Exposure to Dioxins and Furans at the Bormeh Kingtom Dumpsite in Western Freetown, Sierra Leone

Laying the foundation for sustainable UPOPs management at dumpsites in Sierra Leone

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Abstract

Polychlorinated Dibenzo-p-Dioxins (PCDD), commonly known as dioxins, and Polychlorinated Dibenzo Furans (PCDF), commonly known as furans, comprise a large number of distinct compounds which differ in their extent of chlorination and with respect to the position of chlorine atoms in the molecule. Dioxins and furans are introduced into the environment by various pathways (via air emissions, waste water releases, dumping of production residues, contamination of products). However, they enter the food chain predominantly via contamination of vegetables and green feed by airborne particles and in gaseous form. By contrast direct uptake from soil into the roots is of minor importance even if the soil is significantly contaminated. Even though environmental policies have ushered in regulatory agencies to protect people from environmental hazards in Sierra Leone no known action has been taken to follow-up on the signing, ratification, and development of the National Implementation Plan (NIP) on POPs in Sierra Leone, albeit the continuity of activities that are known to release them in the environment. However, the establishment of a POPs related institution, the Environment Protection Agency Sierra Leone (EPA-SL), in addition to the existing Ministry of Lands Country Planning and the Environment, is an advocacy opportunity for domestication of the Stockholm Convention. This work seeks to provide the requisite technical information and guide the policy making process. The objective of the study was to determine the exposure potentials of dioxins and furans in the study area. This was achieved by carrying out the following activities: source identification of dioxins and furans in the study area; source quantification of the dioxins and furans in the study area; and risk assessment of people living within the study area. The Granville Brook dumpsite is located at the east end of Freetown in Sierra Leone and is characterized as open-air waste disposal dump. The main source of UPOPs was the dump sites under study: the Granville Brook dumpsite. Categories of potential sources to look for in the inventory included organic waste, medical waste, plastic materials (including empty water sachets and bottles, scrap tires, wearing, etc), scrap paper, wood shavings. Solid materials that are potential sources of POPs were placed in bags and then weighed on a scale to determine the weight of trips brought in by waste transporters. These weights were used in determining the equivalence of dioxins and furans released per period. The Total UPOPS released from the Granville dumpsite was 128.914 g TEQ/year. This was mainly from plastic materials and wood shavings. No source quantification was done for medical waste, electronic waste, and other sources of the POPs. The main routes of exposure were inhalation, dermal and ingestion of food produced at or close to the dumpsite. The study findings confirmed the suspicion that human health problems could be attributed to POPs release from the dumpsite. Several people have complained of repeated illnesses. One problem of these POPs is that they compromise the immune system and render people susceptible to repeated health problems. Domestication of the Stockholm convention to enhance a national policy and help mitigate POPs release would be the way forward.

BACKGROUND

Polychlorinated Dibenzo-p-Dioxins (PCDD), commonly known as dioxins, and Polychlorinated Dibenzo Furans (PCDF), commonly known as furans, comprise a large number of distinct compounds which differ in their extent of chlorination and with respect to the position of chlorine atoms in the molecule. Dioxins and furans are introduced into the environment by various pathways (via air emissions, waste water releases, dumping of production residues, contamination of products). However, they enter the food chain predominantly via contamination of vegetables and green feed by airborne particles and in gaseous form. By contrast direct uptake from soil into the roots is of minor importance even if the soil is significantly contaminated. Since the degradation and excretion of PCDD is very slow concentrations in human tissue have been observed to increase with the age of the test person.

The lowest value proposed by the US EPA is mainly influenced by the assumption that PCDD must be considered as being carcinogenic. In Germany, a target level of 1.0 mg/kg body weight and per day was set for the daily uptake according to the principle of precaution. Since the average uptake was determined to be higher a variety of measures to identify the emission sources and to reduce the emissions of dioxins and furans were initiated in the late 1980s. Until that time the discussion was mainly focused on accidental dioxin releases from chemical production processes. However, dioxins and furans were discovered in fly ash of a municipal waste incinerator. This observation initiated research on the processes leading to formation of dioxins and furans. After nearly 10 years the so-called "de-novo-synthesis" was identified as the most important formation mechanism for dioxins and furans during combustion processes.

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". These substances vary widely in toxicity. The one considered most toxic is referred to as 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin, or simply TCDD.

Dioxins and furans are also released to the environment through nonindustrial sources that include residential wood burning, incineration of household trash, and diesel exhaust (Shibamoto et al., 2007). Dioxins and furans are also produced through the natural process of a forest fire. However, the largest source of dioxins and furans to the environment in Sierra Leone is the large-scale burning of municipal and medical waste (MoLCPE, 2008).

The term "dioxin" is commonly used to refer to a family of chemicals that share chemical structures and characteristics. These compounds include polychlorinated dibenzo dioxins (PCDDs). There are 210 different dioxin and furan compounds and their demonstrated ability to cause adverse health effects or toxicity varies widely (Van den Berg et al., 1998; Schechter et al., 2006). Generally 17 of the total 210 dioxin and furan compounds characterized are the focus of regulatory action and environmental and human health concern (Mender, 1991; Schechter et al., 2006). The most toxic of the dioxin and furan compounds is the molecule 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin or TCDD (Van den Berg et al., 1998). The toxic effects of dioxin and furan compounds have been extensively studied in the laboratory.

The health effects in humans have been assessed in individuals exposed to these compounds through industrial accidents, contaminated food, and occupational settings (Schechter et al., 2005; National Toxicology Program [NTP], 2004). The studies indicate that disabled Waste Incineration in dump sites have the potential to produce a range of adverse health effects in the laboratory and humans. The health effects associated with human exposure to dioxins and furans include skin disorders such as chloracne, impairments to the immune, endocrine, reproductive, and developing nervous system and certain types of cancer (Schechter et al., 2006; Arisawa et al., 2005; Birnbaum et al., 2003).

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, commonly known as dioxins and furans, are toxic, persistent, bio-accumulative, and result predominantly from human activity. Due to their extraordinary environmental persistence and capacity to accumulate in biological tissues, dioxins and furans have been designated as toxic substances, and are slated for virtual elimination under the Policy for Management of Toxic Substances and the federal Toxic Substances Management Policy (TSMP).

Problem Analysis

The burning of wastes leads to the production of dioxins, furans, and other hazardous substances, which may be released into the atmosphere and deposited onto soil and water bodies. Dioxins and furans are toxic, persistent, and bio-accumulative chemical pollutants formed through uncontrolled burning and industrial processes (Mender, 1991; Kiernan et al., 1985). Industrial sources of dioxins and furans to the environment include incinerators (Ollie, 1980), the manufacture of chlorinated organic compounds, and coal-burning power plants (tier Nan et al., 1985).

Even though environmental policies have ushered in regulatory agencies to protect people from environmental hazards in Sierra Leone no result can pinpoint any robust measures to promote environmentalism as a crucial component of national development. The nation has seen several environmental management plans developed by companies in order to secure environmental licenses, yet none of them seem to have included any plans for minimizing the release of dioxins and furans. The Government of Sierra Leone has signed the Stockholm Convention, and a National Implementation Plan has been developed. Unfortunately it still remains a plan to be implemented by domestication as a national policy. No known action has been taken to follow-up on the signing, ratification, and development of the National Implementation Plan (NIP) on POPs in Sierra Leone, albeit the continuity of activities that are known to release them in the environment. However, the establishment of a POPs related institution, the Environment Protection Agency Sierra Leone (EPA-SL), in addition to the existing Ministry of Lands Country Planning and the Environment, is an advocacy opportunity for domestication of the Stockholm Convention. This work seeks to provide the requisite technical information and guide the policy making process.

Managing landfill fires is a challenging task; it can be controversial and problematic to the social and economic contexts of resource allocation. Notwithstanding that the development of a robust technology that promotes sustainable management of uncontrolled fire at waste dumpsites can, in addition to mitigating release of unintentional POPS (uPOPs) in the environment, promote credible waste management in the nation. This project will monitor the emission pattern of uPOPs from two selected dumpsite and suggest steps to a local and affordable technology to suppress one of the elements in the fire triangle, thereby minimizing the UPOPs release in the environment. Such technical information will serve to guide best practice and update the NIP on POPs.

Although the Minister of Health and Sanitation (MoHS) has the responsibility under the Freetown waste management council waste management disposal regulation (FWMCDR), to grant permits (pursuant to section 5 of the regulations) for the operation of waste dumps and landfills, many sites within Sierra Leone remain unregulated. Many individuals and communities have become increasingly concerned about the adverse effects that environmental contaminants have on human health and the health of the environment on which these communities are highly dependent (Crowe et al., 2001; Dillon, 1983). More specifically, the safety and acceptability of the solid waste management practice of open burning has become a serious concern for many community members from both human and environmental health perspectives. Presently, open-air dumps, coupled with trash burning, are common modes of waste disposal at communities within Sierra Leone.

Significance

According to the UNEP's Standardized Toolkit (2001), polychlorinated dibenzo-p-dioxins (PCDD), commonly known as dioxins, and polychlorinated dibenzo furans (PCDF), commonly known as furans, are two among the 12 unintentional Persistent Organic Pollutants (uPOPs) that are highly toxic to humans and animals. They are persistent, lasting for years or even decades before degrading into less dangerous forms. They evaporate and travel long distances through the air and through water, and they accumulate in fatty tissue. It has been established that combustion processes favor the formation of PCDD/PCDF when mmoderate temperatures (200-450^{0}C) are commonly achieved, low oxygen conditions with high particulate surface area are common, and/or mmaterials containing chlorine and trace metals are commonly burnt.

The Stockholm convention on Persistent Organic Pollutants (POPs) requires signatories to take measures to reduce emissions with a view to eliminating the unintentional production of POPs. The government of Sierra Leone, in its National Implementation Plan (NIP, 2008) for this Convention, asserted that the most prominent source of POPs in the nation was uncontrolled combustion processes in homes, dumpsites, farms/gardens, and public places. It was established that POPs were released on continual basis, given the huge amount of plastic materials contained in waste being burnt. Managing the release of these POPs in the environment is therefore important, giving the rise in persistent health problems with no diagnoses among Sierra Leoneans.

An expected outcome of this work is capacity building: the work would inform the need for training of local personnel in implementing research results from fire mitigation models to minimize release of the uPOPs. Additionally, alternative waste management strategies that are environmentally benign will form part of the training. Data gathered for this work will be used for publication in peer reviewed journals. There will also be institutional capacity building in the process: the University would use the project outcome for curriculum development or strengthening; local and central government will integrate the results into a comprehensive policy strategy to ensure environmental protection. Key stakeholders will include the following:

i. Local Councils
ii. Area heads
iii. Environment Division: Ministry of Lands, Country Planning, and the Environment
iv. EPA-SL
v. Ministry of Health and Sanitation/WHO
vi. Sierra Leone Standards Bureau/UNIDO
vii. Surrounding households
viii. Chemistry Department, Fourah Bay College, University of Sierra Leone
ix. Institute of Environmental Management and Quality Control, Njala University
x. Chemistry Department, Njala University

The research will serve as a spring board to future research work and the conclusions and recommendations will be vital for the focus and activities of the exposure of Dioxins and Furans.

Objective

The objective of the study is to determine the exposure potentials of dioxins and furans in the study area. This will be achieved by carrying out the following activities:

1. source identification of dioxins and furans in the study area;
2. source quantification of the dioxins and furans in the study area; and
3. risk assessment of people living within the study area

<u>Review</u>

In the UNEP's standardized toolkit (2001), exposure to dioxins and furans are mentioned:

PCDD/PCDFs are persistent in the environment and transfers can occur between media (e.g., run-off from soil to water). Such transfers may make an important contribution to human exposure to PCDD/PCDF but quantification of releases from these so-called reservoir sources will not be addressed in this toolkit. Releases from reservoir sources are controlled by site-specific environmental factors. This Toolkit is focused on activities under direct human control. In extreme cases the handling of residues can give rise to a high exposure to PCDD/PCDF……….The potential for residues to cause environmental contamination or exposure to PCDD/PCDF depends to a great degree on how the residue is treated and disposed of. For example whereas contaminated wastes from the chemical industry being incinerated effectively would destroy any PCDD/PCDF present whereas dumping of a residue may result in the creation of a reservoir source. Further, residues from one process may be used as a raw material in another process and without adequate controls, PCDD/PCDF releases to air, water or product can occur.

In general, air releases of PCDD/PCDF will be of concern at the local level. It is usually an issue of occupational exposure/worker hygiene, workplace design, and provision of suitable protective clothes – eventually including filter masks - to potentially exposed workers.

Sources of Dioxins and Furans

In Sierra Leone's National Implementation for the Stockholm Convention on POPs, the following Key Sources and their quantification were done:

Category 1: Waste incineration

Combustion of medical waste

There is one so-called incinerator at the Makeni Government Hospital, in the Northern Province. The waste is inserted into two small openings of a bore hole that is paved, and then put on fire to burn. A lot of smoke is emitted as a result of incomplete combustion.

Category 2: Ferrous and non-ferrous metal production

Sierra Leone does not have any industry for ferrous or non-ferrous metal production.

Category 3: Power generation and heating

Domestic heating and cooking

The quantities of domestic solid fuel and numbers/types of combustion appliances can be reasonably well understood: wood/dry biomass, charcoal, petroleum products. Plastic materials are often used to kindle the burning of wood and charcoal. This is happening on a daily basis and so could contribute to increased flow of the PCDD/PCDF to the environment.

Emissions of dioxins and furans depend on

- Chlorine content of fuel
- Combustion conditions
- Oxygen levels
- Quantity of soot
- Appliances used

Small generators

Starting with the assumption that 56,851 generators consume 0.5 litres of gasoline daily on 365 days per year, the total quantity of gasoline consumed in tonnes would be, considering that 1 litre of gasoline weighs 0.74 kg:

56,851 generators x 0.5 litres x 0.74 [kg/litre] x 365 days = 7,677,000 kg or 7,677 tonnes.

UPOPs emission = 2.5µg TEQ/T x 7,677 = 0.019 g TEQ/a.

Biomass is the major renewable energy used in Sierra Leone's households for cooking. The forest and agricultural by-products provide the main source of fuel wood used. Under the assumption that the heating value of 1 kg of wood is 14 MJ and that almost all wood burned is collected in the forest and therefore virgin wood:

- 4.9 million people burn 1 ton of wood per year each
- 1 ton of wood has a heating value of 14 GJ or 0.014 TJ

- 4,900,000 tons of wood have a heating value of 0.014 x 4,900,000 = 68,600 TJ
- Virgin wood has emission factors of 100 µg TEQ/TJ for air and 20 µg TEQ/TJ for residue
- Emission to air is 100 x 68,600 = 6,860,000 µg TEQ/year or 6.86 g TEQ/year

The combined UPOPs emission of small generators and domestic cooking is 0.019 + 6.86 = 6.88 g TEQ/year.

Category 4: Production of mineral products

The only significant source in this category in Sierra Leone is the cement production. The factory produces 456, 250 tonnes of cement per year. With an emission factor of 5 µg TEQ/t, the emission into air is 0.274 g TEQ/a.

Category 5: Transport

The total number of vehicles of all categories assumed to be in Sierra Leone is 264,697 (source: Road Transport Authority Magazine; Vol.1 No. 2, 2006).

All these vehicles use one of the two types of fuel. 85% of the vehicles imported are used cars, and 80% of them use gasoline. Since it is not clear what percentage of gasoline is leaded, it was assumed that all of it is leaded

80/100 x 264, 697= 211,758 gasoline vehicles and 52,939 diesel vehicles

The annual fuel consumption would be for gasoline

211,758 vehicle x 5 litres x 365 day x 0.74 (kg/l) = 285,979,179 kg/year = 285,979 tonnes/year

For diesel the same calculation yields

52,939 vehicle x 5 litres x 365 day x 0.85 (kg/l) = 82,121,624 kg/year = 82,122 tonnes/year

Assuming that it is leaded, the emissions would be 2.2 µg TEQ/t x 285,979 tonnes/year = 0.629 g TEQ/year for gasoline and 0.1 µg TEQ/t x 82,122 tonnes/year = 0.008 g TEQ/year.

Category 6: Uncontrolled combustion processes

Domestic waste combustion

Combustion of domestic waste is a major source of dioxins and furans, as this is one of the main means of getting rid of household waste. Part of the household waste comprises of plastics and other materials containing chlorine and metals that act as reactants in the formation of PCDD/PCDFs. Residues are likely to be left at the site, which may introduce the PCDD/PCDFs into the soil. There has been an increase in the volume and complexity of waste.

Key uncertainties for the calculation are the amount of waste burnt and the plastic and chlorine content of the waste, the presence of copper (catalyst) and sulphur (inhibitor). Other little known factors are the combustion conditions (oxygen level, air mixing, temperature) and the presence of metals.

Dumpsite waste combustion

Waste combustion at dumpsites is likely to account for most of the dioxins and furans generated in the cities of Sierra Leone. The main dumpsites of the cities of Freetown, Bo, Kenema and Makeni use open burning as one of the main ways of reducing the volume of waste, to allow for continuous flow. No sorting mechanism was identified and so plastic and other chlorine/toxic metal containing substance are usually burned in combination with animal and plant waste. In addition to the main dumps, self created dumps are seen all over the place in all the cities and towns. Village communities mainly bury their waste at backyards or are incorporated into gardens. Residues are likely to be left at the site and subsequently end up in the soil and water bodies.

Key uncertainties:

- Source of ignition: explosive gases, accidental fires in dumped waste or deliberate burning
- Amount of waste burnt
- Plastic and chlorine content of waste
- Presence of copper (catalyst) and sulphur (inhibitor)
- Presence of trace metals and other chemicals

- Emissions depend on details of combustion

The key influences on emissions are:

- Combustion conditions (oxygen level, air mixing, temperature)
- Presence of metals
- Chlorine content of waste

Emissions from waste burning:

The total waste quantity was estimated at 1.76 kg/person/day or 980,025 tons per year in total. It was assumed that half of this quantity is burnt at households and the other half at dumpsites. Since the emission factors into air are 300µg TEQ/t for domestic waste and 1,000µg TEQ/t for dumpsites, an average factor of 650µg TEQ/t was used. The emission factor into residue is the same for domestic waste and dumpsites.

650µg TEQ/t x 980,025 tonnes equals 637 g TEQ/a, emission into air. As for emission into residue, the calculation yields 600 µg TEQ/t x 980,025 t/year = 588 g TEQ/a.

There are significant agricultural and crop residues burnt; the quantity of such biomass that undergoes uncontrolled combustion is estimated at 2 million tons per year. These include animal waste, rice straws, sawdust, cocoa pods, bush fires, etc.”

Estimated emission from uncontrolled burning can be calculated as

Release into air: 5 µg TEQ/t x 2,000,000t/a = 10.00 g TEQ/a

For Land: 4 µg TEQ/t x 2,000,000t/a = 8.00 g TEQ/a

Category 7: Production of chemicals and consumer goods

These are small scale industries with no significant contribution to Sierra Leone's overall UPOPs emissions.

Category 8: Miscellaneous

Most of the sub-categories refer to practices not common in Sierra Leone, such as crematoria or dry cleaning. An estimated 4,900,000 million cigarettes smoked per year cause 0.00018 g TEQ/a emissions into air.

Category 9: Disposal/landfill

Landfill leachate

Waste dumps are a major source of PCDD/PCDF contamination to water. There are two main dumpsites in Freetown, Granville Brook and Bormeh King Tom, and many self created dumpsites all of which are situated by water ways. This same situation applies to the cities of Bo in the south (two main dumpsites), Kenema in the east (one main dumpsite), and Makeni in northern Sierra Leone (one main dumpsite). Many activities that lead to leaching of chemicals, surface runoff, etc., happen on a daily basis; the dumpsites are normally situated in valleys that are flanked by water bodies.

Key uncertainties are the amount of PCDD/PCDF-containing wastewater discharged into waters and the amount of leachate from dumpsites.

Application of sewage sludge to the land is a major practice both in the houses and at dumpsites. All cesspit bowsers empty their contents at the Bormeh King Tom dumpsite directly on the land. This is similar in other cities. Most of the homes in the country empty their sewage sludge in dug holes at the backyard (pit latrines and few septic tanks).

All categories of waste are dumped at backyards and dumpsites. The ashes left from burning are mostly applied to gardens or are just abandoned.

Key uncertainties for release of UPOPs to land are the quantity of sewage sludge dumped on land, the quantity of ash residue, and the quantity, and complexity of waste dumped on the land.

Open water dumping

There are few industrial processes in the country but continuous discharge of wastewater into streams goes on. The industrial activities include brewing and beverage production, small scale gara tie-dying, soap making, etc.

Wastewater discharge from homes may account for most of the UPOPs release to water (dish waters, soapy water, wash water, direct dumping of sewage sludge and other waste types).

Assuming 10L of waste water is released per person per day, the estimated release into water per year is 10L x 4,900,000 x 365 x 5pg TEQ/L = 0.089 TEQ/a

Waste oil disposal

Oil spillage is very common in all operating power stations either in drainages or at the edge field of small streams and swampy areas. **Error! Reference source not found.** is a distinctive example of such common place at the Bo-Kenema power station. There is no evidence of proper handling facilities even at the power stations in Freetown. At this time, the Toolkit does not yet give any emission factors for waste oil.

Health Effects of Dioxins and Furans

Studies have shown that exposure to dioxins cause cancer and other non-cancer health effects. Probable routes of exposure to dioxins are inhalation, ingestion and skin exposure. A nursing baby may also expose to dioxins through its mother milks (UNEP, 2012). Studies have shown that exposure to dioxins has caused chlorines, liver toxicity. The immune system also appears to be very sensitive to dioxin toxicity. The office of Environmental Health Hazard Assessment (OEHHA) has listed dioxins as a compound in which infants and children may be especially susceptible to illness. In addition to the toxicity of dioxin there is concern about dioxins because of the long persistence in the environment and the body. Polychlorinated dibenzo dioxins and furans belong to the family of very toxic chemicals that are unintended trace combustion products. Like hydrochloric acid gas. They form from the presence of chlorine in incineration fuels or conditions despite their low concentration in the environment are very persistent and can accumulate to high enough concentration to increase cancer risk. They are such a danger that the EPA believes that just the background level of exposures to dioxins and furans are enough to increase the risk of cancer.

Approximately 90% of human exposure to dioxin comes from food, especially from beef, fish, and dairy products. Contamination in the food supply comes from dioxin particles that are deposited in water or soil and then proceed up the food chain through fish and livestock, ultimately reaching human tissues through the food we eat. Dioxin bio-accumulates, becoming increasingly concentrated in living tissues as it moves up the food chain.

In humans, there is evidence that high-level exposure to dioxins and furans can cause variations in serum lipid level, microsomal enzyme induction, and gastrointestinal alterations. Other studies of high-level occupational exposure have found associations with some types of cancer, and have concluded that in utero and locational exposures to dioxins and furans are capable of affecting the hypothalamic/pituitary/thyroid regulatory system in human infants. According to U.S. EPA, effects on humans, including hormonal and metabolic changes, have been documented at dioxin body burdens and exposures only slightly higher than those of the general population.

Scientists have studied the effects of dioxins and furans on laboratory animals. They have also researched the health effects on people exposed to dioxins through industrial accidents, contaminated food, and occupational exposure to certain herbicides prior to improved manufacturing processes that have reduced these contaminants.

The studies show that dioxins and furans have the potential to produce a range of effects on animals and humans. Health effects associated with human exposure to dioxins include:

- skin disorders, such as chloracne
- liver problems
- impairment of the immune system, the endocrine system and reproductive functions
- effects on the developing nervous system and other developmental events
- certain types of cancers

It is important to remember that with all toxic substances, including dioxins, the risk of health effects depends on many factors, including:

- The way a person is exposed (e.g., through food, air, water, etc.)
- How much a person is exposed to, and when (e.g., whether it is a large amount on one occasion, or daily exposure to small amounts, etc.)

- individual susceptibility, including general state of health
- whether the person is also exposed to other substances that may be associated with health effects

These issues are very complex. Scientists do not have all of the answers, but they agree that exposures to dioxins and furans should be kept as low as possible

The health effects in humans have been assessed in individuals exposed to these compounds through industrial accidents, contaminated food, and occupational settings (Schechter et al., 2005; National Toxicology Program [NTP], 2004). To date, studies indicate that dioxins and furans have the potential to produce a range of adverse health effect in the environment. The health effects associated with human exposure to dioxins and furans include skin disorders such as chlordane, impairments to the immune, endocrine, reproductive, and developing nervous system and certain types of cancer (Health Canada, 1997; Environment Canadian CCME, 2005; Schechter et al., 2006; Arisawa et al., 2005; Birnbaum et al., 2000) Dioxins and furans can enter your body through breathing contaminated air, drinking contaminated water or eating contaminated food. About 90% of exposure to dioxins and furans is from eating contaminated food.

Emission into the air can result in deposition on to crops, grass, and feed. These deposited dioxins are either eaten by human directly or contamination for humans directly or eaten by livestock and become a source of contamination for humans in beef, poultry and dairy products. In addition, subsistence fisher man can have unusually high levels of dioxin. Generally with dioxins, the potential risk from the food we eat or soil we incidentally ingest for this reason, it is appropriate to conduct a multi pathway health risk assessment rather than just an inhalation only health risk assessment.

Management of Dioxins and Furans

Challenges and Policy options

The environmental impact of historical and current practices of garbage incineration and the potential for dioxin and furan generation and release to the environment as a result of these incineration practices was of particular interest to this community. Members of the Nation as well as the Health Directors of the community initially raised the concerns regarding waste incineration. These concerns were then brought forward to the Freetown waste management Council (FWMC). The Nations views have typically gone unheard and have had little influence, at points of authority, to maintain the balance required to endorse appropriate environmental protection laws and prompt enforcement actions on their lands. Compounded by inadequate funding to address environmental issues and the past industrial exploitation of First Nations land, the safety and acceptability of many solid waste management practices in Freetown has become a serious concern. Historically, poor management, monitoring, and remediation of solid waste facilities across Freetown and the lack of current resolve over this issue has left many First Nations people feeling the consequences of pollution to their rivers, land, and air. There is a vast body of research on the potential environmental and human health effects of wastes and poor waste management practices (Rush ten, 2003).

The potential for human and environmental health effects associated with poor waste management practices has been a long-standing concern for many First Nations communities across Freetown. Most western nations have environmental agencies, policies, statutes, regulations, and mechanisms for evaluating the possible impacts of waste management, for monitoring the continuing effects of existing waste management practices and for adjudicating charges of environmental damage (Hammer, 2003; Masker, 1993). Although several agencies and policies have been developed to protect people from environmental hazards in Freetown, no equivalent mechanisms exist at present within the terms of self-government agreements to enable First Nations people to control environmental impacts on their lands. Historically, First Nations have been left at the margins in policy development and at present the avenues for their participation in federal, provincial, and territorial review processes are not clear or satisfactory (Indian and Northern Affairs Canada, 2004).

Although the Minister of Health and Sanitation () has the responsibility under the Freetown Waste Management Disposal Regulations (FWMDR), to grant permits (pursuant to section 5 of the regulations) for the operation of waste dumps and landfills, many sites within Sierra Leone remain unregulated. Many First Nations communities have become increasingly concerned about the adverse effects that environmental contaminants have on human health and the health of the environment on which these communities are Highly dependent (Crowe et al., 2001; Dillon, 1983). More specifically, the safety and acceptability of the solid waste management practice of incineration has become a serious concern for many community members from both human and environmental health perspectives. Presently, open-air dumps, coupled with trash burning, are common modes of waste disposal on First Nations communities within Sierra Leone. They have identified the potential for contamination of air, soil, surface and groundwater supplies through the practice of waste incineration as a top priority. Monitoring of air, soil, surface and groundwater in the areas of waste incineration on many First Nations communities is not currently performed. Methods of dump and burn came to a halt in most parts of Canada with the enforcement of new clean air regulations in the late 1960s but they continue to be practiced in First Nations communities. The burning of wastes leads to the production of dioxins, furans, and other hazardous substances, which may be released into the atmosphere and deposited onto soil and ground/surface water bodies.

Methodology

Study Area Description

The Granville Brook dumpsite is located at the east end of Freetown in Sierra Leone and is characterized as open-air waste disposal dump. Discussions with community members and visits to the waste disposal site revealed that a formal geological site selection process was not conducted prior to the location assignment of the dump site in the community. The waste site is located in an area of silt sandy soils close to surface of the street, was built without engineered liners, and leachate collection Systems. Thus, the community's waste disposal site could be referred to as a "dump" as opposed to a landfill.

Source Identification

The main source was the dump sites under study: the Granville Brook dumpsite. Categories of potential sources to look for in the inventory included (Figure 1):

1. organic waste
2. medical waste
3. plastic materials (including empty water sachets and bottles, scrap tyres, wearing, etc)
4. scrap paper
5. wood shavings

Figure 1 Potential sources of POPs from dumpsites in Freetown

Source Quantification

The sources were computed using the following methods:

Weight of POPs source

Solid materials that are potential sources of POPs were placed in bags and then weighed on a scale to determine the weight of trips brought in by waste transporters. These weights were used in determining the equivalence of dioxins and furans released per period (Figure 2).

Figure 2 Weight determination

Risk Assessment

The risk assessment was based on the following principles:

Hazard Identification

This involved inventory of sources of POPs at the dumpsite; activity rates were used to quantify the risk gravity.

Exposure Assessment

The routes of exposure: inhalation, dermal, and ingestion were investigated to determine the risk of exposure. Inhabitants around the dumpsites were the principal focus of this aspect of the study.

Results And Discussions

Source Inventory

The main source materials brought into the dumpsite on a daily basis are as follows

Waste plastic sachet

Figure 3 Quantifying waste plastic sachets

Figure 4 Plastic sorted collected and packed by scavengers for sale to recyclers

Scrap paper

Figure 5 Waste cards just brought in

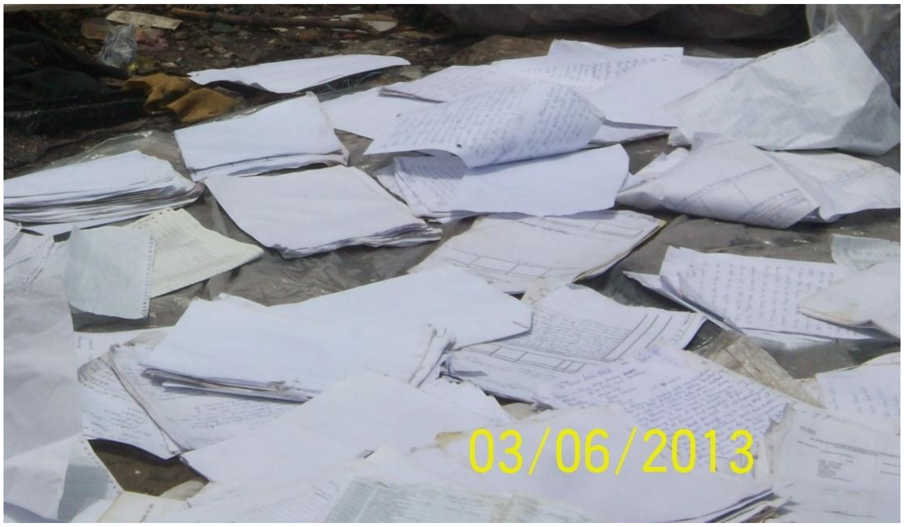

Figure 6 Scrap paper: awaiting open burning

Other plastic materials

Figure 7 Sorting of plastic materials

Scrap tire

Figure 8 Scrap tyre usually burnt for the wire inside

Wood shavings

Figure 9 Wood shavings (biomass) forms majority of most of the waste brought in

Source materials flow rate

Table 1 Flow rate of source materials

Vehicle detail	**Dimension (m)**	**No of trips per day**	**Plastic sachet brought in per day (Kg)**	**Scrap papers/card brought in per day (Kg)**	**Other plastic materials brought in per day (Kg)**	**Scrap vehicles tyres brought in per day**	**Wood shavings**
Nissan: Freetown Waste Management Company	120 x 65 X 40	4	10	8	6	1	10
Ford: Freetown Waste Management Company	244 x 106 x 92	3	12	15	8	3	12
Compactor Farid: Freetown Waste Management Company	234 x 106 x 92	12	13	10	26	15	12
Tricycle: Operation WID	67 x 47 x 23	15	7	6	3	2	5
Wheel Barrow	58 x 55 x13	60	12	4	20	6	10
Individuals		30	5	3	12	0	4
Total		**124**	**59**	**46**	**75**	**27**	**53**

Source Quantification

The annual releases for all vectors from a source or a source category are calculated as shown below. Formulas are adapted from the UNEP's Standardized Toolkit (2001).

Source strength (UPOPs emission per year) = Emission Factor x Activity Rate

The PCDD/PCDF emission is expressed in grams TEQ per year.

Activity Rate = the amount of feed material processed or product produced in tonnes or litres per year by each of the emission factors

Each emission factor is the amount of PCDD/PCDF (in µg I-TEQ) that is released to any of the five vectors per unit of feed material processed or product produced (e.g., tonnes or litres). Default emission factors represent average PCDD/PCDF emissions for each class within each subcategory.

Release from Biomass

Biomass is the major renewable energy used in Sierra Leone's households for cooking. The forest and agricultural by-products provide the main source of fuel wood used (Koroma and Mansaray, 2008). Under the assumption that the heating value of 1 kg of wood is 14 MJ and that almost all wood burned is collected in the forest and therefore virgin wood:

- 19.345 tons of waste wood is dumped per year (0.053 tons per day)
- 1 ton of wood has a heating value of 14 GJ or 0.014 TJ
- 19.345 tons of wood have a heating value of 0.014 x 19.345 = 0.271 TJ
- Virgin wood has emission factors of 100 µg TEQ/TJ for air and 20 µg TEQ/TJ for residue
- Emission to air is 100 x 0.271 = 27.1 µg TEQ/year or 0.0271 g TEQ/year
- In residues: 20 x 0.271 = 5.42 µg TEQ/year or 0.00542 g TEQ/year

The combined UPOPs emission of in the air and residues = 0.021 + 0.00542 = 0.026 g TEQ/year.

Emissions from waste burning

The total source materials (apart from biomass) were estimated at 207 kg/day or 75.555 tons per year in total. The emission factor into air is 1,000µg TEQ/t for dumpsites.

1000µg TEQ/t x 75.555 tonnes = 75.555 g TEQ/year, emission into air. As for emission into residue, the calculation yields 600 µg TEQ/t x 75.555 t/year = 45.333 g TEQ/year.

The combined release per annum: 75.555 + 45.333 = 120.888 g TEQ/year.

Total UPOPS released from the Granville Brook dumpsite is 120.888 + 0.026 = 128.914 g TEQ/year.

Routes of Exposure

The main routes of exposure were inhalation, dermal and ingestion of food produced at or close to the dumpsite.

Inhalation

People living nearby (and within) the dumpsite do inhale the smoke emitted from open burning on a daily basis. There have been complaints of repeated illnesses with minimal cure. Studies have inculpated UPOPs of compromising the immune system, thereby making victims susceptible to all sorts of illnesses.

Figure 10 Workers and scavengers are exposed to smoke all day long

Figure 11 Settlements around the dumpsite are always exposed to smoke

Dermal

Inhalation is always accompanied by skin exposure to the smoke. Additionally, children playing in the dirt may be exposed via the release to residues and adults scavenging for useful materials as well (Figure 12).

Figure 12 Scavengers may be exposed to POPs released in residues

Ingestion of food grown at the dumpsite

Swine faming is one of the main economic activities at the dumpsite. The animals feed on waste materials deposited at the dumpsite. Studies have shown that POPs can accumulate in the fatty tissues of animals like pigs.

Figure 13 Swine industry at the dumpsite

Vegetable gardening (Figure 14) is another major economic activity at the dumpsite. The vegetable is grown here for the advantage of organic manure. However, the release into residues makes bioaccumulation a possibility. And the vegetable is shipped and sold at markets in Freetown.

Figure 14 Vegetable gardening within the dumpsite

Conclusion

This work sought to delineate the exposure of people to dioxins and furans released from the Granville Brook dumpsite. The objective was achieved by carrying out source identification, source quantification and exposure mechanisms.

Dioxins and furans are among a host of chemicals that have been considered harmful to humans. The Stockholm Convention requires governments to adopt mitigation measures and improve the living standards of the world's populations. This study asserted that a total of 128.914 g TEQ of dioxins and furans is released into the air and residues per year. This amount is limited only to plastic materials and wood shavings; it does not include release from medical and other types of waste.

Most of the POPs are released in smoke resulting from uncontrolled burning. The main routes of exposure are inhalation, dermal, and ingestion of food produced at the dumpsite. The study findings confirmed the suspicion that human health problems could be attributed to POPs release from the dumpsite. Several people have complained of repeated illnesses. One problem of these POPs is that they compromise the immune system and render people susceptible to repeated health problems.

Domestication of the Stockholm convention to enhance a national policy and help mitigate POPs release would be the way forward. Sierra Leone is a signatory and has developed the National Implementation plan. Putting this plan into practice and led by agencies such as EPA-SL will be good practice.

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