**DETERMINATION OF HEAVY METAL CONCENTRATION IN BOTTOM ASH IN MEDICAL WASTE INCINERATORS: THE CASE STUDY OF**

**DAR ES SALAAM CITY**

**HONEST E. ANICETUS**

**A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES (HEALTH) OF**

**THE OPEN UNIVERSITY OF TANZANIA**

**2014**

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# CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Open University of Tanzania (OUT) a dissertation titled “Determination of Heavy Metal Concentration in Bottom Ash in the Medical Waste Incinerators: The Case Study of Dar es Salaam City”, in partial fulfilment of the requirements for the degree of Master of Science in Environmental Studies (Health) of the Open University of Tanzania.

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Signature

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Date

# DEDICATION

This study is dedicated to my wife Grace Tairo and my Daughters Irene and Clara who strugled taking cover of various responsibilities and family ties to ensure welfare of our families during the period of my studies. God bless them all.

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# ABSTRACT

The use of medical waste incinerators appears to be rapidly expanding in developing countries including Tanzania. Nuisance arising from medical waste has received much attention but relatively less consideration has been given to bottom ash. This study focused on determination of heavy metal concentration in bottom ash in medical waste incinerators found in different medical hospitals in Temeke, Ilala and Kinondoni Municipalities, Dar es Salaam. Samples of bottom ash were collected and analyzed at the Government Chemist Laboratory Agency. Statistical analysis of the data was done in the SAS software. The results show that, three types of incinerators namely high tech pyloritic, low cost pyloritic and single chamber are used in the study areas. Meanwhile, the findings show that the mean concentration value for Hg, Cd and As was below detectable limits while highest mean concentration of Fe was (9484.806 mg kg-1), Pb was (67.413 mg kg-1), Cu was (28.873 mg kg-1), Cr was (743.750 mg kg-1), and that of Ni was (596.906 mg kg-1). The amount of Cr, Zn, and Ni were above MPL (above 1,100, 150 and 100 mg/Kg respectively) for some hospitals. However, the levels of Cu and Pb obtained in all tested bottom ash were within maximum permissible levels (MPL) to be discharged to the environment. The excess Cd, Cr, Zn and Ni when leaching may contaminate the environment and results into public health risks The study recommends designing of engineered treatment methods for safe disposal of medical waste incinerator bottom ash to reduce contamination of surface and ground water, and soil in general.

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**ACRONYMS AND ABBREVIATIONS**

Ar Arsenic

Cd Cadmium

Cr Chromium

Cu Copper

GCLA Government Chemist Laboratory Agency

HCWM Healthcare waste management

HCWH Healthcare Without Harm

Hg Mercury

MCL [Maximum Contaminant Level](http://en.wikipedia.org/wiki/Maximum_Contaminant_Level)

MOI Muhimbili Orthopaedic Institute

Mn Manganese

MSW Municipal Solid Waste

Ni Nickel

OSHA [Occupational Safety and Health Administration](http://en.wikipedia.org/wiki/Occupational_Safety_and_Health_Administration)

OUT Open University of Tanzania

Pb Lead

PCDDs Polychlorinated dibenzodioxin

PCDFs Polychlorinated dibenzofurans

TIRDO Tanzania Industrial Research Development Organization

USEPA [U.S. Environmental Protection Agency](http://en.wikipedia.org/wiki/U.S._Environmental_Protection_Agency)

Zn Zinc

# CHAPTER ONE

# 1.0 INTRODUCTION

## 1.1 Background Information

Human activities create wastes and it is the way these wastes are handled, stored, collected and disposed that constitutes risks to the environment and public health (Onibokun, 1999). In the urban areas, especially in the rapid urbanizing cities of the under developed world like Dar es Salaam city, problems and issues of solid waste management are of critical debate. This is due to rapid population growth overwhelms the capacity of most municipal authorities to provide even the basic services. When wastes are collected, they are disposed off in uncontrolled dumpsites and/or burnt, polluting water resources, air and soil (Onibokun, 1999).

To minimize the hazards, incineration of medical waste is a significant alternative way for disposal of this category of waste. One of the medical waste treatments methods used worldwide is medical waste incineration. Unfortunately, incineration is not a clean process. Emissions of heavy metals and organic pollutants from these facilities cause significant environmental harm (Anamul, 2012).

Tanzania like other developing countries still faces the problem of healthcare waste management (HCWM). The unsafe disposal of health-care waste (for example, contaminated syringes and needles) poses public health risks (Manyele and Mujuni, 2010). Contaminated needles and syringes represent a particular threat as the failure to dispose it of safely may lead to dangerous recycling and repackaging which lead to unsafe reuse. Contaminated injection equipment may be scavenged from waste areas and dumpsites and either be reused or sold to be used again. The use of medical waste incinerators appears to be rapidly expanding in developing countries and Tanzania is no exception. In the past, treatment of medical waste was primarily performed on-site at hospitals in dedicated medical waste facilities through incineration (Stewart-Pinkham, 1989). All those medical wastes which are incinerated are not sorted or separated prior to treatment. The big assumption is to reduce the volume of the waste, sterilizing the waste, and eliminating the need for pre-processing the waste before treatment.

The resulting incinerated waste can be disposed of in traditional methods, such as brought to a landfill. Incinerators discharge hundreds of pollutants into the atmosphere (Stewart-Pinkham, 1989). Many of these chemicals are both toxic and bio accumulative, building up over time in the body in an insidious fashion with the risk of chronic effects at much lower exposures (Takata, 2003). In developing country like Tanzania, very little attention has been paid to the problem for the major chemicals emitted in order to avoid acute local toxic effects.

The exact composition of emissions from incinerators will vary with what waste being is burnt at any given time, the efficiency of the installation and the pollution control measures in place (Takata, 2003). A municipal waste incinerator will take in a great variety of waste contaminated by heavy metals and by man-made organic chemicals. During incineration more toxic forms of some of these substances can be created. The three most important constituents of the emissions, in terms of health effects, are particulates, heavy metals and combustion products of man -made chemicals; the latter two can be adsorbed onto the smaller particulates making them especially hazardous. In Tanzania, most hospitals have low incineration capacity, with few of them having fire brick incinerators (Manyele and Anicetus, 2006).

Incineration is a [waste treatment process](http://en.wikipedia.org/wiki/List_of_solid_waste_treatment_technologies) that involves the [combustion](http://en.wikipedia.org/wiki/Combustion) of [organic](http://en.wikipedia.org/wiki/Organic_matter) substances contained in waste materials. Incineration and other high-temperature waste treatment systems are described as "[thermal treatment](http://en.wikipedia.org/wiki/Thermal_treatment)" (Batterman, 2004). Incineration of waste materials converts the waste into [ash](http://en.wikipedia.org/wiki/Incinerator_bottom_ash), [flue gas](http://en.wikipedia.org/wiki/Flue_gas), and heat. The ash is mostly formed by the [inorganic](http://en.wikipedia.org/wiki/Inorganic) constituents of the waste, and may take the form of solid lumps or [particulates](http://en.wikipedia.org/wiki/Atmospheric_particulate_matter) carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the [atmosphere](http://en.wikipedia.org/wiki/Atmosphere). In some cases, the heat generated by incineration can be used to generate [electric power](http://en.wikipedia.org/wiki/Electric_power) or heat the water system (Batterman, 2004).

In several countries, there are still concerns from experts and local communities about the environmental impact of incinerators (Batterman, 2004). Many of these incinerators especially from poor countries were built just a few decades ago and often did not include a [materials separation](http://en.wikipedia.org/wiki/Material_recovery_facility) to remove hazardous, [bulky](http://en.wikipedia.org/wiki/Bulky_waste) or [recyclable](http://en.wikipedia.org/wiki/Recyclable_waste) materials before combustion (Batterman, 2004). These facilities tended to risk the health of the community around due to inadequate levels of gas cleaning and combustion process control (Batterman, 2004).

Incineration has a number of outputs such as the ash and the emission to the atmosphere of [flue gas](http://en.wikipedia.org/wiki/Flue_gas). The flue gases may contain significant amounts of [particulate matter](http://en.wikipedia.org/wiki/Atmospheric_particulate_matter), [heavy metals](http://en.wikipedia.org/wiki/Heavy_metals), and other toxic gases (Stewart-Pinkham, 1989). Heavy metal soil contamination is particularly problematic because they are not degraded in soil. At best they can be locally reduced by redistribution in the ecosystem or removed from circulation by immobilization (Scuhmacher, 1997). These heavy metals and their compounds have different physical and chemical characteristics and pose diverse toxicological characteristics. Human beings are poisoned through inhalation, ingestion and skin absorption. Acute exposures to high levels cause nausea, anorexia, vomiting, gastrointestinal abnormalities and dermatitis (Mahoney and Moy, 2005).

Generally, humans are exposed to these metals by ingestion (drinking or eating) or inhalation (breathing). Working in or living near incinerators which sometimes are installed closer to living and working premises these metals and their compounds increases ones risk of exposure, as does living near a site where these metals have been improperly disposed. Subsistence lifestyles can also impose higher risks of exposure and health impacts because of hunting and gathering activities (Stewart-Pinkham, 1989).

Many people believe that waste disappears when it is burnt. In fact the burnt waste is transformed into ashes and gas. As this happens, chemical reactions lead to the formation of hundreds of new compounds, some of which are extremely toxic. The number of substances released from a waste incinerator may run into thousands. So far, scientists have identified a few hundred substances as hazardous (Anamul, 2012). A Metal like cadmium and cadmium compounds are known human carcinogens. Smokers get exposed to significantly higher cadmium levels than non-smokers. Severe damage to the lungs may occur through breathing high levels of cadmium. Chromium compounds are toxins and known human carcinogens. Breathing high levels of chromium can cause irritation to the lining of the nose; nose ulcers; runny nose; and breathing problems, such as asthma, cough, shortness of breath, or wheezing. Lead is a probable human carcinogen. Lead can affect every organ and system in the body (Scuhmacher *et al*., 1997).

Long-term exposure of adults can result in decreased performance in some tests that measure functions of the nervous system; weakness in fingers, wrists, or ankles; small increases in blood pressure and anaemia. Exposure to high lead levels can severely damage the brain and kidneys and ultimately cause death.

In pregnant women, high levels of exposure to lead may cause miscarriage (Mahoney and Moy 2005). Its toxicity is linked with reproduction problem because it affects sperm and reduces birth weight (Oliver, 1997). Mercury combines with other elements to form organic and inorganic mercury compounds. Exposure to high levels of mercury can permanently damage the brain, kidneys, and developing foetuses. Effects on brain malfunctioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems (Takata, 2003).

Numerous studies in developed countries confirm that a typical incinerator releases a cocktail of toxic chemicals, including dioxins, lead, cadmium, mercury and fine particles, into the atmosphere. However, there has been little follow up investigation into the effects of these poisons on people near incinerators. Therefore, it is the intention of this study to determine the contamination of bottom ash from these incinerators so as to add knowledge in Africa.

The approximate chemical composition of hospital waste is 37% carbon, 18% oxygen and 4.6% hydrogen, as well as numerous other elements (Liberti, *et al*., 1994). The toxic metals that are found in health-care waste and that are readily emitted during combustion include lead, mercury, cadmium, arsenic, chromium and zinc. In the past, elemental compositions were used to estimate the products of combustion, but this can be misleading since health-care waste varies widely.

Moreover, persistent organic pollutants such as polychlorinated dioxins and furans cannot be predicted reliably from basic elemental compositions. These dioxins and furans are toxic at extremely low concentrations. However, decreasing the percentage of halogenated plastics (such as polyvinyl chloride) reduces the amounts of hydrogen chloride and other halogenated pollutants.

Hem Chandra (1999) of International Society of Environmental Botanists in his article on “Hospital Waste- An Environmental Hazard and its Management defined hospital waste as all waste generated, discarded during the patient care and not intended for further use in the hospital. He further classified hospital waste into seven categories namely General waste, pathological waste, infectious waste, sharps, pharmaceutical waste, chemical wastes, and radioactive waste. Further classification and the source of healthcare waste at the facility level based on functional areas/units was provided by the (HCWH, 2012).

**Table 1.1: Sources and types of healthcare waste**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Department** | | **Sharps** | **Infectious and pathological waste** | | **Chemical, pharmaceutical and cytotoxic waste** | **Non-hazardous or**  **general waste** |
| Medical ward | | Hypodermic needles, intravenous set needles; broken vials and ampoules | Dressings, bandages, gauze, and cotton contaminated with blood or body fluids; gloves and masks contaminated with blood of body fluids | | Broken thermometers and blood pressure gauges; split medicines; spend disinfectants | Packaging, food scraps, paper, flowers, empty saline bottles, non-bloody diapers; non-bloody IV tubing and bags |
| Operating theatre | | Needles, IV sets, scalpels, blades, saws | Blood and other body fluids; suction canisters; gowns, gloves, masks, gauze, and other waste contaminated with blood and body fluids; tissues, organs, foetuses, body parts | | Spent disinfectants | Packaging, uncontaminated gowns, gloves, masks, hats and shoe covers |
| Laboratory | | Needles; broken glass, Petri dishes, slides and cover slips; broken pipettes | Blood and body fluids; microbiological cultures and stocks; tissue; infected animal carcasses; tubes and containers contaminated with blood or body fluid | | Fixatives; formalin; xylene, toluene, methanol, methylene chloride, and other solvents; broken lab thermometers | Packaging; paper, plastic containers |
| Pharmacy store | | Broken bottles, broken thermometers |  | | Expired drugs, Spilled drugs Empty containers | Packaging; paper, empty containers |
| Radiology | |  |  | | Silver; fixing and developing solutions; acetic acid; glutaraldehyde | Packaging, paper |
| Chemotherapy | | Needles and syringes |  | | Bulk chemotherapeutic waste; vials, gloves and other material contaminated with cytotoxic agents; contaminated excreta and urine. IV sets containing chemotherapy drugs are cytotoxic waste | Packaging, paper |
| Department | | Sharps | Infectious and pathological waste | | Chemical, pharmaceutical and cytotoxic waste | Non-hazardous or general waste |
| Vaccination campaigns | | Needles and syringes |  | | Bulk vaccine waste; vials, gloves | Packaging |
| Cleaning Services | | Broken glass |  | | Disinfectants (glutaraldehyde, phenols, etc.), cleaners, spilled mercury, pesticides | Packaging, flowers, newspapers, magazines, cardboard, plastic and glass containers, yard waste |
| Engineering | |  |  | | Cleaning solvents, oils, lubricants, thinners, asbestos, broken mercury devices, batteries | Packaging, construction or demolition waste, wood, metal |
| Food services | |  |  | |  | Food scraps; plastic, metal and glass containers; packaging |
| Other sources: | | | | | | |
| Physicians’ offices | Needles and syringes, broken ampoules and vials | | | Cotton, gauze, dressing, gloves, masks and other materials contaminated with blood or other body fluids | Broken thermometers and blood pressure gauges; expired drugs; spent disinfectants | Packaging, office paper, newspapers, magazines, uncontaminated gloves and masks |
| Dental offices | Needles and syringes, broken ampoules | | | Cotton, gauze, gloves, masks and other materials contaminated with blood | Dental amalgam; spent disinfectants | Packaging, office paper, newspapers, magazines, uncontaminated gloves and masks |
| Home health care | Lancets and insulin injection needles | | | Bandages and other material contaminated with blood or other body fluids | Broken thermometers | Domestic waste |

*Source:* HCWH (2012)

## 1.2 Statement of the Problem

Nuisance arising from medical waste has received much attention but relatively less consideration has been given to bottom ash. Bottom ash is dumped on the soil which mixes into the soil as diffused pollutant. In practice, for most health facilities with incinerator across the country bottom ash after incineration is considered as harmless and is disposed off as non hazardous waste or some tend to bury it in a dug pit or take it to dumpsite. A recent study by the Ministry of Health and Social Welfare(MOHSW) and Tanzania Industrial Research Development Organization (MOHSW and TIRDO, 2007) in regards to combustion efficiency of the incinerators, found that the average concentrations of toxic gases at incinerator were 1413.2 mg/m3, 140.12 mg/m3 and 50.8 mg/m3 for CO, SO2 and NOx respectively. This suggests that there is a high possibility of toxic and bio-accumulative toxic substances such as heavy metals in the ash as well as in flying ash.

The problem of exceeded levels of pollutant emission is generally caused by lack of adhering to specification of the designs of the incinerators MOHSW, 2007). Waste segregation practices are generally deficient in most health facilities, which may result into injuries such as needle stick injury to healthcare workers (Kayumba and Anicetus, 2012), In some cases those injuries incidences have resulted into acquiring of infections by healthcare works employees during health delivery services (Kassile *at el.*, 2014). Also, lack of waste segregation practices adherence to operation principles increases the possibility of increasing pollutants in bottom ash after incineration (MOHSW and TIRDO, 2007).

This study focused on the determination of concentration level of toxic heavy metals from the bottom ashes in different incinerators mostly, Mercury, Cadmium, Lead, Arsenic, Iron, Zinc, Manganise, Chromium, Nickel, and Copper in bottom ash after incineration in the selected health facilities with incinerators. The study information will be useful in designing and developing the best disposal options for the bottom ash to avoid its contribution to the environmental and Public Health hazards.

## 1.3 Objectives

### 1.3.1 General Objective

To assess the concentration of heavy metal in bottom ash from medical waste incinerators and predict their possible public health effect.

### 1.3.2 Specific Objectives

1. To categorize types of incinerators currently in use in different health facilities in Dar es Salaam city.
2. To analyze levels of heavy metals concentration in sampled bottom ash after incineration.

### 1.3.2 Hypotheses

1. There are various categories of incinerators for handling medical waste in Dar es salaam City.
2. There is a high level of heavy metals in bottom ashes after incineration of medical waste associated with health care waste.

# CHAPTER TWO

# 2.0 LITERATURE REVIEW

## 2.1 Introduction

Hem Chandra, (1999), defined hospital waste as all waste generated and discarded during and after the patient care and not intended for further use in the hospital. Hospital waste is a potential health hazard to the healthcare workers, public and flora and fauna of the area (Chandra, 1999).

To minimize potential hazards of medical waste, incineration as one of the medical waste treatments used worldwide of medical waste is a significant alternative way for disposal of this category of waste. But relatively less attention has been given to bottom ash. Normally the bottom ash is dumped on the soil which mixes in to the soil as diffuse pollutant (Anamul, 2012). Unfortunately, incineration is not a clean process. Emissions of heavy metals and organic pollutants from these facilities cause significant environmental harm (Anamul, 2012).

Although incineration can reduce the weight of waste by more than 70%, large amounts of combustion residues, especially bottom ash, still remain after incineration. In some densely populated big cities, disposal of the waste ash is becoming increasingly difficult, owing to high cost, diminishing land availability, more stringent regulation, and frequent public opposition to the sifting of new landfills (Anamul, 2012). The environmental impact of medical waste incinerators has become the subject of public debate.

The scenario is more complex for medical waste as these contain not only pathological waste but also hazardous waste which includes radioactive and pharmaceuticals waste. The major by product of this incineration process of medical waste is bottom ash which also contains noticeable amount of heavy metals (Anamul, 2012). Therefore, it is the intention of this research to explore the need for more practical knowledge about heavy metal concentration in bottom ash after incineration of medical waste.

## 2.2. Biomedical Waste Management

Medical waste forms 15% of the hospital waste which is considered as hazardous and may be toxic or radioactive (WHO, 1994). Management of hospital waste if not done properly can cause significant inconvenience and health risk (Naioova, 2000; Sheshinski *et al.,* 2002; WHO, 2004). The management practice may pose as a risk, and may very likely pollute the environment through emitted smoke and improperly disposed of bottom ash of incinerators (Ford, *et al.*, 2004). Incineration of medical waste as a treatment option is viewed as dangerous (Ridlington *et al.*, 2004). The practice is worsened by operation of incinerators by untrained or improperly trained operators (Batterman, 2004). While incinerating medical waste, waste that may contain heavy metals should be segregated and excluded for separate treatment so as to ensure that the environment is not polluted by their emissions and residues posing a risk to public health. However, this step is not done and making assumed the end product is potentially highly contaminated.

Further to that, healthcare waste containing mercury if incinerated without care would release mercury vapour in the environment which if inhaled by humans may be toxic, fatal or lead to life threatening injuries to lungs and neurological systems (Howard, 2002; UNEP, 2009).

The ashes that remain at the bottom of the incinerator after combustion potentially contain heavy metals. Medical waste has more heavy metals than municipal solid waste (Takeuchi *et al*., 2005; Sabiha-Javied and Tufai, 2008; Zhaho *et al.,* 2010). Other studies revealed that waste from dental clinics broken thermometers mistaken as sharps contain mercury (EPA, 2011; Vieira *et al*., 2009; Azrui, 2010; Calhoum, 2003) in which if incinerated leave mercury residue while the rest is released in the environment posing a great risk to the public.

## 2.3 Incineration Process

Incineration is a [waste treatment process](http://en.wikipedia.org/wiki/List_of_solid_waste_treatment_technologies) that involves the [combustion](http://en.wikipedia.org/wiki/Combustion) of [organic](http://en.wikipedia.org/wiki/Organic_matter) substances contained in waste materials (Knox and Andrew, 2005). Incineration and other high-temperature waste treatment systems are described as *"*[*thermal treatment*](http://en.wikipedia.org/wiki/Thermal_treatment)*".* Incineration of waste materials converts the waste into [ash](http://en.wikipedia.org/wiki/Incinerator_bottom_ash), [flue gas](http://en.wikipedia.org/wiki/Flue_gas), and heat. The ash is mostly formed by the [inorganic](http://en.wikipedia.org/wiki/Inorganic) constituents of the waste, and may take the form of solid lumps or [particulates](http://en.wikipedia.org/wiki/Atmospheric_particulate_matter) carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before release into the [atmosphere](http://en.wikipedia.org/wiki/Atmosphere). In some cases, the heat generated by incineration can be used to generate [electric power](http://en.wikipedia.org/wiki/Electric_power) (Knox and Andrew, 2005).

Incineration with energy recovery is one of several [waste-to-energy](http://en.wikipedia.org/wiki/Waste-to-energy) (WtE) technologies such as [gasification](http://en.wikipedia.org/wiki/Gasification), [pyrolysis](http://en.wikipedia.org/wiki/Pyrolysis) and [anaerobic digestion](http://en.wikipedia.org/wiki/Anaerobic_digestion). While incineration and gasification technologies are similar in principle, the energy product from incineration is high-temperature heat whereas combustible gas is often the main energy product from gasification. Incineration and gasification may also be implemented without energy and materials recovery (Pirkle *et al.,* 1998; Bernard *et al.,* 1995).

Incinerators reduce the solid mass of the original waste by 80–85% and the volume (already compressed somewhat in [garbage trucks](http://en.wikipedia.org/wiki/Garbage_truck)) by 95–96%, depending on composition and degree of recovery of materials such as metals from the ash for recycling ([Ramboll](http://en.wikipedia.org/wiki/Ramboll), 2006). This means that while incineration does not completely replace [land filling](http://en.wikipedia.org/wiki/Landfill), it significantly reduces the necessary volume for disposal ([Ramboll](http://en.wikipedia.org/wiki/Ramboll), 2006).

The incineration process generates two types of solid residues: bottom ash, and fly ash (Walter, 2002). The amount of ashes generated in the process is approximately 20% to 30%/wt of the incoming solid waste (Walter, 2002). Besides, the inherent ash content of Municipal Solid Waste (MSW), fly ash can also contain additional mass by virtue of chemical reagents used to treat the inherent fly ash. Systems must be included in the facility design to handle and treat the two ash streams; however they can be processed in combination. Heavy metals are not destroyed in the incineration process but are simply concentrated up to high levels in the ash residues or dispersed over the surrounding environment from the incinerator stack (Pirkle *et al.,* 1998). For example, exposure to elevated levels of lead has been associated with numerous adverse effects on renal function, development and reproduction in animals and humans (Pirkle *et al*., 1998; Bernard *et al*., 1995).

## 2.4 Bottom Ashes- Heavy Metal Concentration

Incinerator ash is divided into two categories which are bottom ash and fly ash. Most of the ash after incineration is bottom ash that is the residues inside the burner after incineration (Anamul, 2012). Fly ash settles on post burner equipment such as scrubbers. Therefore, bottom ash is the residue resulting from the incineration of waste (Anamul, 2012). Anamul, (2012) reported that metals, such as Ni and Zn in bottom ashes from a medical waste incinerator exhibit high leaching ability. The useful ways to safely get ride ashes is to put ashes in construction materials, or in cement, or to solid waste landfills. However, medical waste bottom ash has some special characteristics that must be taken into consideration before it can be reused. Medical waste contains large amounts of disposal metallic or plastic materials (Anamul, 2012).

The bottom ash from medical waste incineration may contain a large proportion of toxic metallic elements or organic compounds that might hinder its reuse. Previous studies have indicated that medical waste bottom ash contains higher amounts of heavy metals such as Ni, and Zn than does MSW bottom ash (Anamul, 2012). Recent report further show that even though bottom ash is regarded as a non-hazardous material, its TCLP and PBET leachate also showed bio-toxicity (Anamul, 2012).

Currently, there are large amounts of low-standard medical waste incinerators are being operated by some rural and urban medical institutions, which are lack of air pollution control devices and without secondary combustion chamber and burning temperature are usually not so high (Anamul, 2012). Thus, the composition and distribution of toxic elements in bottom ash from these incinerators may vary depending on the type of incinerator in use (Anamul, 2012).

In the study conducted elsewhere, the quantities of bottom ash from the municipal incinerators shows some difference in ash characteristics depending on the types of incinerator (Ontiveros *et al.,* 1988). The Ash composed of high concentration of toxic heavy metals such as mercury (Hg), arsenic (As), lead (Pb), cadmium (Cd), silver (Ag), iron (Fe) and zinc (Zn) (Ontiveros *et al.,* 1988). Anastasiadou *et al.* (2011) analyzed the composition of medical waste incineration fly and bottom ash and revealed that the major elements of the fly ash were CaO (89.2%), SiO2 (6.0%) and Na2O (2.5%), while the major elements of the bottom ash were SiO2 (39.74%), CaO (27.77%), Na2O (9.13%), Al2O3 (5.16%) and Fe2O3 (4.53%) respectively. Sabiha-Javied *et al*. (2008)analyzed the heavy metal (Cd, Cr, Cu, Ir, Pb and Zn) concentration in medical waste incineration ash the high concentration of Pb and Zn was found relatively higher than that of other constituents in the waste. Higher concentration of heavy metals and dioxins such as Polychlorinated dibenzodioxin (PCDDs) and polychlorinated dibenzofurans (PCDFs) was also observed in medical waste incinerator ash by several researchers (Gidarakos *et al*., 2009; Racho and Jindal, 2004; Verma and Srivastava, 2000).

Santarsiero and Ottaviani (1995) indicated the land filling of the solid residues (slags) from the hospital waste incineration and suggested that the heavy metal concentration should be controlled before the final disposal of the slag to landfill. The results showed the potential toxicity of Cd, Cr, Cu, Ni, Pb and Zn with reference to their concentration. The obtained results also showed that the absolute concentration of examined metals in slag is not such as to classify them as toxic and harmful.

## 2.5 Types of Incinerators

An incinerator is a [furnace](http://en.wikipedia.org/wiki/Furnace) for burning [waste](http://en.wikipedia.org/wiki/Waste). Modern incinerators include pollution mitigation equipment such as [flue](http://en.wikipedia.org/wiki/Flue) gas cleaning. There are various types of incinerator plant design: burn barrel, medi-burner, pyrolitic incinerators (low cost and High tech incinerators), moving grate, rotary-kiln, fluidized bed, and wet scrubbers (Batterman, 2004).

### 2.5.1 Burn Barrel

The burn barrel is a somewhat more controlled form of private waste incineration, containing the burning material inside a metal barrel, with a metal grating over the exhaust. The barrel prevents the spread of burning material in windy conditions, and as the combustibles are reduced they can only settle down into the barrel. The exhaust grating helps to prevent the spread of burning chambers. Typically steel 55-US-gallon (210 L) drums are used as burn barrels, with air vent holes cut or drilled around the base for air intake. Over time, the very high heat of incineration causes the metal to oxidize and rust, and eventually the barrel itself is consumed by the heat and must be replaced (Batterman, 2004**).**

Most urban communities ban the use of burn barrels, and certain rural communities may have prohibitions on open burning, especially those home to many residents not familiar with this common rural practice system (Batterman, 2004).

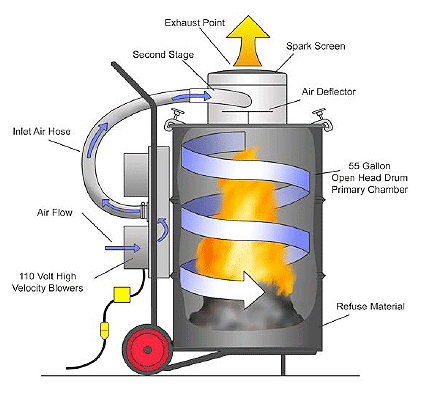
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Figure 2.1: A Burn Burrel

*Source:* Adama, (2003)

### 2.5.2 Med burner MBR 172

This propane powered 72 kw unit is rated 12 kg/hr (6 safety boxes/hr). General cycle is to preheat < 30 min, incinerate < 40 min, pause approx 10 min, incinerate < 40 min, cool-off to 200 °C requiring from 30 - 60 min. A unit was tested by Oulu University Energy Laboratory (Finland) in three tests using medical wastes, batch loads from 1.9 to 3.2 kg and temperatures at high (780 – 1200 C) and low (530 – 1160 C) ranges. Concentrations of most pollutants (HCl, metals except Pb, Cr, Cd, Tl, and dioxin/furan) in stack gases fell below detection limits (Adama, 2003).



Figure 2.2: A Med burner MBR 172

*Source:* Adama (2003).

### 2.5.3. Pyrolytic- Air Controlled incinerator

These relatively inexpensive high thermal capacity incinerators come in various models.

### 2.5.3.1 Demont fort Incinerator

There are various prototype ranging from smaller models: Mark 1: 12 kg/h of waste and Mark 3: 50 kg/h (for hospitals up to 1000 beds) (Adama (2003).



Figure 2.3: Demontfort Incinerator

*Source:* Adama (2003).



Figure 2.4: Demontfort incinerator- Bagamoyo District Hospital

*Source:* Adama (2003).

### 2.5.3.2 SICIM Incinerators

Vulcan 160 (single chamber) incinerator can handle approximately 400 kg/day and achieve temperatures of 900 C (Batterman, 2004).



Figure 2.5: SICIM incinerator

*Source:* Adama (2003)

### 2.5.4. Pyrolytic- Air Controlled Operated Incinerators

The incineration furnaces is of double combustion chambers, which is fabricated from mild-steel, with refractory lined chambers, and insulated from inside. The first combustion chamber is the primary combustion chamber (PCC), which is known as incinerating combustion chambers, the second combustion chamber is the secondary combustion chamber (SCC), also known as thermal oxidation chamber.

### 2.5.4.1 Pyrolytic Fuel Burner Operated Incinerator

Pyrolytic Fuel Burner operated Incinerator is composed of primary chamber, secondary chamber and post incineration chamber (Fig. 2.6). The primary combustion chamber is equipped with charging door, ash removal door, and automatic oil-burner operated by temperature indicating controller (thermostat) which is set at 800±50°C, connected to the electric control panel. Waste is to be fed manually inside the primary combustion chamber through the charging door. Also, the ash is removed manually through ash removal door.

The secondary combustion chamber (thermal oxidation chamber) is equipped with automatic oil-burner operated by temperature indicating controller (thermostat), which is set at 1150±50°C connected to the electric control panel. A Minimum of 2 second residence time is provided for flue gases in this chamber (according to law 94/1994). Additional combustion air from air blower is provided through a number of internal ports fitted in the side walls of the primary and secondary combustion chambers. This additional combustion air is used to ensure the completeness of incineration and pyrolysis processes in primary combustion chamber, and the completeness of oxidation of pyrolytic off-gases in secondary combustion chamber.

The primary oil-burner is used to ignite the wastes and generate heat, so volatilization of waste is achieved in primary combustion chamber through supply of air through various ports on all sides of the primary combustion chambers. Therefore, in the incineration process, the waste is thermally decomposed in the primary combustion chamber at a temperature of 800±50°C. The pyrolytic off-gases products (volatile mater) are completely oxidized in the secondary combustion chamber due to "3Ts Rule": sufficient residence time (2 seconds), high temperature (1150±50°C.) high mixing turbulence with excess air oxygen (Wahid, 2013 ).

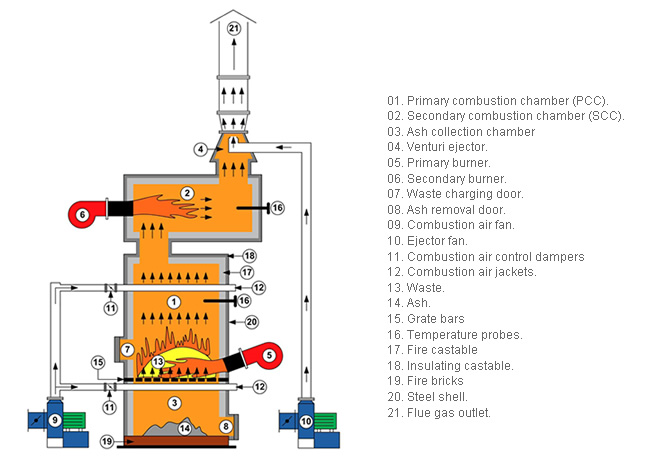


Figure 2.6: Pyrolytic Fuel Burner Operated Incinerator

*Source:* Adama (2003)



Figure 2.7: Pyrolytic Incinerator YD range

***Source:* Adama (2003)**

### 2.5.4.2 Moving Grate

The typical incineration plant for [municipal solid waste](http://en.wikipedia.org/wiki/Municipal_solid_waste) is a moving grate incinerator. The moving grate enables the movement of waste through the combustion chamber to be optimised to allow a more efficient and complete combustion. A single moving grate boiler can handle up to 35 metric tons (39 short tons) of waste per hour, and can operate 8,000 hours per year with only one scheduled stop for inspection and maintenance of about one month's duration. Moving grate incinerators are sometimes referred to as Municipal Solid Waste Incinerators (MSWIs) (WB, (1999).

The waste is introduced by a [waste crane](http://en.wikipedia.org/wiki/Grab_(tool)) through the "throat" at one end of the grate, from where it moves down over the descending grate to the ash pit in the other end. Here the ash is removed through a water lock (WB, 1999) .

[](http://en.wikipedia.org/wiki/File:Movinggrate.jpg)

Figure 2.8: Moving Grate

*Source:* Adama (2003)

Municipal solid waste in the furnace of a moving grate incinerator capable of handling 15 metric tons (17 short tons) of waste per hour. The holes in the grate elements supplying the primary combustion air are visible (WB, (1999). Part of the combustion air (primary combustion air) is supplied through the grate from below. This air flow also has the purpose of cooling the grate itself. Cooling is important for the mechanical strength of the grate, and many moving grates are also water-cooled internally (WB, (1999).

Secondary combustion air is supplied into the boiler at high speed through nozzles over the grate. It facilitates complete combustion of the flue gases by introducing [turbulence](http://en.wikipedia.org/wiki/Turbulence) for better mixing and by ensuring a surplus of oxygen. In multiple/stepped hearth incinerators, the secondary combustion air is introduced in a separate chamber downstream the primary combustion chamber (WB, 1999).

According to the European [Waste Incineration Directive](http://en.wikipedia.org/wiki/Waste_Incineration_Directive), incineration plants must be designed to ensure that the [flue gases](http://en.wikipedia.org/wiki/Flue_gas) reach a temperature of at least 850 °C for two seconds in order to ensure proper breakdown of toxic organic substances. In order to comply with this at all times, it is required to install backup auxiliary burners (often fuelled by oil), which are fired into the boiler in case the [heating value](http://en.wikipedia.org/wiki/Heating_value) of the waste becomes too low to reach this temperature alone (WB, 1999)

### 2.5.4.3 Rotary-kiln

The [rotary-kiln](http://en.wikipedia.org/wiki/Rotary_dryer) incinerator is used by municipalities and by large industrial plants. This design of incinerator has 2 chambers: a primary chamber and secondary chamber. The primary chamber in a rotary kiln incinerator consists of an inclined refractory lined cylindrical tube. The inner refractory lining serves as sacrificial layer to protect the kiln structure. This refractory layer needs to be replaced from time to time. Movement of the cylinder on its axis facilitates movement of waste. In the primary chamber, there is conversion of solid fraction to gases, through volatilization, destructive distillation and partial combustion reactions. The secondary chamber is necessary to complete gas phase combustion reactions (WB, 1999).

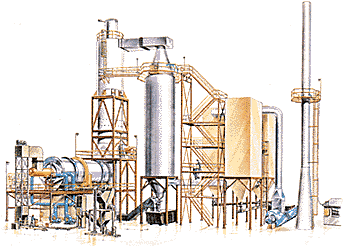


Figure 2.9: Rotary kiln Incinerator

*Source: (*WB, 1999)

The clinkers spill out at the end of the cylinder. A tall flue-gas stack, fan, or steam jet supplies the needed [draft](http://en.wikipedia.org/wiki/Flue-gas_stack#Flue-gas_stack_draft). Ash drops through the grate, but many particles are carried along with the hot gases. The particles and any combustible gases may be combusted in an "afterburner" (Earle, 2003).

### 2.5.4.4 Fluidized bed

A strong airflow is forced through a sand bed. The air seeps through the sand until a point is reached where the sand particles separate to let the air through and mixing and churning occurs, thus a [fluidized bed](http://en.wikipedia.org/wiki/Fluidized_bed) is created and fuel and waste can now be introduced (Earle, 2003).

The sand with the pre-treated waste and/or fuel is kept suspended on pumped air currents and takes on a fluid-like character. The bed is thereby violently mixed and agitated keeping small inert particles and air in a fluid-like state. This allows all of the mass of waste, fuel and sand to be fully circulated through the furnace (Earle, 2003).

### 2.5.5 High Tech incineration – Wet scrubber

Controlled combustion, burn back prevention systems are essential as dust when suspended resembles the fire catch phenomenon of any liquid petroleum gas Earle, 2003). Incinerator is of twin chamber design, where refractory lined chambers are either mounted on top of each other or placed separately. Volatilization of waste is achieved in primary chamber through supply of air through various nozzles on all sides of the primary chambers. Heat is generated with fuel oil burner with auto operation system. Waste is to be fed inside the primary chamber of the Incinerator manually (Wahid, 2013). However, automatic waste feeding system is also available.

Volatilised/gasified matters from waste are taken to the secondary chamber with residence time of minimum of 1 second. The heat source in this secondary chamber is auto controlled fuel oil secondary burner. After the gases leave the secondary chamber, they enter the venturi scrubber where gases are treated with caustic and scrubbed (Wahid, 2013). A re-circulating pump of stainless steel construction is provided in the system for circulation of caustic and water inside the scrubber. The re-circulation pump is common for the scrubber and droplet separator.

All the interconnecting piping is of stainless steel. The gases finally enter the droplet separator wherein the moisture is removed from the gases (Wahid, 2013). This reduces the flue gas temperatures making it safe to be let out in the atmosphere. A fan is provided at the end to release the gases to a 30 m high stack. In the incineration process, the waste is thermally decomposed in the primary chamber at a temperature of 800±50°C ( Earle, (2003). Both the chambers are fitted with burners to fire support fuel for initial heating up of chambers to required temperatures as well as maintain these temperatures.

### 2.5.5.1 Control panel

The control panel supplied along with the Incinerator is placed separately. It houses the primary and secondary burner controls, primary and secondary chamber temperature controllers, and motors starters, re-circulating pump controls, isolator switches, overload relays for burners and fans, flue gas temperature indicator and audio visual alarms for abnormal workings (Earle, 2003).

### 2.5.5.2 Main Combustion Chamber/Primary Chamber

This is fabricated out of Mild Steel and is refractory lined and insulated from inside. This is equipped with loading door, ash removal door and automatic burner operated by temperature indicating controller which is set at 800±50°C. High pressure air from a blower is provided through a number of nozzles fitted in the walls of the primary chambers. Since refractory is very thick and air is circulated within the chamber, it ensures a very low skin temperature of the Incinerator. The primary chamber is provided with a waste charging door and separate ash door for removal of ash from the Incinerator (Wahid, 2013).

### 2.5.5.3 Post Combustion Chamber/ Secondary Chamber

This is also fabricated out of Mild Steel and refractory lined similar to primary chamber. This is equipped with automatic burner. A temperature controller is provided, which is connected to the control panel. The operating temperature is 1050±50°C. A Minimum of 1 second residence time is provided for flue gases in this chamber. The residence time can be increased on customer's request by increasing the size of the chamber **(**Earle, 2003).

### 2.5.5.4 Venturi Scrubber

The flue gases from the Cyclone separator are then sent to venturi scrubber. Venturi scrubber is a high energy device (fabricated out of stainless steel) where particulate matter as well as acidic pollutants are scrubbed. Here the acidic gases are removed by absorption with caustic and the particulates by the inertial impaction energy. A high-pressure drop across the venture scrubber occurs (WB, 1999).



Figure 2.10: Wet Scrubber Incinerator

*Source:* Wahid, (2013)

## 2.6 Toxicology of Heavy Metals

### 2.6.1 Characteristics of Heavy Metals

A heavy metal is a member of a loosely defined subset of elements that exhibit metallic properties. It mainly includes the [transition metals](http://en.wikipedia.org/wiki/Transition_metal), some [metalloids](http://en.wikipedia.org/wiki/Metalloid), [lanthanides](http://en.wikipedia.org/wiki/Lanthanide), and [actinides](http://en.wikipedia.org/wiki/Actinide). Many different definitions have been proposed some based on [density](http://en.wikipedia.org/wiki/Density), some on [atomic number](http://en.wikipedia.org/wiki/Atomic_number) or [atomic weight](http://en.wikipedia.org/wiki/Atomic_weight), and some on [chemical properties](http://en.wikipedia.org/wiki/Chemical_properties) or [toxicity](http://en.wikipedia.org/wiki/Toxic_metal) (USPHS, 1997; Alloway, 1990).Heavy metals have a density of 6.0 g/cm3 or more (much higher than the average particle density of soils which is 2.65 g/cm3) and occur naturally in rocks but concentrations are frequently elevated as a result of contamination. The most important heavy metals with regard to potential hazards and occurrence in contaminated soils are: arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb) and zinc (Zn) (Oliver, 1997).

The sources of heavy metal pollutants are metal mining, metal smelting, metallurgical industries, and other metal-using industries, waste disposal, corrosions of metals in use, agriculture and forestry, forestry, fossil fuel combustion, and sports and leisure activities. Heavy metal contamination affects large areas worldwide. Hot spots of heavy metal pollution are located close to industrial sites, around large cities and in the vicinity of mining and smelting plants. Agriculture in these areas faces major problems due to heavy metal transfer into crops and subsequently into the food chain (Puschenreiter *et al.* 2005).

Heavy metal toxicity can result in damaged or reduced mental and [central nervous function](http://en.wikipedia.org/wiki/Central_nervous_system), lower energy levels, and damage to [blood](http://en.wikipedia.org/wiki/Blood) composition, [lungs](http://en.wikipedia.org/wiki/Lung), [kidneys](http://en.wikipedia.org/wiki/Kidneys), [liver](http://en.wikipedia.org/wiki/Liver), and other vital organs. Long-term exposure may result in slowly progressing physical, muscular, and neurological degenerative processes that mimic [Alzheimer's disease](http://en.wikipedia.org/wiki/Alzheimer%27s_disease), [Parkinson's disease](http://en.wikipedia.org/wiki/Parkinson%27s_disease), [muscular dystrophy](http://en.wikipedia.org/wiki/Muscular_dystrophy), and [multiple sclerosis](http://en.wikipedia.org/wiki/Multiple_sclerosis). [Allergies](http://en.wikipedia.org/wiki/Allergies) are not uncommon and repeated long-term contact with some metals (or their compounds) may cause [cancer](http://en.wikipedia.org/wiki/Cancer) (Schaumberg *et al.,* 2004).

Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and mercury rank among the priority metals that are of public health significance. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure. They are also classified as human carcinogens (known or probable) according to the US Environmental Protection Agency and the International Agency for Research on Cancer (Sauve *et al.* 1997).

### 2.6.2 Lead (Pb)

When lead is released into the environment it has a long residence time compared with most pollutants. As a result, it tends to accumulate in soils and sediments. Due to low solubility, it can remain accessible to the food chain and to human metabolism far into the future (Sauve et al., 1997).

Plants and animals can accumulate lead from water, soil and sediment, with organic forms being more easily absorbed than inorganic. The highest lead concentrations are found in aquatic and terrestrial organisms that live near to lead mining, smelting, and refining facilities; storage battery recycling plants; areas affected by high automobile and truck traffic; sewage sludge and spoil disposal areas; sites where dredging has occurred; areas of heavy hunting (spent lead shot); and in urban and industrialized areas (USPHS, 1997).

The toxic effects of lead are the same, irrespective of whether it is ingested or inhaled, and blood levels as low as <10-100 µg/dl in children, and 10-100 µg/dl in adults have been associated with a wide range of adverse effects including nervous system disorders, anaemia and decreased haemoglobin synthesis, cardiovascular disease, and disorders in bone metabolism, renal function and reproduction. Of particular concern, is the effect of relatively low exposure on cognitive and behavioural development in children (Pirkle et al., 1998 and Nriagu, 1988).

### 2.6.3 Cadmium (Cd)

Cadmium has no biochemical or nutritional function, and it is highly toxic to both plants and animals (USPHS, 1997; WHO, 1992; Alloway, 1990). In humans and animals, there is strong evidence that the kidney is the main target organ of cadmium toxicity, following extended exposure (USPHS, 1997; Elinder and Jarup, 1996; Goyer, (1996); Roels *et al*., 1993; Iwata *et al*., 1993; WHO 1992; Mueller *et al*., 1992).

Renal damage includes tubular proteinuria (the excretion of low molecular weight proteins) and a decrease in the glomerular filtration rate. The latter results in a depressed re-sorption of enzymes, amino acids, glucose, calcium, copper, and inorganic phosphate. Furthermore, studies have shown that even when cadmium exposure ceases, proteinuria does not decrease, and renal tubular dysfunction and reduced glomerular filtration increase in severity (USPHS, 1997; Jarup *et al*., 1997; Elinder and Jarup 1996; Goyer, 1996; Iwata *et al*., 1993; WHO, 1992; Nriagu 1988). Other toxic effects of cadmium, based on findings from occupation, animal, and epidemiological studies, can be summarized as follows:

Case studies indicate that calcium deficiency, osteoporosis, or osteomalacia (softening of the bones) can develop in some workers after long-term occupational exposure to high levels of cadmium (USPHS, 1997; Goyer *et al*., 1994; WHO, 1992). A progressive disturbance in the renal metabolism of vitamin D and an increased urinary excretion of calcium is often seen, suggesting that bone changes may be secondary to disruption in kidney’s vitamin D and calcium metabolism (USPHS, 1997; Goyer *et al*., 1994; WHO, 1992). In the Jinzu River Basin, a cadmium-contaminated area in Japan, cadmium induced skeletal disorder known as *Itai-Itai* disease disabled many children born to women of middle age and poor nutrition (Alloway, 1996)*.*

The inhalation of high levels of cadmium oxide fumes or dust is intensely irritating to respiratory tissue, and acute high-level exposures can be fatal. There have been a number of epidemiological studies intended to determine a relationship between occupational (respiratory) exposure to cadmium and lung and prostatic cancer, and these along with animal studies have provided considerable support for the carcinogenic potential of cadmium (IARC, 1998; Goyer 1996). Cadmium, aheavy metal also common in red bags used to store infectious waste (Hill, 1997; Lee and Huffman, 2002), if incinerated and taken by humans, bio-accumulates in kidneys with the content increasing with age. It causes human kidney damage and emphysema Cadmium and certain cadmium compounds are therefore listed by the International Agency for Research on Cancer (IARC) as carcinogenic (IARC 1998). 2.6.4 Arsenic

Exposure to arsenic occurs mostly in the workplace, near hazardous waste sites, or in areas with high natural levels. Symptoms of acute arsenic poisoning are sore throat from breathing, red skin at contact point, or severe abdominal pain, vomiting, and diarrhoea, often within 1 hour after ingestion. Other symptoms are anorexia, fever, mucosal irritation, and arrhythmia. Cardiovascular changes are often subtle in the early stages but can progress to cardiovascular collapse (Harada, 1995).

Chronic or lower levels of exposure can lead to progressive peripheral and central nervous changes, such as sensory changes, numbness and tingling, and muscle tenderness (Harada 1995). A symptom typically described is a burning sensation ("needles and pins") in hands and feet. Neuropathy (inflammation and wasting of the

nerves) is usually gradual and occurs over several years.

There may also be excessive darkening of the skin (hyper pigmentation) in areas that are not exposed to sunlight, excessive formation of skin on the palms and soles (hyperkeratosis), or white bands of arsenic deposits across the bed of the fingernails (usually 4-6 weeks after exposure). Birth defects, liver injury, and malignancy are possible.

### 2.6.5 Mercury (Hg)

[Mercury](http://customers.hbci.com/~wenonah/hydro/hg.htm) can combine with a methyl group to become methyl mercury. This form of mercury is found in a variety of environmental pollution situations and can produce a range of toxicities. Elemental mercury is less labile but produces a similar set of toxic manifestations (Harada, 1995).

Organic or inorganic mercury can both precipitate protein in a local reaction. In the GI tract, acute poisoning produces a sloughing away of the mucosa to an extent where pieces of the intestinal mucosa can be found in the stools (Harada, 1995). This produces a large loss of fluids and electrolytes. Mercury also breaks down barriers in the capillaries. This results in edema throughout the body. A range of neurological toxicities are also common. These include lethargy (at low doses), excitement, hyper-reflexia, and tremor (Harada, 1995).

Organic mercury compounds, specifically methyl mercury, are concentrated in the food chain. Fish from contaminated waters are the most common culprits. Industrial mercury pollution is often in the inorganic form, but aquatic organisms and vegetation in waterways such as rivers, lakes, and bays convert it to deadly methyl mercury (Harada, 1995).

Fish eat contaminated vegetation, and the mercury becomes biomagnified in the fish. Fish protein binds more than 90% of the consumed methyl mercury so tightly that even the most vigorous cooking methods (e.g., deep-frying, boiling, baking, pan-frying) cannot remove it (Takeuchi *et al*., 1996).

In chronic intoxication there is mercury line at the gingival border similar to the *"lead line".* Mercury is especially poisonous to rapidly growing tissue (Harada, 1995). A common effect is deterioration of alveolar bone in the jaw, with a subsequent loosening of the teeth. There are also substantial liver and kidney toxicity because of mucosal degeneration

### 2.6.6 Copper (Cu)

Copper in the blood exists in two forms: bound to [ceruloplasmin](http://en.wikipedia.org/wiki/Ceruloplasmin) (85–95%), and the rest "free", loosely bound to [albumin](http://en.wikipedia.org/wiki/Albumin) and small molecules (Stern, 2010). Free copper causes toxicity, as it generates [reactive oxygen species](http://en.wikipedia.org/wiki/Reactive_oxygen_species) such as [superoxide](http://en.wikipedia.org/wiki/Superoxide), [hydrogen peroxide](http://en.wikipedia.org/wiki/Hydrogen_peroxide), and the [hydroxyl radical](http://en.wikipedia.org/wiki/Hydroxyl_radical). These damage [proteins](http://en.wikipedia.org/wiki/Protein), [lipids](http://en.wikipedia.org/wiki/Lipid) and [DNA](http://en.wikipedia.org/wiki/DNA).

Acute symptoms of copper poisoning by ingestion include vomiting, hematemesis (vomiting of blood), hypotension (low blood pressure), melena (black "tarry" feces), coma, jaundice (yellowish pigmentation of the skin), and gastrointestinal distress. Individuals with glucose-6-phosphate deficiency may be at increased risk of hematologic effects of copper. Hemolytic anemia resulting from the treatment of burns with copper compounds is infrequent (Ralph and McArdle, 2001).

Chronic (long-term) effects of copper exposure can damage the liver and kidneys. Mammals have efficient mechanisms to regulate copper stores such that they are generally protected from excess dietary copper levels.

The [U.S. Environmental Protection Agency](http://en.wikipedia.org/wiki/U.S._Environmental_Protection_Agency)'s [Maximum Contaminant Level](http://en.wikipedia.org/wiki/Maximum_Contaminant_Level) (MCL) in drinking water is 1.3 mg/L. The MCL for copper is based on the expectation that a lifetime of consuming copper in water at this level is without adverse effect (gastrointestinal). The USEPA lists evidence that copper causes testicular cancer as "most adequate" according to the latest research at Sanford-Burnham Medical Research Institute.

The [Occupational Safety and Health Administration](http://en.wikipedia.org/wiki/Occupational_Safety_and_Health_Administration) (OSHA) has set a limit of 0.1 mg/m3 for copper fumes (vapor generated from heating copper) and 1 mg/m3 for copper dusts (fine metallic copper particles) and mists (aerosol of soluble copper) in workroom air during an eight-hour work shift, 40-hour work week (Ralph and McArdle, 2001).

Copper and [copper alloys](http://en.wikipedia.org/wiki/Copper_alloys) such as [brass](http://en.wikipedia.org/wiki/Brass) have been found to be toxic to bacteria via the [oligodynamic effect](http://en.wikipedia.org/wiki/Oligodynamic_effect). The exact mechanism of action is unknown, but common to other heavy metals. Viruses are less susceptible to this effect than bacteria.

Associated applications include the use of brass doorknobs in hospitals, which have been found to self-disinfect after eight hours, and [mineral sanitizers](http://en.wikipedia.org/wiki/Mineral_sanitizer), in which copper can act as an algicide. Over use of copper sulphate as an algaecide has been speculated to have caused a copper poisoning epidemic on [Great Palm Island](http://en.wikipedia.org/wiki/Great_Palm_Island) in 1979 (Ralph and McArdle, 2001).

### 2.6.7 Iron

Iron poisoning is an [iron overload](http://en.wikipedia.org/wiki/Iron_overload) caused by a large excess of [iron](http://en.wikipedia.org/wiki/Iron) intake and usually refers to an acute overload rather than a gradual one (Hart at el, 1928). The term has been primarily associated with young children who consumed large quantities of iron supplement pills, which resemble sweets and are widely used, including by pregnant women approximately 3g is lethal for a 2 year old). Targeted packaging restrictions in the US for supplement containers with over 250 mg elemental iron have existed since 1978, and recommendations for unit packaging have reduced the several iron poisoning fatalities per year to almost nil since 1998 (Hart et al., 1928).

No known cases of iron poisoning have been identified that are associated with [iron mining](http://en.wikipedia.org/wiki/Iron_mining). The amount of iron ingested may give a clue to potential toxicity. The therapeutic dose for iron deficiency anemia is 3–6 mg/kg/day (Hart et al., 1928). Toxic effects begin to occur at doses above 10–20 mg/kg of elemental iron. Ingestions of more than 50 mg/kg of elemental iron are associated with severe toxicity. In terms of [blood values](http://en.wikipedia.org/wiki/Blood_values), iron levels above 350-500 [µg](http://en.wikipedia.org/wiki/Microgram)/dL are considered toxic, and levels over 1000 µg/dL indicate severe iron poisoning. (Hart et al., 1928).

The first indication of iron poisoning by ingestion is a pain in the stomach, as the stomach lining becomes ulcerated. This is accompanied by nausea and vomiting. The pain then abates for 24 hours as the iron passes deeper into the body resulting in [metabolic acidosis](http://en.wikipedia.org/wiki/Metabolic_acidosis), which in turn damages internal organs, particularly the [brain](http://en.wikipedia.org/wiki/Brain) and the [liver](http://en.wikipedia.org/wiki/Liver). The body goes into shock and death from [liver failure](http://en.wikipedia.org/wiki/Liver_failure) if intake of iron is prolonged in a period of time, of which symptoms are likely similar to other causes of [iron overload](http://en.wikipedia.org/wiki/Iron_overload) (Hart et al., 1928).

### 2.6.8 Nickel (Ni)

Nickel occurs in the environment only at very low levels. Humans use nickel for many applications like the use of nickel as an ingredient of steel and other metal products. Foodstuffs have low natural content of nickel but high amounts can occur in food crops growing in polluted soils. Humans may also be exposed to nickel by inhalation, drinking water, smoking, and eating contaminated food. Uptake of high quantities of nickel can cause cancer, respiratory failure, birth defects, allergies, and heart failure (Rendall *et al.,* 1994; Hostynek, 2006).

### 2.6.9 Chromium (Cr)

It is required for carbohydrate and lipid metabolism and the utilization of amino acids. Its biological function is also closely associated with that of insulin and most Cr-stimulated reactions depends on insulin. However, excessive amount can cause toxicity. Toxic levels are common in soils applied with sewage sludge. Heavy metals toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and mercury rank among the priority metals that are of public health significance. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure (Harada, 1995).

## 2.7 Prediction of Health Impact/Risks Associated With Heavy Metals in the Environment

It is very important to identify the relationship between the presence of heavy metals in drinking water and the prevalence of renal failure, liver cirrhosis, hair loss, and chronic anemia diseases (Salem *et al*., 2000). The prevalence of these diseases has markedly increased in the last few years due to air pollution, water pollution, and hazards over uses of pesticides in agriculture. Trace amounts of metals are common in water, and these are normally not harmful human health. In fact, some metals are essential to sustain life. Calcium, magnesium, potassium, and sodium must be present for normal body functions. Cobalt, copper, iron, manganese, molybdenum, selenium, and zinc are needed at low levels as catalysts for enzyme activities.(Salem *et al*., 2000).

Drinking water containing high levels of these essential metals, or toxic metals such as aluminium, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver, may be hazardous to our health (Salem *et al*., 2000). Metals in our water supply may occur naturally or may be the result of contamination. Naturally occurring metals are dissolved in water when it comes into contact with rock or soil material. Other sources of metal contamination are corrosion of pipes and leakage from waste disposal sites (Salem *et al*., 2000*).*

One of the major symptoms of chemical toxicity seems to be a breakdown of the immune system, which opens the gateway for all kinds of diseases in the body (Salem *et al*., 2000). Also, another major symptom seems to be damage to the nervous system and increased nervousness. Toxic doses of chemicals cause either acute or chronic health effects. The levels of chemicals in drinking water, however, are seldom high enough to cause acute health effects (Salem *et al*., 2000).

Patients suffer from renal failure were related to contaminant drinking water mainly with lead and cadmium. Lead is a dangerous element; it is harmful even in small amounts (Salem *et al.*, 2000). Lead enters the human body in many ways. It can be inhaled in dust from lead paints, or waste gases from leaded gasoline. It is found in trace amounts in various foods, notably fish, which are heavily subject to industrial pollution. Some old homes may have lead water pipes, which can then contaminate drinking water. Most of the lead we take in is removed from our bodies in urine; however, there is still risk of build up, particularly in children (Salem *et al*., 2000). Exposure to lead is cumulative over time. High concentrations of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys (Jennings *et al*., 1996). This damage commonly results in behavior and learning problems (such as hyperactivity), memory and concentration problems, high blood pressure, hearing problems, headaches, slowed growth, reproductive problems in men and women, digestive problems, muscle and joint pain (Salem *et al*., 2000). Studies on lead are numerous because of its hazardous effects. Lead is considered the number one health threat to children, and the effects of lead poisoning can last a lifetime. Not only does lead poisoning stunt a child’s growth, damage the nervous system, and cause learning disabilities, but also it is now linked to crime and anti-social behavior in children (US. General Accounting Office report, 2000).

Metals such as lead and cadmium will interfere with essential nutrients of similar appearance, such as calcium and zinc. Because of size and charge similarities, lead can substitute for calcium and included in bone. Children are especially susceptible to lead because developing skeletal systems require high calcium levels. Lead that is stored in bone is not harmful, but if high levels of calcium are ingested later, the lead in the bone may be replaced by calcium and mobilized. Once free in the system, lead may cause neurotoxicity and hypertension. The pollution of drinking water with lead and cadmium arise from industrial sources at the studied areas and renal failures were related to them (Salem *et al*., 2000). Patients suffer from liver cirrhosis in this study were related to contaminant drinking water mainly with copper and molybdenum. Copper is essential substance to human life, but chronic exposure to contaminant drinking water with copper can result in the development of anemia, liver and kidney damage (Madsen *et al*., 1990; Bent and Bohm, 1995). This disease was a result of drinking water contaminated from corrosion of water pipes made of copper and industrial wastes. Diarrhea in young children could also occur due to high copper exposure. The adverse health effects caused by drinking water contaminated with copper are abdominal pain, vomiting, headache, nausea, and diarrhea. Copper in large doses is dangerous to infants and people with certain metabolic disorders. On the other hand, lack of copper intake causes anemia, growth inhibition, and blood circulation problems (Jennings *et al*., 1996).

Patients suffer from hair loss in this study were related to contaminant drinking water with nickel and chromium. Nickel is used as alloys product, nickel-plating for anticorrosion and in the manufacture of batteries. It is regarded as an essential trace metal but toxic in large amount to human health. It is considered as carcinogenic to human. Ambrose *et al*. (1976) reported that high-dose of nickel in rats and dogs significantly decreased their body weights. The pollution of water with nickel and chromium arises from industrial sources and/or agricultural activities at the studied areas. Its toxicity is enhanced in the presence of other metals such as cobalt, copper, iron and zinc in drinking water.

Many studies have been published regarding nickel sensitivity in humans. Numerous other studies have been conducted to attempt to establish the relationships between nickel exposure and dermal irritation. Kaaber *et al*. (1978, 1979) reported worsening of eczema for human exposed to high level for nickel. Hair loss patients are related to contaminant drinking water and nickel can be related to derma toxicity in hypersensitive humans. On the other hand, chromium is essential to animals and human. Chromium in excess amounts can be toxic especially the hexavalent form. Chromium is used in metal alloys and pigments for paints, cement, paper, rubber, and other materials. Electroplating can release chromic acid spray and air-borne Cr-trioxide, both can result in direct damage to skin and lungs (Grounse *et al*., 1983) as well as chromium dust has been considered as a potential cause of lung cancer (Hyodo *et al*., 1980). Subchronic and chronic exposure to chromic acid can cause dermatitis and ulceration of the skin (US- EPA, 1999). Long-term exposure can cause kidney and liver damage, and damage too circulatory and nerve tissue. Chromium often accumulates in aquatic life, adding also to the danger.

Industry is an important source of heavy metals. Industrial air pollution releases a number of heavy metals into the atmosphere which become potential sources of water pollution after dry or wet deposition. Agriculture soils are rich in heavy metals as a result of the use of various phosphatic fertilizers, organic matters, and pesticides as well as the presence of decaying plant and animal residue. The use of wastewater irrigation and sewage sludge has further increased the quantity of heavy metals in agriculture soils. The agricultural run-off together with soil erosion is the potential source of water pollution.(Salem *et al*., 2000).

On the other hand, cadmium is generally classified as toxic trace element. It is found in very low concentration in most rocks, as well as in coal and petroleum and often in combination with zinc. Geologic deposits of cadmium can serve as sources to groundwater and surface water, especially when in contact with soft, acidic waters. There is no evidence indicating its essentiality to humans. Cd appears to accumulate with age, especially in the kidney and is thought to cause a cancer and cardiovascular diseases. Webb (1979) reported that geochemical implications of Cd in human health related to: (a) bone and renal disease in populations exposed to industrially contaminated drinking water, (b) lung and renal dysfunction in industrial workers exposed to air-borne Cd and (c) implication in human hypertension. Galvanized steel is plated with zinc, which is normally contains about 1% Cd. Cd also has specific uses in paint, photography, and nickel-cadmium batteries.

Some cases of cadmium poisoning are linked to cadmium-plated food utensils. It is introduced into the environment from paint and pigments, and plastic stabilizers mining and smelting operations and industrial operations, including electroplating, reprocessing cadmium scrap, and incineration of cadmium containing plastics. The remaining cadmium emissions are from fossil fuel use, fertilizer application, and sewage sludge disposal. Cadmium may enter drinking water as a result of corrosion of galvanized pipe. Landfill leachates are also an important source of cadmium in the environment.

In low doses, cadmium can produce coughing, headaches, and vomiting. In higher doses, cadmium can accumulate in the liver and kidneys, and can replace calcium in bones, leading to painful bone disorders and to a renal failure. The kidney is considered to be the critical target organ in humans chronically exposed to cadmium by ingestion (EPA, 1999).

# CHAPTER THREE

# 3.0 METHODOLOGY

## 3.1 Introduction

This chapter gives the methodology of the study. It describes the study areas, sampling procedure, ethical issues, and data analysis.

## 3.2 Research Areas

This study was conducted in Dar es Salaam region which consists of three administrative Municipalities namely Ilala, Temeke and Kinondoni (Fig 3.1). The selection of the study areas was done conveniently based on the geographical location of the region in relation to where the incinerators are located, and whether they were functioning at the period of designing of the study.



Figure 3.1[: Dar es Salaam map showing three Municipality of Ilala, Temeke and Kinondoni](#_Toc397608174)

*Source:* http//www.tzgisug.org/wp/tzgisug

The study considered in particular health facilities or hospitals from within the three aforementioned Municipalities. Five incinerators were found functioning with different prototype of incinerators in the respective hospitals within the three Municipalities. The hospital incinerators where the samples were collected were: Muhimbili Orthopaedic institute (MOI), Mwananyamala Regional Hospital, Amana Regional Hospital, Temeke Regional Hospital, Buguruni Anglican Health Centre, and Magomeni Health Centre.

## 3.3 Sampling

A triplicate batch of bottom ash from the selected hospital incinerator was sampled, labeled and weighed in triplicate packs each of about 100g. This was done in the hospitals for three consecutive days. The research assistant who was also a trained health technician, practicing in the hospital was instructed on how to take bottom ash samples from an incinerator through quartering method to arrive at quantities of ashes sufficient to make 100g sample packs in triplicate that excluded stone pebbles. The chief investigator worked with the technician for the whole period of data collection.

## 3.4 Data Analysis

The Government Chemist Laboratory Agency (GCLA) was used for the analysis of the samples. The ash samples obtained were air-dried at ambient temperature in the laboratory for five days. The samples were then sieved through a 2mm screen, then a 0.2 mm screen to obtain a homogenous particle size. The samples were then put into Kjelder tubes and then dissolved with *Aqua Regia* (a mixture of 5mL of Nitric Acid HNO3 and concentrated Sulphuric Acid H2SO4 at a ratio of 1:3. The solution was then heated for 2 hours using Kjelder instrument at 180oC to reduce the volume of the acid to about 2mL. About 4 anti bumping balls were added to avoid bumping or overflow. The digest was again diluted with 10mL distilled water, and then filtered through What-man No. 42 filter paper into a 50 mL volumetric flask. All the ash samples were analyzed for Pb, Hg, Fe, Mn, Cr, Ni, Zn, Cu, Ar, and Cd using Inductively Coupled Plasma - Optical Emission Spectrometer (ICP-OES).

The concentration levels of the sampled metals were measured in mg/L (Table A1 of Appendix I) but converted into mg/Kg using the following conversion formula:

Re-write the equation properly.



 /Weight of sample measured in g, expressed as A= B\*C/D

Where A = Metal concentration (mg/kg)

B= Concentration of metal in digested solution (mg/L)

C = Final Volume of digested solution (100mls)

D= Weight of sample taken for analysis in g

The data that were obtained (Table A2 of Appendix I) using the above conversion were subjected for analysis using the analysis of variance (ANOVA) technique based on which differences in means among the heavy metals were estimated. Under the ANOVA test, the null hypothesis (*H*0) tested was that the mean concentrations for all heavy metals were equal. That is, there were no significant differences in mean concentrations from all heavy metals. This was tested against the alternative hypothesis (*H*1) that some differences existed in the mean concentration between heavy metals.

Mathematically, the null and alternative hypotheses can be formulated; 

 for at least one . That is, at least one heavy metal differs from another heavy metal or groups of heavy metals in terms of mean concentration.

If the null hypothesis is rejected using the ANOVA technique, further analysis can be carried out to find out which mean or groups of means differ from another mean or groups of means. This can be achieved using different simultaneous pair wise comparison procedures. In the present study, the null hypothesis was rejected under the ANOVA test, and the Duncan’s Multiple Range Test was further used to ascertain which pairs of means of metals were statistically significantly different while controlling for the Type I comparison wise error rate. A probability (*p*) value < 0.05 was considered significant. The analysis was done in the SAS system version 9.2 (SAS Institute Inc., USA) while taking into account repeated measurements obtained from each health facility. Means are given in form of mean ± standard deviation (SD).

# CHAPTER FOUR

# 4.0 RESULTS AND DISCUSSION

## 4.1 Introduction

The present chapter provides the study findings and associated discussion. The findings presented here follows the study objectives presented in Chapter one.

## 4.2 Types of Incinerators Currently in Use

The findings in Table 4.1 show that seven (7) incinerators were found in the study areas. It was observed that these incinerators are of different types depending on the level (status), types and amount of waste generated by the health facility. Three types of incinerators were found in the study area, (i) High tech pyloritic incinerator found in Muhimbili national hospital and Orthopaedic Institute, Amana, Temeke and Mwananyamara Hospital; (ii) Prototype of Low Cost Pyloritic Incinerator at Buguruni hospital; and (iii) Single chamber incinerator at in Magomeni Hospital. High tech pyloritic incinerator is designed to handle large quantities of medical waste (>15 kg/hour) compared to others for short period of time. Prototype of Low Cost Pyloritic Incinerator this is the type of incinerator designed to handle medical waste and it operates at temperatures of 800ºC and higher. Its performance varies depending on the moisture content of the medical waste but a throughput of up to 15 kg/hour can be achieved. Unlike the high tech incinerator Single chamber incinerator is does the same activities but under lower temperature (300ºC-400 ºC) compared to the other. Although the three types of incinerators can achieve efficiency in disinfection or treatment/removal of medical waste, if not well managed they can result into toxic emission to air (Allsopp *et al*2001), and lower removal or treatment of medical waste due to temperature fluctuations, if not managed effectively.

In the context of Tanzania, regional hospitals are considered as referral units for patients who cannot receive the recommended treatment at the lower-level health facilities. As a result, hospitals are expected to use a wide range of chemicals and of large amounts compared to health centres which are designated for treatment of uncomplicated illnesses and execution of minor operations. Though Muhimbili hospital is regarded as a National hospital, currently its incinerator is not working, thus render health and environmental risks from the huge amount of medical waste generated. However the with exception of Muhimbili National hospital, the remaining incinerators in other hospitals within the study area are functioning well.

The findings in Table 4.1 show that different types of incinerators are used in the study areas and types of incinerators used differ mainly depending on the level (status) of the health facility. This is because regional hospitals are considered as referral units for patients who cannot receive the recommended treatment at the lower-level health facilities.

In terms of status or condition of the incinerator, the findings show that majority of incinerators (86%) were functioning. The non-operational incinerator was for Muhimbili National Hospital.

**Table 4.1: Type of incinerators used in the surveyed health facilities**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Location** | **Name of the Hospital** | **Level of the Hospital** | **Type of Incinerator** | **Condition** |
| Ilala Municipality | Muhimbili National Hospital | National Referral Hospital | Pyloritic High Tech Incinerator | Not functioning |
| Muhimbili Orthopaedic Institute | National Special Hospital | Pyloritic High Tech Incinerator | Functioning |
| Amana Regional Hospital | Regional Hospital | Pyloritic High Tech Incinerator | Functioning |
| Buguruni Anglican Health Centre | Health Canter | Low tech incinerator – Demontfort – Dual Chamber | Functioning |
| Temeke Municipality | Temeke Regional Hospital | Regional Hospital | Pyloritic High Tech Incinerator | Functioning |
| Kinondoni Municipality | Magomeni Health Centre | Health Centre | Single Chamber Incinerator | Functioning |
| Mwananyamala Regional Hospital | Regional Hospital | Pyloritic Incinerator | Functioning |

*Source:* Study Findings

The types of incinerators found in the study areas were as shown in fig 4.1 – 4.3

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Figure 4.: High Tech Pylori tic Incinerator at Temeke and Mwananyamala Hospital respectively

*Source:* Study Findings



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Figure 4.: Low Cost Incinerator - Double Chamber Demont fort Incinerator at Buguruni

*Source:* Study Findings

# G:\WhatsApp\Media\WhatsApp Images\IMG-20141104-WA0000.jpg

Figure 4.: Low Cost Incinerator - Single chamber incinerator at Magomeni Health Centre

*Source:* Study Findings



Figure 4.: Bottom Ashes after Incineration

*Source:* Study Findings

This shows that hospitals are operating without a recommended disposal facility will end up contaminating the living environment which may pose risk to health of the people in a number of ways like microbial infection, inhalation of polluted and contaminated air, water and soil.

Qadeer (2013), in his assessment of Karachi hospitals without incinerators revealed that most of the hospitals were without safe disposal facilities and waste was disposed of with other municipal garbage. This resulted in high risk practices leading to the spread of deadly transmittable diseases including AIDS, hepatitis B and C among many others especially among scavengers.

The hospital waste is also hazardous for garbage collecting staff on municipalities who transport the waste to the landfill sites. Hospital waste includes human anatomical waste, waste from surgeries and autopsies, needles, syringes, saws, blades, broken glass, nails, pathological waste, tissues, organs, body parts, human flesh, foetuses, blood and body fluids (Qadeer, 2013).

## 4.3 Concentration of Heavy Metals in Sampled Bottom Ash

#### Table 4.2 gives descriptive statistics for the different heavy metals studied. The estimated operating temperatures for the sampled incinerator at the study areas were between 300oC minimum and 850oC maximum. It was worth to noting that, As, Cd, and Hg were below the detection Limit.

### 4.3.1 Comparison of Concentration of Heavy Metals Between Health Facilities

Detailed comparison of the concentrations between health facilities is presented in Table 4.3. Appendix II provides a graphic comparison of concentration levels of heavy metals between samples within the same health facility. That is, it assesses the magnitude of the difference between samples 1, 2, and 3 as measured from each health facility.

**Table 4.2: Summary statistics of concentration (mgkg-1) of heavy metals**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Metals** | **N** | **Concentration mg/kg** | | | |
|  |  | **Mean±SD** | **Median** | **Minimum** | **Maximum** |
| As | 18 | BD | BD | BD | BD |
| Cd | 18 | 0.0 | BD | BD | BD |
| Cu | 18 | 19.747±10.563 | 15.877 | 11.257 | 56.284 |
| Fe | 18 | 3695.815±3832.253 | 1935.645 | 221.179 | 12453.658 |
| Hg | 18 | BD | BD | BD | BD |
| Pb | 18 | 43.869±22.013 | 31.383 | 18.157 | 80.092 |
| Cr | 18 | 294.069±470.183 | 82.065 | 0.000 | 1544.638 |
| Mn | 18 | 34.981±26.199 | 26.149 | 6.562 | 90.094 |
| Ni | 18 | 210.199±324.880 | 63.856 | 2.861 | 1251.750 |
| Zn | 18 | 1628.336±1126.445 | 1541.443 | 252.294 | 3825.235 |

BD – Below detection

*Source:* Study Findings

The findings reveals presence of all the heavy metals samples analysed (As, Ni, Mn, Fe, Cu, Pb, Cr, Zn and Hg), however their concentration differs among the six hospitals incinerators. The amount of mercury and Arsenic were below detectable concentration in bottom ash of the sampled incinerator. This may imply that a certain amount of metallic species were vaporized or underwent sublimation and discharged as mercury vapour in the environment. According to Tanzania Bureau of Standards- National Environmental Standard Compendium it was observed that the amount of As, Cu, Pb, Hg, heavy metals obtained in all tested bottom ash samples from six hospitals incinerators (Table 4.3) are within Maximum Permissible Levels (MPL) to be discharged to the environment.

**Table 4.3: Mean concentration (mgkg-1) of heavy metals in bottom ash**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Metals** | **Buguruni** | **MOI** | **Amana** | **Magomeni** | **Mwananyamala** | **Temeke** |
| As | BD | BD | BD | BD | BD | BD |
| Cd | BD | BD | BD | BD | BD | 0.017±0.847 |
| Cu | 28.873±23.747 | 21.328±5.470 | 13.209±1.955 | 15.539±5.121 | 16.010±0.403 | 23.521±7.917 |
| Fe | 4091.709±5359.609 | 1260.027±702.989 | 758.714±253.508 | 3530.665±2927.157 | 3048.971±2013.462 | 9484.806±3148.740 |
| Hg | BD | BD | BD | BD | BD | BD |
| Pb | 27.537±4.373 | 51.571±27.330 | 67.413±11.064 | 66.315±7.773 | 27.772±3.406 | 22.607±3.907 |
| Cr | 97.848±39.150 | 60.328±38.396 | 61.477±16.742 | 507.805±855.061 | 743.750±693.762 | 293.209±265.879 |
| Mn | 52.574±23.527 | 17.130±7.918 | 8.267±0.103 | 36.297±30.552 | 33.915±11.722 | 61.704±32.544 |
| Ni | 7.506±3.608 | 18.013±19.034 | 32.858±51.716 | 596.906±625.913 | 212.298±140.305 | 393.615±208.951 |
| Zn | 2067.344±482.422 | 3047.588±1303.801 | 1853.374±1108.560 | 1369.911±847.663 | 349.367±10.053 | 1082.434±719.721 |

*Source:* Study Findings

Figures 4.5 through 4.11 provide comparisons of levels of heavy metals between health facilities.

### 4.3.1.1 Arsenic Concentration

The average concentration (SD) of *A*rsenicin the samples was below detection limit. However, the implication of the negative concentration value of *As* in the samples is that this heavy metal was below a detectable threshold value. This is ascribed to the fact that at a high temperature of 850 degrees most of mercury and arsenic go into exhaust gas passing fabric filter and so easily contaminate the fly ashes (Izumikawa (2008). The volatilization rates increase with the increase of the temperature.

### 4.3.1.2 Cadmium Concentration

From Table 4.2, the average (SD) concentration of Cd was below detection limit. The undetected levels of Cd were due to the fact that about 90% of cadmium is volatilized and contaminate fly ash. Thus Cd can be easily detected in fly ash than in bottom ashes. (Izumikawa, 2008).

In contrast to *As*, the mean concentration of *Cd* in the samples seems to vary between hospitals. Cd metal, amount attained in all hospitals were within MPL except that obtained in Amana Hospital. This situation was also revealed by Calhoum (2003). Hill, (1997) in his case study that found Cadmium, Mercury and lead heavy metals occurred at trace level in the bottom ash and the possible source identified was from red liner plastic bags used for refuse bins.

Furthermore SUN Lu-shi at el, (2004), on the study on Volatilization of heavy metals during incineration of Municipal Solid Wastes indicated that the emission intensities of Cd Vs. time in the flue gas under different atmosphere at 865oC it was found that the gaseous metal concentration exhibited a peak almost instantaneously after injecting the samples into the fluidized bed.

### 4.3.1.3 Copper Concentration

The average (SD) concentration of *Cu* in the samples was 19.747 (10.563) mg kg-1 and ranged from 11.257 to 56.284 mg kg-1. The median value was 15.877 mg kg-1 suggesting that half of the samples had *Cu* concentration of at least 15.877 mg kg-1 while the remaining half (50%) had *Cu* concentration value below 15.877 mg kg-1 .

Figure 4.5: Comparison of levels of Copper between health facilities (mg/kg)

*Source:* Study Findings

The mean concentration of Cu in the samples displays some variability between health facilities. The average concentration of Cu was highest (28.873 mg kg-1) for ash samples collected from Buguruni Anglican Health Centre. The minimum average of15.539 mg kg-1 *Cu* concentration was found for ash samples collected from Amana Regional Hospital. However, Amana’s average concentration value appears to be similar to that obtained for ash samples collected from Magomeni Health Centre (15.539 mg kg-1) or Mwananyamala Regional Hospital (16.010 mg kg-1). (Fig. 4.5).

Freire *et al*, (2007), on his case study on the feasibility application of Portuguese MSWI bottom ash to road construction characterized the chemical composition and found that the mean concentration for Cu was 860mg/kg, The difference is more to do with type of waste being incinerated. In this case it is obvious that the higher the amount of waste with various composition of waste is the major factor for observed different value per facilities. This is because Earth alkali metals and transition element metals such as Fe, Cu, Ni, Cu and Al tend to remain in the bottom ash during incineration (Izumikawa 2008). Similarly the variation between Buguruni, Temeke and MOI could be due to the type of waste incinerated in the period of conducting the study. Copper is used in building’s wiring, plumbing, heating, air conditioning, refrigeration, architectural materials, electrical and electronic products, industrial machinery, valves and fittings, heat exchangers, automobiles, trucks, railroads, aircraft, appliances, ordnance, fasteners, coinage, and utensils and cutlery. Copper compounds are used in fungicides, algicides, insecticides, bactericides, pigments, wood preservatives, electroplating, animal feeds, dietary supplements, antifouling paints, and as heat and light stabilizers in polymers. (Arita and Costa, 2009).

### 4.3.1.4 Iron Concentration

The results (Table 4.2) show that Fe had the highest mean concentration.

Figure 4.6: Comparison of levels of Iron between health facilities

*Source:* Study Findings

The mean concentration of *Fe* in the samples shows large variability between health facilities. The average concentration of *Fe* was highest (9484.806 mg kg-1) for ash samples collected from Temeke Regional Hospital. The minimum average (758.714 mg kg-1) *Fe* concentration was found for ash samples collected from Amana Regional Hospital. The variability could be due to the amount and type of waste generated and collected for incineration. However it is a common metal found in any incinerated medical waste. It was difficult to establish any reference regarding Fe because TBS has not provided any specifications for this metal. However WHO provides standard for consumption of Fe not exceed 0.8mg/Kg of body weight. Based on WHO, the amount of Fe analysed from hospital incinerators bottom ash is too high to be discharged into the environment. Toxic effects begin to occur at doses above 10–20 mg/kg of elemental iron. Ingestions of more than 50 mg/kg of elemental iron are associated with severe toxicity. In terms of [blood values](http://en.wikipedia.org/wiki/Blood_values), iron levels above 350-500 [µg](http://en.wikipedia.org/wiki/Microgram)/dL are considered toxic, and levels over 1000 µg/dL indicate severe iron poisoning. (Hart *et al*., 1928). Therefore is metal leaches to the ground water source may affect the quality of drinking water and cause health risks associated with iron toxicity.

### 4.3.1.5 Mercury Concentration

The findings show further that *Hg* had concentration value similar to that of *As* and *Cd* observed in 4.3.1.1 and 4.3.1.2. As seen from the results in Table 4.2, the mean (SD) concentration of *Hg* in the sampled ash was not detected. This is with fact that at a temperature of 1300 degrees most of mercury and arsenic go into exhaust gas passing fabric filter. (Izumikawa, 2008). The volatilization rates increase with the increase of the temperature. Healthcare waste containing mercury, incinerated without due care would release mercury vapour in the environment which if inhaled by humans may be toxic, fatal or lead to life threatening injuries to lungs and neurological systems (Howard, 2002; UNEP, 2009).

### 4.3.1.6 Lead Concentration

The mean (SD) concentration value in the samples for *Pb* was 43.869 (22.013) mg kg-1 and the concentration ranged from 18.157 to 80.092 mg kg-1. The median value was 31.383 mg kg-1 implying that half of the samples had *Pb* concentration of at least 31.383 mg kg-1 while the remaining half (50%) of the ash samples had *Pb* concentration value below 31.383 mg kg-1(Fig. 4.7)

Figure 4.7: Comparison of Levels of Lead Between Health Facilities

*Source:* Study Findings

*Pb* mean concentration was highest (67.413 mg kg-1) for ash samples collected from Amana Regional Hospital. However, there appears to be some similarity in terms of (average concentration of *Pb*) between Amana Regional Hospital and Magomeni Health Centre (66.315 mg kg-1). Temeke Regional Hospital had the minimum (22.607 mg kg-1) average concentration of *Pb* in the ash samples. The variations of concentration depend on the quality of waste and incineration process (Izumikawa (2008).The investigation by (Incineration Assessment Working Group (IAWG) in Japan revealed the behavior of lead and cadmium in the incineration process. Izumikawa (2008), in his study on the behaviour of metals in the incineration process shows that about 30% of lead contained in the waste are volatilized in the incineration process are recovered in a fly ash. SUN Lu-shi at el, (2004), on the study on Volatilization of heavy metals during incineration of Municipal Solid Wastes indicated that the emission intensities of Pb Vs. time in the flue gas under different atmosphere at 865oC found that the vaporization of Pd was kept the same trend after injecting the samples into the fluidized bed. Almost all of lead is volatilized at a temperature of 1000 degrees. This means all incinerators under study operated below temperature 1000oc as indicated in this study. Thus the lower temperature the high chances of detecting Pd in the bottom ashes.

### 4.3.1.7 Chromium Concentration

The results show that Chromiumhad a mean (SD) concentration value of 294.069 (470.183) mg kg-1 and the concentration ranged from 0.000 to 1544.638 mg kg-1. The median value was 82.065 mg kg-1 implying that half of the samples had *Cr* concentration of at least 82.065 mg kg-1 while the remaining half (50%) of the ash samples had *Cr* concentration value below 82.065 mg kg-1(Fig 4.8).

Figure 4.8: Comparison of levels of Chromium between health facilities

*Source:* Study Findings

*Cr* average concentration shows large differences between health facilities. Chromiumwas highest (743.750 mg kg-1) for ash samples collected at Mwananyamala Regional Hospital. Ash samples collected at MOI had the minimum (60.328 mg kg-1) average concentration of Cr. Ash samples collected from Magomeni Health Centre appear to have a similar average concentration value (61.477 mg kg-1) of Cr to those of MOI. The same findings was observed by Freire, *et al*, (2007), on his case study on the feasibility application of Portuguese MSWI bottom ashes to road construction who characterized the chemical composition and found that the mean concentration for Cr was 66.5mg/kg. Meraj **and** Shakeel **(**2014), in their analysis of heavy metals in bottom ashes of a Pharmaceutical Industry indicated that Chromium concentration varied because of the variation in production pattern of raw materials used by the industry.

Therefore the varied concentration levels of Cr might be due to the type of waste materials incinerated. Since most of hospital equipments and drugs constitute these heavy metals it is possible to find them when these equipment and other medical waste incinerated. These including PVCs materials IV bags, IV tubing, blood bags, anesthesia masks, gloves, feeding tubes, bed pans, collection and specimen bags; glasses such as petri dishes, vials, bottles, cover slips, pipettes and slides, other needles, scarples, gauze etc. This situation was also revealed by Calhoum (2003).

### 4.3.1.8 Manganese Concentration

The mean (SD) concentration value for *Mn* in the samples was 34.981 (26.199) mg kg-1 and the concentration ranged from 6.562 to 90.094 mg kg-1. The median value was 26.149 mg kg-1 implying that half of the samples had *Mn* concentration of at least 26.149 mg kg-1 while the remaining half (50%) of the ash samples had *Mn* concentration value below 26.149 mg kg-1 (Fig 4.9).

Figure 4.9: Comparison of levels of Mn between health facilities

*Source:* Study Findings

Much variability in mean concentration of *Mn* also exists between health facilities (Fig4.9). The results in Table 4.3 show that the *Mn* was highest (61.704 mg kg-1) in ash samples collected at Temeke Regional Hospital. Ash samples collected from Amana Regional Hospital had the minimum average concentration value (8.267 mg kg-1) of *Manganese.* Labunska, *et al*, (2000), in the assessment of concentrations of heavy metals and organic contaminants in ash collected from the Izmit hazardous/clinical waste incinerator in Germany, indicated that Managanese concentration level was 457mg/kg. The variability could be attributed to the type of waste being incinerated.

### 4.3.1.9 Nickel Concentration

The results (Table 4.2) show that *Ni* had a mean (SD) concentration value in the samples of 210.199 (324.880) mg kg-1 and the concentration ranged from 2.861 to 1251.750 mg kg-1. The median value was 63.856 mg kg-1 implying that half of the samples had *Ni* concentration of at least 63.856 mg kg-1 while the remaining half (50%) of the ash samples had *Ni* concentration value below 63.856 mg kg-1 (Fig 4.10).

Figure 4.10: Comparison of levels of Nickel between health facilities

*Source:* Study Findings

Relative to other health facilities, *Ni* was highest (596.906 mg kg-1) on average, in ash samples collected at Magomeni Health Centre. Buguruni Anglican Health Centre had the minimum (7.506 mg kg-1) average concentration of *Ni* in the ash samples. Freire *et al, (*2007), on his case study on the feasibility application of Portuguese MSWI bottom ash to road construction characterized the chemical composition and found that the mean concentration for Ni was 52.5 mg/kg. The difference is more to do with the type of waste being incinerated. This is because Earth alkali metals and some metals such as Fe, Cu, Ni, Cu and Al tend to remain in the bottom ash during incineration (Izumikawa, 2008). In this case it is obvious that the higher the amount of waste with various composition of waste materials is the major factor for observed different value per facilities. Merajand Shakeel **(**2014), in their analysis of heavy metals in bottom ashes of a Pharmaceutical Industry indicated that Nickel concentration varied because of the variation in production pattern of raw materials used by the industry in the manufacturing of medicine. ie processing of antibiotics. Therefore the varied concentration levels of Cr might be due to the type of waste materials being incinerated. Since most of hospital equipments and drugs constitute these heavy metals it is possible to find them when these equipment and other medical waste are incinerated.

### 4.3.1.10 Zinc Concentration

The results show that *Zn* had mean concentration value somewhat similar (in magnitude) to that of *Fe*. The average (SD) concentration value in the samples for *Zn* was 1628.336 (1126.445) mg kg-1 and the concentration ranged from 252.294 to 3825.235 mg kg-1. The median value was 1541 mg kg-1 implying that half of the samples had *Zn* concentration of at least 1541.443 mg kg-1 while the remaining half (50%) of the ash samples had *Zn* concentration value below 1541.443 mg kg-1 (Fig 4.11).

Figure 4.11: Comparison of levels of Zinc between health facilities

*Source:* Study Findings

In terms of Zn concentration, the results in Figure 4.11 show that ash samples collected at MOI had the highest (3047.588 mg kg-1) average value. On the other hand, Mwananyamala Regional Hospital had the minimum (349.367 mg kg-1) average concentration. About 40% of zinc and copper remain in a slag and remaining 60% of them are volatilized and go into the fly ash. The rate of volatilization is strongly depending on the melting temperature and depending on the metals Izumikawa (2008). Therefore, the amount of zinc in a slag is decreasing with increasing temperature. Freire, *et al,* 2007, on his case study on the feasibility application of Portuguese MSWI bottom ash to road construction characterized the chemical composition and found that the mean concentration for Zn was 3510 mg/kg. This indicates that Zn metal is obvious to be found in the bottom ashes. Although zinc is an essential element in human body still its excess uptake of zinc can cause epigastric pain, skin irritations, diarrhoea, vomiting, nausea and anaemia, focal neuronal deficits, lethargy, metal fume fever, elevated risk of prostate cancer (Plume *et al.,* 2010).

### 4.3.2 Testing for Mean Differences in Concentration between Heavy Metals

Table 4.4 provides ANOVA results for testing for mean differences between heavy metals. Overall, the result for testing the null hypothesis that the mean concentrations were all equal was rejected at the 0.05 level of significance (p<0.0001). This indicates in that not all heavy metals have the same mean concentrations. This finding is supported further by the Type I or Type III sum of squares ANOVA results from which a p<0.0001 for testing for heavy metal differences is reported.

**Table 4.4: Testing for mean concentration in heavy metals**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Source of Variation** | **DF** | **Sum of Squares** | | **Mean square** | | **F value** | **P-value** |
| Model | 26 | 260933311.9 | | 10035896.6 | | 6.17 | <0.0001 |
| Error | 153 | 248818038.4 | | 1626261.7 | |  |  |
| Total | 179 | 509751350.3 | |  | |  |  |
|  |  | |  | |  | |  |
| *R*-square | Coefficient of Variation | | Root MSE | | Mean Concentration | | |
| 0.511884 | 215.4277 | | 1275.250 | | 591.9618 | | |
|  |  | |  | |  | | |

**Type I Sum of Squares ANOVA**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source of Variation** | **DF** | **Type I Sum of Squares** | **Mean Square** | ***F* value** | ***P*-value** |
| Measurement (hospitals) | 17 | 28003239.0 | 1647249.4 | 1.01 | 0.4475 |
| Heavy metal | 9 | 232930073.0 | 25881119.2 | 15.91 | <0.0001 |
|  |  |  |  |  |  |

**Type III Sum of Squares ANOVA**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source of Variation** | **DF** | **Type IIII Sum of Squares** | **Mean Square** | **F value** | **P-value** |
| Measurement (hospitals) | 17 | 28003239.0 | 1647249.4 | 1.01 | 0.4475 |
| Heavy metal | 9 | 232930073.0 | 25881119.2 | 15.91 | <0.0001 |

*Source:* Study Findings

As can be seen from Table 4.4, the Type I or Type III Sum of Squares ANOVA table for testing for significant differences in mean concentration levels among the repeated measurements from the six health facilities (hospitals) reports a *p*-value=0.4475. This provides not enough evidence to reject the null hypothesis that there is no difference in the concentration of heavy metals between health facilities. The ash samples collected from the different health facilities had the same average concentration levels of heavy metals.

### 4.3.2.1 Duncan’s Multiple Range Test

Table 4.5 gives Duncan’s Multiple Range Test for concentration of metals in ash samples. As can be seen from Table 4.5, eight heavy metals namely Cr, Ni, Pb, Mn, Cu, Hg, As, and Cd are all marked by the same letter. This indicates that no significant difference exists in the mean concentrations of these heavy metals. Consequently, samples of bottom ash collected from the six different health facilities had the same (in statistical terms) mean concentrations across all these eight heavy metals.

In contrast, there are significant differences between the eight last eight heavy metals (Cr, Ni, Pb, Mn, Cu, Hg, As, and Cd) and each of the first listed heavy metals. That is, between the eight last heavy metals and Fe, and between the last eight heavy metal and Zn. The findings indicate that Fe has the highest mean (3695.8 mgkg-1) concentration value compared to all the heavy metals analysed. Furthermore, the results show that significant differences exist between Fe and Zn.

**Table 45: Duncan’s multiple range test for mean concentration of heavy metals**

|  |  |  |  |
| --- | --- | --- | --- |
| **Means with the same letter are not significantly different** | | | |
| **Duncan grouping** | **Mean** | **N** | **Heavy metal** |
| A | 3695.8 | 18 | Fe |
| B | 1628.3 | 18 | Zn |
| C | 294.1 | 18 | Cr |
| C | 210.2 | 18 | Ni |
| C | 43.9 | 18 | Pb |
| C | 35.0 | 18 | Mn |
| C | 19.7 | 18 | Cu |
| C | -2.3 | 18 | Hg |
| C | -2.3 | 18 | As |
| C | -2.8 | 18 | Cd |

*Source:* Study Findings

A comparison of the six heavy metals (Hg, Cd, Pb, As, Fe, and Cu) that the study primarily wanted to ascertain their concentration levels in bottom ash samples reveals that most of the heavy metals were not significantly different between them. Of the six heavy metals, five (Pb, Cu, Hg, As, and Cd) were classified within the group (Table 4.5). Accordingly, based on Duncan’s Multiple Range Test, the mean concentration levels for these five heavy metals are not statistically significant at the 0.05 level. Only Fe differs significantly from the other five aforementioned heavy metals.

## 4.5 Prediction of Health Impact/Risks Associated with Heavy Metals in the Environment

The findings reveal presence of heavy metals in the incinerators bottom ash. Improper management or disposal of these incinerators waste (ash) might end up in contaminating the environment (Zhao *et al.,* 2008). The higher concentration of Cd, Cr, Ni, Fe and Zn detected in the bottom ash when leaching to the environment may result into contamination of both soil and water bodies. Consumption of plant grown in the contaminated soil, drinking water contaminated by these metals which are above Maximum Permissible Levels (MPL) and inhalation of incinerators bottom ash may result into exposure of individuals to multiple health disorders as explained hereafter.

Long exposure of people near hazardous waste e.g. incinerators bottom ash waste containing high concentration of cadmium can result into detrimental health effect including cancer, damage of lungs and central nervous systems, diarrhea, stomach pain, severe vomiting, reproductive failure, infertility, bone fracture and psychological disorders (Jarup *et al.,* 1998; Jarup,2003; Boffetta *et al.,* 2011). Cadmium can be transported over great distances when it is absorbed by sludge or leaching into soil, thus pollute surface waters as well as soils.

When cadmium is inhaled or consumed, it is first transported to the liver through the blood where it binds to proteins to form complexes that are transported to the kidneys. Accumulation of cadmium in kidneys damages filtering mechanisms (Bernad, 2008). Thus it affects the whole process of proteins and sugars excretion from the body and lastly cause kidney damage. In addition accumulation of cadmium for long residence time in the renal and cortex can aggravates the possibility of having nephrotoxic effect and cancer.

When human beings inhaled different compounds of chromium might ending up suffer in respiratory tract irritation, lung nasal or sinus cancer, low blood sugars (hypoglycemia), stomach problems, kidney and liver failure, alteration of genetic materials depending on the dose and duration of exposure (Arita and Costa, 2009).

Furthermore, exposure of individuals to nickel through inhalation, oral or dermal can results into adverse health effects depending on the route of exposure. The adverse effects on Nickel include lung cancer, nose cancer, larynx cancer and prostate cancer, Sickness and dizziness after exposure to nickel gas. Other health effects includes, lung embolism, respiratory failure, birth defects, asthma and chronic bronchitis, allergic reactions such as skin rashes, mainly from jewelry and heart disorders (Rendall *et al.,* 1994; Hostynek, 2006). The study done to human beings working in Nickel industry by IARC (1990) concluded that all nickel compounds, except metallic nickel are carcinogenic to human.

Unlike other heavy metals, Zinc is an important element for human health, plant and animals (Neek *et al*., 2011). It has a number of roles and function to play for human body including stabilization of cellular components and membranes; it is an essential component/cofactor for more than 300 enzymes involved in the synthesis and metabolism of carbohydrates, lipids, proteins, nucleic acids and other micro-nutrients (Dodig-curkovic *et al.,* 2009); it is essential for cell division and is needed for normal growth and development during pregnancy, childhood and adolescence; it is involved in DNA synthesis and the process of genetic expression; it is important for immune function (both cellular and humoral immunity); it is involved in wound healing and tissue repair, it is needed for the senses of taste and smell. However excess uptake of zinc can cause epigastric pain, skin irritations, diarrhoea, vomiting, nausea and anaemia, focal neuronal deficits, lethargy, metal fume fever, elevated risk of prostate cancer (Dodig-curkovic *et al.,* 2009) .

Like Zinc, Iron is another important element needed in the human body; it is a part of all cells, protein (haemoglobin) carrying oxygen from lungs throughout the body, enzymes which helps human body to digest food (Conrad *et al.,* 1999 and Lieu *et al.,* 2001). According to WHO (1996), the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day and the average lethal dose of iron is 200–250 mg/kg of body weight. Excessive iron uptake can result into hemochromatosis (Bothwell *et al.,* 1979). This is a condition which occurs when the body absorbs too much iron and it causes extra iron to gradually build up in the body’s tissues and organs. If this disease is not treated, it can damage the body’s organs.

Although the concentration of some metals (Mn, Cu, Pb,) detected was within the Maximum Permissible Levels (MPL) by TBS, proper disposal of these is crucial to reduce their rate of accumulation to the environment.

## 4.6 Potential Health Risks in Handling Bottom Ash in the Environment

Several health hazards are reported as possible human carcinogens or toxins, from exposure to Cd, Cr, Ni, Pb, Hg, As, Ba, and Be. Al, Cu, Fe, Pb, Ti and Zn which are found largely in slag (Anamul, 2012). More volatile elements such as Cd, Pb, Sb,and Sn are vaporized and condense on fine particles, which are either trapped or escape to the atmosphere as suspended particulates. Volatile chlorides of elements including As, Cd, Ni, Pb, Sb, and Zn are also formed, which greatly increase their presence in fly ash and suspended particulates (Anamul, 2012). Over 80% of in putted Hg, largely from Hg batteries, is estimated to be released in gas phase as halides. Some of the waste that goes through the incineration process, however, might exit the system in one of the following forms.

(1) Combustion gases-can exit through the stack if they are not completely removed by air-pollution- control devices. (2) Particulate emissions-lightweight particles can exit the combustion chamber along with combustion gases, if they are small enough to get post pollution-control devices.

(3) Fly ash-toxic particles light enough to be borne upward with combustion gases; a portion of these might not be heavy enough to fall or might not be large enough to be captured by pollution control devices before exiting the stack. Comprising approximately 25% of all incinerator ash, fly ash often contains high levels of heavy metals, acid gas constituents, and Prior Informed Consents (PICs) procedures chemicals such as dioxin (Anamul, 2012).

(4) Bottom ash—un-combusted waste such as glass and metal, generally considered nontoxic; approximately 75% of all incinerator ash (Anamul, 2012).

# CHAPTER FIVE

# 5.0 CONCLUSSIONS AND RECOMMENDATIONS

## 5.1 Conclusion

Based on the results from this study, it is here by concluded that, generally heavy metals were observed high in concentration level being contained with medical waste bottom ash, with exception of few metal. The positions of the six incinerators under study in the six hospitals by virtue of their situation render the heavy metals they discharge a public health risk.

This is a real threat because though *mercury, Cadmium and Arsenic* were below detectable concentration traces in bottom ash of the sampled incinerator, it implies that there is possibility that much of it are vaporized or undergo sublimation and discharged as vapour in the environment. Thus, serious environmental problems can be caused by incineration of waste containing such metals due to their escapes through chimney. High concentrations of metallic elements, such as Zn, Mn and Ni were also determined.

From the findings the average the mean concentration of *Fe* was highest (9484.806 mg kg-1), Pb highest was (67.413 mg kg-1), , Cu highest was (28.873 mg kg-1), Cr highest was (743.750 mg kg-1), Ni highest was (596.906 mg kg-1). Ananias *et al.,* (2013), in the case study of Kenyata National Hospital Nairobi and Moi Teaching and Referral Hospital – Eldoret Incinerators showed that the bottom ash had a mean concentration of heavy metals of total chromium, cadmium, lead, silver and mercury of 5297, 140, 4299, 2092 and 57 mg/kg respectively.

The concentration level differs from one hospital to the other depending on the amount and type of biomedical waste taken for incineration which again depends on the size of the incinerator. Zhao *et al*. (2008) demonstrated that bottom ashes from medical incinerators with heavy metal residues if not properly disposed of could leach from the ashes and pollute the environment.

Thus, alternative safe methods and interventions for safe management of hazardous waste bottom ash must be sorted out to safely protect the public health and the environment.

## 5.2 Recommendation

Following the findings of this study, recommendations are here made for the future development and research on heavy metals in medical waste incinerators bottom ash:

1. A proper and safe waste management system should be employed to safely dispose hazardous biomedical waste.
2. In order to protect ground water, medical waste incinerator bottom ash should be disposed of properly by designed-engineered treatment and disposal methods. For example disposal of ashes in a leak proof constructed pit would be much valuable than in a dug pit.
3. Health facilities must practice waste segregation to avoid waste containing heavy metals not deliberately put into incinerators.

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# APPENDICES

**Appendix 1: Concentrations of Bottom Ash from Hospital Incinerators in Dar es Salaam**

**Table A1: Concentration (mgL-1) of heavy metals in bottom ash samples**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample**  **code** | **As** | **Cd** | **Cu** | **Fe** | **Hg** | **Pb** | **Cr** | **Mn** | **Ni** | **Zn** | **Sample weight (g)** | **Name of hospital** | **Date of**  **measurement** |
| 1 | -0.0053 | -0.0082 | 0.2817 | 1.1070 | -0.0155 | 0.1559 | 0.6076 | 0.3064 | 0.0399 | 12.4500 | 0.50050 | Buguruni | 5/5/2014 |
| 2 | -0.0050 | -0.0025 | 0.0793 | 51.2800 | 0.0000 | 0.1446 | 0.6002 | 0.3544 | 0.0546 | 10.9200 | 0.50230 | Buguruni | 7/5/2014 |
| 3 | -0.0229 | -0.0000 | 0.0729 | 9.2430 | -0.0147 | 0.1136 | 0.2638 | 0.1300 | 0.0185 | 7.7180 | 0.50100 | Buguruni | 8/5/2014 |
| 4 | -0.0266 | -0.0008 | 0.0799 | 10.1400 | -0.0160 | 0.1016 | 0.0843 | 0.1300 | 0.0185 | 7.7180 | 0.50040 | MOI | 7/5/2014 |
| 5 | -0.0080 | -0.0058 | 0.1060 | 5.5620 | -0.0167 | 0.3186 | 0.3739 | 0.0737 | 0.0539 | 18.9400 | 0.50170 | MOI | 8/5/2014 |
| 6 | -0.0072 | -0.0068 | 0.1345 | 3.2260 | -0.0148 | 0.3546 | 0.4481 | 0.0536 | 0.1981 | 19.1300 | 0.50010 | MOI | 9/5/2014 |
| 7 | -0.0107 | -0.0070 | 0.0760 | 3.1120 | -0.1256 | 0.3128 | 0.3521 | 0.0417 | 0.4638 | 3.7300 | 0.50100 | Amana | 7/5/2014 |
| 8 | -0.0162 | -0.0068 | 0.0661 | 3.0210 | -0.1200 | 0.2988 | 0.3602 | 0.0408 | 0.0157 | 14.8200 | 0.50040 | Amana | 8/5/2014 |
| 9 | -0.0089 | -0.2114 | 0.0564 | 5.2700 | -0.0144 | 0.4015 | 0.2114 | 0.0418 | 0.0143 | 9.2940 | 0.50130 | Amana | 9/5/2014 |
| 10 | -0.0143 | -0.4575 | 0.0566 | 6.3320 | -0.0145 | 0.3773 | 0.1426 | 0.0329 | 0.0232 | 1.9670 | 0.50200 | Magomeni | 6/5/2014 |
| 11 | -0.0108 | -0.0015 | 0.0708 | 12.5000 | -0.0147 | 0.3166 | 7.4870 | 0.1739 | 2.6760 | 9.1470 | 0.50080 | Magomeni | 7/5/2014 |
| 12 | -0.0072 | -0.0024 | 0.1061 | 34.1800 | -0.0163 | 0.3029 | 0.0000 | 0.3381 | 6.2600 | 9.4590 | 0.50010 | Magomeni | 8/5/2014 |
| 13 | -0.0130 | -0.0027 | 0.0815 | 26.8800 | -0.0148 | 0.1583 | 7.7340 | 0.2373 | 1.8250 | 1.8000 | 0.50070 | Mwananyamala | 7/5/2014 |
| 14 | -0.0112 | -0.0034 | 0.0780 | 8.7880 | -0.0161 | 0.1333 | 1.8000 | 0.1310 | 0.4420 | 1.7520 | 0.50170 | Mwananyamala | 8/5/2014 |
| 15 | -0.0107 | -0.0018 | 0.0813 | 10.1700 | -0.0144 | 0.1261 | 1.6450 | 0.1417 | 0.9248 | 1.7030 | 0.50178 | Mwananyamala | 9/5/2014 |
| 16 | -0.0133 | -0.0022 | 0.1334 | 49.1100 | -0.0145 | 0.1210 | 0.0000 | 0.3443 | 2.4430 | 7.3210 | 0.50020 | Temeke | 6/6/2014 |
| 17 | -0.0078 | -0.0028 | 0.1474 | 62.4800 | 0.0000 | 0.1278 | 2.6020 | 0.4520 | 2.7010 | 7.6830 | 0.50170 | Temeke | 7/6/2014 |
| 18 | -0.0123 | -0.0048 | 0.0728 | 31.0000 | 0.0000 | 0.0910 | 1.8100 | 0.1313 | 0.7725 | 1.2650 | 0.50140 | Temeke | 8/6/2014 |

*Source:* Study findings

Table A2: Concentration (mgkg-1) of heavy metals in bottom ash samples

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample code** | **As** | **Cd** | **Cu** | **Fe** | **Hg** | **Pb** | **Cr** | **Mn** | **Ni** | **Zn** | **Name of Hospital** | **Date of measurement** |
| 1 | BD | BD | 56.284 | 221.179 | BD | 31.149 | 121.399 | 61.219 | 7.970 | 2487.512 | Buguruni | 5/5/2014 |
| 2 | BD | BD | 15.793 | 10209.038 | BD | 28.788 | 119.490 | 70.555 | 10.860 | 2174.000 | Buguruni | 7/5/2014 |
| 3 | BD | BD | 14.543 | 1844.910 | BD | 22.675 | 52.655 | 25.948 | 3.689 | 1540.519 | Buguruni | 8/5/2014 |
| 4 | BD | BD | 15.961 | 2026.379 | BD | 20.304 | 16.855 | 25.979 | 3.693 | 1542.366 | MOI | 7/5/2014 |
| 5 | BD | BD | 21.128 | 1108.631 | BD | 63.504 | 74.527 | 14.694 | 10.734 | 3775.164 | MOI | 8/5/2014 |
| 6 | BD | BD | 26.895 | 645.071 | BD | 70.906 | 89.602 | 10.716 | 39.612 | 3825.235 | MOI | 9/5/2014 |
| 7 | BD | BD | 15.166 | 621.158 | BD | 62.435 | 70.279 | 8.323 | 92.575 | 744.511 | Amana | 7/5/2014 |
| 8 | BD | BD | 13.203 | 603.717 | BD | 59.712 | 71.982 | 8.149 | 3.139 | 2961.631 | Amana | 8/5/2014 |
| 9 | BD | BD | 11.257 | 1051.267 | BD | 80.092 | 42.170 | 8.330 | 2.861 | 1853.980 | Amana | 9/5/2014 |
| 10 | BD | BD | 11.269 | 1261.355 | BD | 75.159 | 28.406 | 6.562 | 4.622 | 391.833 | Magomeni | 6/5/2014 |
| 11 | BD | BD | 14.131 | 2496.006 | BD | 63.219 | 1495.008 | 34.724 | 534.345 | 1826.478 | Magomeni | 7/5/2014 |
| 12 | BD | BD | 21.216 | 6834.633 | BD | 60.568 | 0.000 | 67.606 | 1251.750 | 1891.422 | Magomeni | 8/5/2014 |
| 13 | BD | BD | 16.277 | 5368.484 | BD | 31.616 | 1544.638 | 47.394 | 364.490 | 359.497 | Mwananyamala | 7/5/2014 |
| 14 | BD | BD | 15.547 | 1751.644 | BD | 26.570 | 358.780 | 26.111 | 88.100 | 349.213 | Mwananyamala | 8/5/2014 |
| 15 | BD | BD | 16.206 | 2026.785 | BD | 25.131 | 327.833 | 28.239 | 184.304 | 339.392 | Mwananyamala | 9/5/2014 |
| 16 | BD | BD | 26.669 | 9818.073 | BD | 24.190 | 0.000 | 68.832 | 488.405 | 1463.615 | Temeke | 6/6/2014 |
| 17 | BD | BD | 29.380 | 12453.658 | BD | 25.473 | 518.637 | 90.094 | 538.370 | 1531.393 | Temeke | 7/6/2014 |
| 18 | BD | BD | 14.515 | 6182.688 | BD | 18.157 | 360.989 | 26.187 | 154.069 | 252.294 | Temeke | 8/6/2014 |

*Source:* Study findings

Figure B1: General distribution and trend of heavy metal in the six medical waste incinerators

*Source:* Study Findings