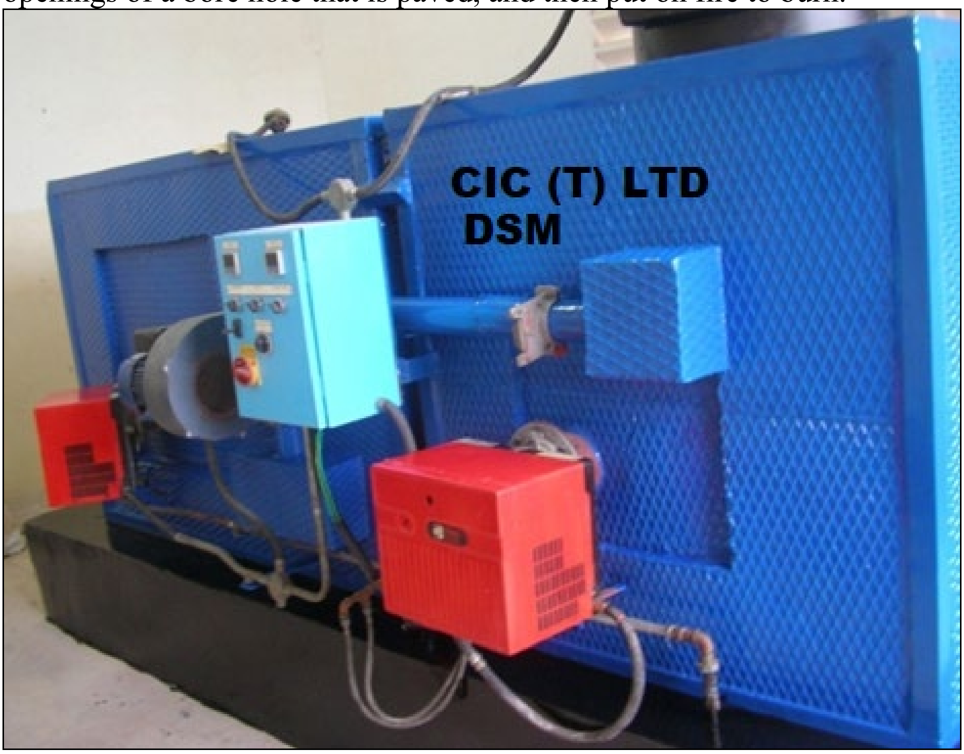

Figure 2: High-Tech incinerator at Temeke Referral Regional Hospital

According to Baharun *et al.,* (2005) in order for the combustion efficient of incinerator to be 99.99% the temperature must be ≥1100°C. Batterman, (2004), in his study has indicated, in most cases the residue of incinerator (bottom ash) collected ranged between 20 - 90 kg/day which is about 5.41% of the total waste incinerated per day, indicating that 95.59% must be converted into gaseous by-products including toxic gases like SO_2, CO, O_2, NOx, HCl and recently Hg is regularly conducted at modern incinerators, as well as metals like Hg, As and POPs. Incinerators produce dioxins (polychlorinated dibenzo-para-dioxins or PCDDs) and furans (polychlorinated dibenzofurans or PCDFs) as a result of the combustion of chlorine-containing wastes, e.g., polyvinyl chloride and other plastics (WHO 1999,2001).

Categories of hospital healthcare waste
Infectious waste: These includes the waste contaminated with blood and other bodily fluids (e.g. from discarded diagnostic samples), cultures and stocks of infectious agents from laboratory work (e.g. waste from autopsies and infected animals from laboratories), or waste from patients with infections (these are like used bandages, swabs and disposable medical devices) (WHO, 2022).

Non-infectious waste: These are waste that doesn't pose a health risk to human beings. These includes packaging materials such as cardboard, office paper, leftover food, cans etc. Sharps this is medical term for devices with sharp points or edges that can puncture or cut skin. Example of sharps is needles, syringes, lancets (finger stick), auto injector; infusion tubing sets (Munir *et al.,* 2014).

Plastics: These refers to, rubbers and polymer composite based materials used in hospital. Sharps waste are all disposable scalpels, hypodermic needles and blades, contaminated glass and certain plastics, and guide wires used in surgery (WHO/UNICEF, 2015). Sharps waste contains items that can cause cuts or puncture wounds to healthcare workers. Whether sharps are infected or not, are considered highly dangerous and potentially infectious waste, due to their puncture or cutting property (Matee and Manyele, 2016).

There are different types of plastic present in healthcare waste in form of different disposable products (example plastic bottles), packaging plastic bags and plastic medical instruments (Blessy *et al.,* 2021). Also PVC is one of the plastic materials in the medical devices (Chia *et al.,* 2020). In most of the healthcare centers the used plastics are either disposed in landfills or inadequately incinerated hence increases the release of POP (Baruah *et al.,* 2018).

RESULTS AND DISCUSSION

Amount of healthcare wastes generated

The average infectious waste generated at Mwananyamala hospital ranged from 42.4 – 1.7.8 kg/day with an average of 65.4 kg/day (Figure 3).

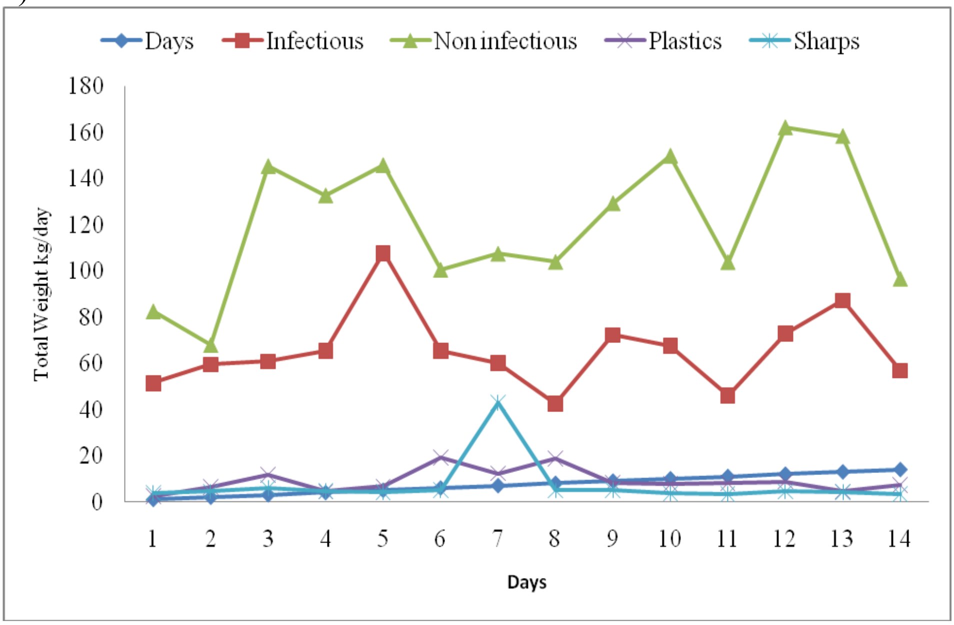

Figure 3: Weight of healthcare waste at mwananyamala hospital for 14 days

At Temeke hospital ranged between 1.3.4-214.5 kg/day with an average of 98.0 kg/day (Figure 4). These values correspond with values detected earlier at Mwananyamala hospital with 84.1 ± 29.0 kg/day (Honest, *et al.,* 2020), but lower than values obtained earlier from Amana Hospital recorded 649 kg/day (Kagonji and Manyele, 2011).

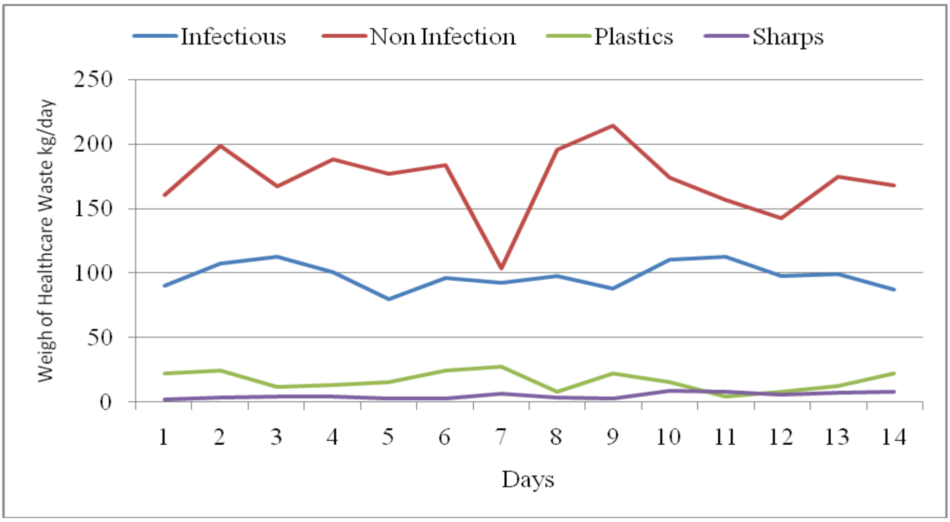

Figure 4 weight of healthcare waste at temeke hospital for 14 days

The amount of non-infectious wastes at Mwananyamala Hospital ranged from 67.9 to 162.2 kg/day average of 120.5 kg/day (Figure 2), at Temeke hospital ranged from 103.4 to 214.5 kg/day with average of 171.7 kg/day (Figure 3). These values are lower than value determined earlier in Dar es Salaam city with an average of 739 kg/day (Kagonji and Manyele, 2011).

The amount of plastics ranged from 2.5 to 18.9 kg/day average of 9.2 kg/day at Mwananyamala Hospital and it 4.6% of the total waste collected. At Temeke hospital the weight of plastics ranged between 4.5 and 27.7 kg/day with average of 16.9 kg/day, which is 5.8% of the total waste collected. These values are lower than the values determined earlier (McGain *et al.,* 2009) of about 30% of entire waste collected.

Results from figure 2 indicated the weight of sharps at Mwananyamala hospital ranged from 3.2 to 5.9 kg/day with an average of 4.4kg/day which is 2.2% of the entire waste collected. At Temeke hospital (Figure 3) the weight of sharps ranged from 2.2 to 8.9 kg/day with an average of 5.2 kg/day which is 1.8% of the total weight collected. These values are lower than the value detected in Dar es Salaam city earlier (Manyele *et al.,* 2011), who detected about 24.41 kg/day.

Estimation of dioxin and furans levels

The estimation of dioxin/furan was based on the materials subjected to incineration. Incineration has been the main method for disposing of the wide range of combustible materials that constitute healthcare waste, because it can significantly reduce the volume of waste material and it can destroy organic matter (Weir, 2002). In this study, the weight of non-infectious waste material was not considered in estimation of dioxin/furan as this type of waste is taken to municipal dump.

The estimation of the annual releases for POPs is calculated based on the UNEP's Standardized Toolkit (2013). The emission of each source group such that:

$$POP_{Year} = [(EF_{Air} xAR) + (EF_{Residue} xAR)] \text{ .... (Eq i)}$$

Where:

POPs/Y = PCDD/PCDF released/year in µg□□□□□Q/Year
□□□□Q/Year = International Toxic Equivalent

AR = Waste Processed (Tons/Year)

EF_{air} = Emission Factor in air (µg □□□□Q/Tons of waste processed). The EF_{air} Standard is 3000 µg I-TEQ/Tons of waste processed (Zhang *et al.,* 2019)

$EF_{Residue}$ = Emission Factor in residue (Fly or bottom ash) (µg□□□□Q/Tons of waste processed). (The $EF_{Residue}$ Standard is 20 µg I-TEQ/Tons of waste processed) (Batterman, 2004).

The average waste incinerated in a year from Temeke Hospital is 43.8 Tons/year while at Mwananyamala is 28.8 Tons/year (Table 2). These values are extremely lower than one determines in Taiwan (Cheng *et al.,* 2009), where the total amount of medical waste was estimated to 526.3 Tons/year. The lower the volume of waste generated was not surprising because in these hospitals there is an installation of bio-digesters in which most of placentas, human tissues and food remains are now considered as raw materials (Honest *et al.,* 2020). The volume of healthcare waste generated in both hospitals is also lower than one generated in Ghara (Oduro-Kwarteng *et al.,* 2021) estimated to be about 69 Tons/year.

Table 2: Estimation levels of dioxin and furans from the measured healthcare waste

	Mwananyamala Hospital			Temeke Hospital		
Categories	Infectious	Plastics	Sharps	Infectious	Plastics	Sharps
Average kg/day	65.4	9.2	4.4	98.0	16.9	5.2
Total kg/day	79.0			120.1		
Total kg/year	28,835			43,836.5		
Ton/year	28.8			43.8		
Air (µg I-TEQ / year)	8.7×10^4			1.3×10^5		
Residue (µg I-TEQ/ year)	5.8×10^2			8.8×10^2		
Total (µg I-TEQ / year)	8.7×10^4			1.32×10^5		
Total (g I-TEQ / year)	8.7×10^{-2}			1.32×10^{-1}		
Total (g I-TEQ / day)	2.38×10^{-4}			3.62×10^{-4}		

Total dioxin/furan released at Mwananyamala hospital from 0.087 g I-TEQ/year) while at Temeke hospital is 0.132 g I-TEQ / year). These values are lower than values determined earlier in hospital at Ethiopia (Akele and Tarekegn, 2017), where results were 9.57 g I-TEQ/year of dioxin/furan released. In another study elsewhere, the quantity was 56.172 g I-TEQ/year released due to medical waste incineration (Ritter *et al.,* 1995).

According to FAO/WHO (2001), the tolerable daily intake (TDI) of dioxin/furans for an adult is 1.75×10^{-10} g I-TEQ/day. The value obtained in this study (2.38×10^{-4} g 1-TEQ/day) at Mwananyamala hospital and 3.62×10^{-4} g 1-TEQ/day at Temeke is about 1.36×10^6 and 2.07×10^6 times higher than the recommended value for adults respectively.
Su-Saharan African countries are high health risk due to high level emissions of dioxin/furans from poor performing incinerators. Golder (1999) in his report indicated the highest concentration of toxic effluents can be found very close to the incinerator (within 100 m). To most of developing countries, Tanzania is not exceptional, patients, staff and healthcare visitors are at adversely health risk because most of hospital departments are within that range from incinerators, burning structures or open burning space.

CONCLUSION AND RECOMMENDATION

The Stockholm Convention on Persistent Organic Pollutants states that each party to the convention should reduce emissions of unintentional POPs at their source, or if possible, eliminate the emission of PCDD/PCDFs. The present study focused on the estimation of POPs in selected hospitals of Tanzania.

In this study, the average waste generated from Temeke Hospital is 105 Tons/year while at Mwananyamala is 67.1 Tons/year. These waste lead to releases of POPs of about 5.56 $X10^{-4}$ g I-TEQ/day and 8.71 g I-TEQ / day at Mwananyamala and Temeke hospitals respectively. The tolerable daily intake (TDI) of dioxin/furans for an adult is 1.75 x 10^{-10} g I-TEQ/day, while to children is 2.74 x 10-12 g I-TEQ/day.

The results show that people are at adversely health risk due to exposure of dioxins/furans from incinerated healthcare materials at these hospitals. The best practices are like adoption of best available technology for healthcare disposal services such as incinerators with flue gas management, increasing public and stakeholders' awareness, participation and capacitating the responsible government organizations. Emission of dioxin/furan from hospitals must be controlled and, if possible, reduced below the limit recommended level. More detailed studies and the permanent monitoring of air quality around different healthcare facilities would be appropriate.

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