EVALUATING THE MANAGEMENT PRACTICE OF ANTHROPOGENIC MERCURY RELEASE IN ADDIS ABABA, ETHIOPIA

By

Girma Gemechu

A thesis submitted to the College of Development Studies of Addis Ababa University in partial fulfillment of the requirements for the Master's Degree in Environment and Sustainable Development

Advisor: Engdawork Assefa, (Ph.D)

June 2019
ADDIS ABABA, ETHIOPIA

DECLARATION

Girma Gemechu, do hereby declare that this thesis is my original work and that it has not been submitted partially or fully by another person for an award of a degree in any other university.

Name of participant Girma Gemechu signature----------Date June 9, 2019

This thesis has been submitted for examination with my approval as a university supervisor**.** **Name of Advisor: Engdawork Assefa (Ph.D)**

APPROVAL

The undersigned certify that they have read and hereby recommend to the Addis Ababa University to accept the Thesis submitted by Girma Gemechu entitled "Evaluating the management practice of anthropogenic mercury release in Addis Ababa", for partial fulfillment of the requirements for the award of a Master's Degree in Environment and Sustainable Development

Name of Supervisor **Engdawork Assefa (Ph.D)** Signature…….

Date June 9, 2019

Name of Internal Examiner **Feyera Senbeta (Ph.D)** Signature----------

Date June 9, 2019

Name of External Examiner **Tariku Dejene (Mr.)** Signature----------

Date June 9, 2019

Name of Head of Department---------- Signature ----------

Date June 9, 2019

ACKNOWLEDGEMENT

First of all I would like to extend my thanks to my advisors Dr. Engedawork Assefa for his professional comments, critiques and perpetual correction with great patience in developing and finalizing this thesis.

Next, my appreciation and gratitude goes to my lovely family Saba Abriham my wife, Nahol Girma, Sumeya Girma and Markan Girma for their incredible support through different ways to accomplish this Master's program.

The last but not least, my humble gratitude goes to the Almighty God for blessing me with health and life opportunities including the opportunity for this study.

Table of Contents

LIST OF TABLE

LIST OF FIGURES

LIST OF ANNEX

ABBREVIATIONS AND ACRONYMS

AABOFED	Addis Ababa Bureau of Finance and Economic Development
AAHB	Addis Ababa Health Bureau
APMMN	Asia Pacific Mercury Monitoring Network
BAT	Best Available Technology
BEP	Best Environmental Practice
CSA	Central Statistics Agency
EGSM	Ethiopia Google Satellite Map
EFCCC	Environment, Forest and Climate Change Commission
GTP	Growth and Transformation Plan
IARC	International Agency for Research on Cancer
MEA	Multi-Lateral Environmental Agreement
MeHg	Methylmercury
MIA	Minamata Initial Assessment
NAAEC	North American Agreement on Environmental Cooperation
NAFTA	North American Free Trade Agreement
NUPI	National Urban Planning Institute
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
SDGs	Sustainable Development Goals
UN	United Nation
UNEP	Untied Nation Environment Program
UN-Habitat	Untied Nation- Habitat
UNIDO	United Nation Industry Development Organization
US EPA	United States Environment Protection Authority
USA	United States of America
WHO	World Health Organization
EPA	Environment Protection Authority

Abstract

Many changes like increment of the population, expansion of health and other services delivery and utilization of bulk consumer products containing mercury and increasing of transportation demand have increased the mercury release in Addis Ababa. A sector source based cross-sectional study has been carried out to quantify the mercury release and evaluate its management practices.

The quantity of mercury released from the source groups were quantified using the UNEP toolkit for quantification of Mercury (Hg). Open and close-ended questionnaires, observation, and key informant interview have been used to collect primary information and then evaluate the management practice in the city Addis Ababa.

Seven **(7)** main source categories of anthropogenic mercury releases such as extraction and use of fuels/energy source, production of other minerals, consumer products with intentional use of mercury, other intentional products, waste incineration and burning, Waste deposition/landfilling, wastewater treatment and cemetery was identified as mercury release in the city.

From the identified source group it has been found out the release of mercury was quantified using UNEP Excel program for quantification of mercury and a total of **5534.5 Kg** mercury was released and of this release **1284.2 Kg** to the air, **1130 Kg** to the water, **1826.2 Kg** to the Land, **0.6 Kg** to the Byproducts and impurities **1118.8 Kg** to the general waste and **174.6 Kg** to the sector-specific treatment/ disposal media. The assessment showed that almost all organizations are following week management system which was not supported by technology, awareness-raising and legal framework. The study concluded that significant amount of Mercury was released to the environment and the current management practices do not comply with the interest of the Minamata Convention that aimed protecting human and the environment from the adverse effect of anthropogenic mercury source. Finally, the study suggests the development of national legal management framework, an adaptation of best available technology with less mercury footprint, increasing public and stakeholder's awareness and participation and capacitating the concerned government organization.

Keywords: Minamata Convention, Bioaccumulation Mercury release, Persistent, quantification, release/emission

CHAPTER ONE:

INTRODUCTION

1.1. Background

Today's world society is rapidly becoming urbanized and such rapid urbanization comes up with its multi-variant socio-economic and environmental consequences. Among many variables characterizing urbanization in the century, the most prominent one is population growth rate. World urban population growth rate is estimated about 1.8% whereas that of Africa and Ethiopia is 4.4% and 5.4%, respectively (World Urbanization Prospects; UNEP Department of Economic and Social Affairs 2018).

Over the years, rising population has led to unsustainable exploitation of natural resources. The effect of these problems has led to degradation and pollution of environments like ground water, soil, river bank, air and another urban ecosystem (Cobbett, 2006; National Urban Planning Institute of Ethiopia, NUPI, 2003).

Among many pollutants released in urban environment, Mercury (Hg) is recognized as a substance producing significant adverse neurological and other health effects, with particular concerns expressed about its harmful effects on unborn children and infants. Atmospheric deposition of Hg has demonstrated its potential for assessing the impacts of natural and anthropogenic activities on the global Hg cycle (Vandal *et al.*, 1993; Nriagu, 1996; Martínez-Cortizas *et al*., 1999).

Mercury enters into the environment in variety of forms. The majority of the release to air is in the form of gaseous elemental mercury, which can be transported globally to regions far from the emissions source. The remaining releases are in the form of gaseous inorganic ionic mercury forms (such as mercuric chloride) or bound to emitted particles. The release of processed mercury can lead to a progressive increase in the amount of atmospheric mercury, which enters the atmospheric-soil-water distribution cycles where it can remain in circulation for years.

Despite the major efforts that have been made over recent years to clean up the environment, pollution remains a major problem and poses continuing risks to human health. The problems are indisputably greatest in the developing world, where traditional sources of pollution such as industrial emissions, poor sanitation, inadequate waste management, contaminated water

supplies and exposures to indoor air pollution from biomass fuels affect large numbers of people. Even in developed countries, however, environmental pollution persists, most especially amongst poorer sectors of society (Samet JM, *et al*, 2001).

In recent decades, too, a wide range of contemporary pollutants have emerged—not least, those associated with road traffic and the use of modern chemicals in the home, in food, for water treatment, and for pest control. Most of these pollutants are rarely presents in excessively large concentrations, so effects on health are usually far from immediate or obvious. Detecting small effects against a background of variability in exposure and human susceptibility, and measurement error pose severe scientific challenges. Taubes G (1995)

Heavy metals particularly Mercury is one of the most toxic metals in the environment (Castro and Mendez, 2008). Up to 90% of most organic mercury compounds are absorbed from food. Mercury can be detected in most foods and beverages, at levels of < 1 to 50 μg/kg (Reilly, 2007).

Ethiopia is one of the least urbanized countries where about 80.6% of the population lives in rural areas, it is one of the countries where the high urbanization process taking place. Currently, the urban population of Ethiopia is about 17.4 million and more than one fourth of the total urban resident in the country is living in the capital Addis Ababa. Studies show that the figure will increase to 30 million in 2030 with an annual growth rate of 5% (UN-Habitat National Urban Profile 2018).

This indicated that when the population increases, it will have an increase in natural resource exploitation, waste generation, and energy consumption, etc. because of this the entire environment obligated to serve beyond its carrying capacity. Thus, a management practice of mercury release in Addis Ababa is the focus of this research.

1.2. Statement of the problem

The presence of Mercury in the urban ecosystem causes human to be exposed for health problems. The human exposure to mercury poisoning is the result of exposure to mercury or mercury compounds resulting in various toxic effects depend on its chemical form and route of exposure. The major route of human exposure to Methylmercury (MeHg) is largely through eating contaminated fish, seafood, and wildlife which have been exposed to mercury through ingestion of contaminated lower organisms. Ingested mercury may undergo bioaccumulation leading to progressive increases in body burdens. Kevin.M.Rice 2104

The Minamata Convention on Mercury is an international treaty intended to protect people and the environment from the harm caused by exposure to mercury. It is named after a city in Japan where inhabitants were poisoned by the release of mercury in wastewater from a chemical factory in the mid-20th century. The convention perhaps best understood as having four essential aims such as; Supply and trade controls of Mercury, phase-outs of Products containing Mercury, Process reductions that result mercury release and the requirement of Air emission controls. (UNEP 2013)

Ethiopia has signed the convention on 10 October 2013 in Kumamoto, Japan. And the convention highlighted actions to be taken by parties for controlling and where feasible reducing the release and emission source of mercury to the atmosphere from the anthropogenic sources. (MIA 2016)

Developing an action plan to identify, characterize and address potential mercury release is the major obligation of each party. The action plan should evaluate the current and projected releases, develop source inventories and release estimates. It should also evaluate the efficacy of laws and policies relating to the management of such releases. In addition to the action plan, each party is required to (i) promote feasible, practical measures that can expeditiously achieve a significant on the reduction of these releases; (ii) promote and/or require the use of substitute materials or processes to prevent the formation of these chemicals; (iii) promote and implement, in accordance with the action plan, the use of best available techniques and best environmental practices for existing and any newly identified sources of mercury. (UNEP 2013)

The management of mercury is global concern owing to its long atmospheric transport; its persistence in the environment once introduced, its ability to bio accumulate in the ecosystem and its significance negative effects on human health and the environment. Monica Gaba Kapadia, 2013; and Frank Pinto, Hilda van der Veen 2014; highlighted the link mercury management has with the Sustainable Development Goals (SDGs) particularly with goals 1, 2, 3, 7, 8, 12 and 14. (UNEP 2016)

Mercury from deferent anthropogenic sources are released into different environmental media. with the increasing use of mercury in industrial process and products, mercury released into the environment from anthropogenic sources has been reported worldwide (Mukherjee *et al*, 2000, AMAP/UNEP 2008; Niksa and Fujiwara, 2009; Pacyna *et al*., 2010; Kim *et al*, 2011 Kumari, 2011; Al Razi Hiroshi, 2012; Nelson *et al* 2012; Wan and Lee, 2012UNEP 2013 b)

Addis Ababa, an urban center and capital of Ethiopia has been attaining an economic development which consequently has led to huge inflow from rural centers. From the census (2007) as sighted by Leulsegged (2011), Even though there are more than 900 urban centers in Ethiopia, Addis Ababa consisted of about 23% of the countries' urban population (World Bank Group, 2015).

Previous studies related to mercury in Addis Ababa, (Ataro, Wondimu and Chandravanshi 2003; Kebede and Wondimu 2004; Fitamo Itana and Olsson 2007; Desta *et al* (2007) determined mercury in fish collected from Tinishu Akaki River (TAR) and other rivers in the country using a flow injection mercury system. Similarly Itanna (1998), Fitamo, Itana and Olsson 2007; determined mercury but in vegetable farms and soils irrigated from (TAR) using ICP- AES, ICP-MS and CV-AAS, respectively.

Therefore, this study intended to evaluate the management practices of mercury release from the anthropogenic source in Addis Ababa through identifying the source categories and quantifying the release to environment media using a mass balance determination of mercury release.

1.3. Objectives of the Study

General Objective

The general objective of this study is to evaluate the management practice of anthropogenic mercury release in Addis Ababa, Ethiopia.

Specific Objectives

- To assess and categorize anthropogenic source of Mercury release in Addis Ababa.
- To examine the quantity of mercury release from anthropogenic source in city.
- To assess the current management practices and challenges of mercury release in Addis Ababa.

1.4. Research questions

- What are the main source categories for anthropogenic source mercury release in the city?
- What are the quantities of Mercury released in Addis Ababa? How much does it be released and exist in environment media such as air, water, land?
- What is look like the current management practice of mercury release in the city? And what are the policy and legal instruments that exist to regulate the release of mercury in the city?

1.5. Significances of the study

Nowadays, lots of dramatic changes are occurring in the capital city of Ethiopia. For instance, economic growth due to the establishment and expanding of the industrial activities and flooding of an immigrant from a rural area to the city can be taken as an indicator of these changes.

Thus, these changes can lead to pushing down the quality of the city environment as well as human health. Therefore, strengthening the performance of environmental governance system is crucial, unless the problems gradually create threats for the present and future environment and human welfare.

Thus, this study designed to evaluate the management practices of Mercury release and therefore, the findings of this research are intended;

- To review and develop policy instrument for the management Mercury
- To Encouraging other interested individuals to carry out further research in the area,
- To provide the service and industrial sector to consider their expansion and new products to be consider the issue of mercury.

1.6. Scope of the Study

The scope of this study was focused on the capital city of Ethiopia, with special references to the management practices of the anthropogenic source of mercury in Addis Ababa. The study mainly concentrated on governmental and private organizations that have role in the management of mercury release.

1.7. Limitation of the study

Several limitations namely of unavailability of activity data in some organization, lack of willingness from the organization for direct observation which exhaustively to assess the management practices of mercury release, absence of country emission factor to quantify the release of mercury, and less respondent awareness about the issue of mercury management was been some major limitation encountered during the study.

1.8. Organization of the research

The study is organized in five chapters the first chapter deals with the introduction of the study which composed of the background of the study, statement of the problem, objective, significance, scope and limitation of the research. The second chapter deals with literature review within two brood classifications theoretical and empirical literature review and the third chapter contend design and methodology of the research, and the fourth chapter contends result and discussion and finally the fifth the chapter has conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

Reviewing the available literature on the topics will be conducted so as to check whether the problem was addressed by the previous researchers or not; acquire insights on how previous addressed similar issues; identify the research gap and to refine the research problem. Thus the topic is divided into two parts. Part one deal with the theoretical literature review and part two discusses the empirical literature review. Under the theoretical review, mercury and human health, Toxicity of mercury, release of mercury and environmental impact, the birth of Minamata convention, quantification of mercury release and policy and legal framework for the management of mercury will be disused. The empirical literature review includes the discussion of experience and practices in different countries. Finally, research gap and conclusion of this chapter will be presented.

2.1. Conceptual definition

Mercury; Mercury is a heavy metal naturally present in the environment. It can be released due to natural processes or human activities. In the environment, mercury can be converted to methyl mercury, the form of mercury to which humans are most often exposed,

Anthropogenic Mercury Release; The process mercury is emitted to water, land and air media as a result of human activities such as the burning of fossil fuels and municipal or medical waste.

Mercury quantification: a process of identifying sources and quantifying the consumption and releases of mercury from these sources.

Toolkit is a tool intended to assist countries to develop a national mercury releases inventory.

Bioaccumulation; is the process by which organisms (including humans) take up contaminants more rapidly than their bodies can eliminate them, thus the amount of mercury in their body accumulates over time.

Minamata Convention; is an international treaty designed to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds

Mercury release

Mercury Management; The Collection of activities by the government or by public which guided by policy and strategy to reduce the impacts of mercury on the environment and human health by reducing the source emission from anthropogenic source

Environmental Impacts; The potential effect on the environment such as water, air land and esthetic value as a result of anthropogenic activities

Public Perception; The belief or opinion or information or understanding often held by many people regarding mercury, its management and environmental impacts

2.2. Theoretical Literature review

Under this section, different concepts and theories will reviewe such as the mercury and human health, Toxicity of mercury, release of mercury and environmental impact, the birth of Minamata convention, quantification of mercury release and policy and legal framework for the management of mercury will be presented

2.2.1. The birth of Minamata Convention

The Minamata Convention on Mercury is a global treaty to protect human health and the environment from the adverse effects of mercury. It was agreed at the fifth session of the Intergovernmental Negotiating Committee on mercury in Geneva, Switzerland 10 October 2013 in Kumamoto, Japan. It starts with a short description of the global risks posed by mercury and the findings of the global assessment of 2002 that led to the proposal by Norway and Switzerland in 2003 to develop a legally binding instrument on mercury (HenrikSelin 2018)

2.2.2. Heavy metals and Human health

Heavy metals is the generic term for metallic elements having an atomic weight higher than 40.04 (the atomic mass of Ca). Heavy metals enter into the environment by natural and anthropogenic means. Such sources include: natural weathering of the earth's crust, mining, soil erosion, industrial discharge, urban runoff, sewage effluents, pest or disease control agents applied to plants, air pollution fallout, and a number of others (Morais, 2012). Although some individuals are primarily exposed to these contaminants in the workplace, for most people the main route of exposure to these toxic elements is through the diet (food and water). The contamination chain of heavy metals almost always follows a cyclic order: industry, atmosphere, soil, water, foods and human (Matta, 2015).

Even though toxicity and the subsequent threat to human health of any contaminant are, of course, a function of concentration, it is well-known that chronic contact to heavy metals and

metalloids at relatively low levels can cause adverse effects (Castro and Mendez, 2008). While focusing on developing countries the conditions is getting more catastrophic due to increase in industrial complexes with minimal follow up of environmental and pollution control guidelines (Matta, 2015; 2014; Arora, 2014).

Mercury is one of the most toxic heavy metals in the environment (Castro and Mendez, 2008). Higher levels are often found in marine foods. Up to 90% of most organic mercury compounds are absorbed from food. Mercury can be detected in most foods and beverages, at levels of < 1 to 50 μg/kg (Reilly, 2007).

2.2.3. Impacts of mercury on Environment and Human health

The Sources of exposure are widespread and this include mercury vapors in ambient air, ingestion via drinking water, fish, vaccines, occupational exposures, home exposures including fluorescent light bulbs, thermostats, batteries, red tattoo dye, skin lightening creams, and over-the-counter products such as contact lens fluid and neosynephrine, dental amalgams, and more. Amalgam exposure is estimated to be from 3 to 17 micrograms per day from slow corrosion, chewing, brushing and grinding (RaoultRatard 2004) as reviewed by Mark H. Hyman, MD 2004. Methylmercury is a well-known potent neurotoxin which causes adverse impacts on the developing human brain. It passes readily through the placental barrier and the blood-brain barrier making any exposure during pregnancy of great concern. Methylmercury is considered possibly carcinogenic by the International Agency for Research on Cancer (IARC, 1993) and classed as group 2B.

The children born of exposed parents (congenital cases) showed a higher level of symptoms than the parents. Symptoms included severe disturbance of nervous functions and highly delayed developmental skills. Common symptoms of the disease include sensory disorders in hands and feet, ataxia, narrowing field of vision, hearing impairment, balance impairment, speech impediment, trembling in hands and feet and disorders in ocular movement. It is estimated that 8 to 10% of American women have mercury levels that would induce neurological disorders in any child they gave birth to, according to both the Environmental Protection Agency and National Academy of Science (Haley, 2005).

The brain remains the target organ for mercury, yet it can impair any organ and lead to malfunctioning of nerves, kidneys and muscles. It can cause disruption to the membrane

potential and interrupt with intracellular calcium homeostasis. Mercury binds to freely available thiols as the stability constants are high (Patrick, 2002). Methylmercury is a neurotoxic compound which is responsible for microtubule destruction, mitochondrial damage, lipid peroxidation and accumulation of neurotoxic molecules such as serotonin, aspartate, and glutamate (Patrick, 2002).

The toxicity of mercury depends on its chemical form (ionic < metallic < organic) (Clarkson, 2006). These forms of mercury are present widely in water resources such as lakes, rivers and oceans where they are taken up by the microorganisms and get transformed into methyl mercury within the microorganism, eventually undergoing bio magnifications causing significant disturbance to aquatic lives. Consumption of this contaminated aquatic animal is the major route of human exposure to methyl mercury (Trasande, 2005). Organic mercury compounds easily pass across bio membranes and are lipophilic. Therefore elevated mercury concentrations are mainly found in liver of lean species and in fatty fish species. Methyl mercury has a tendency to accumulate with fish age and with increasing trophic level. This leads to higher mercury concentrations in old fatty predatory species like tuna, halibut, redfish, shark, and swordfish (Oehlenschlager, 2002).

2.2.4. Mercury release and management practice

Global efforts sparked by the Minamata convention are underway to reduce release of mercury (Hg) to the environment (Selin et al 2018). These efforts, in addition to the global alarms such as climate change, have the potential to greatly alert the worldwide distribution and impacts of Hg, as described in campaign papers (Eagles-Smith et al.2018; Obrist et al.2018 Selin et al. 2018).

Since mercury is a toxic and ubiquitous metal that has broad uses in various fields, the control of mercury emission throughout its cycling in the ecosystem has been the most important factor in the developing countries to prevent its toxic effects on the environment and human health. Several countries have been involved in preparing the control policy and guidelines to reduce the use of mercury (Rhee s 2014).

2.2.5. Assessment of the identification and quantification of mercury release in Ethiopia

According to MIA 2016 the national mercury inventory for the year 2014 has been carried out. The inventory covered ten main categories taking into account the six release vectors such as air, water, land, byproducts and impurities, general waste and sector specific treatment/ disposal. The result of the inventories showed that "Consumer products" is the major contributor for the total mercury release by source categories which is about 33% of the total 666,656 Kg Hg/y followed by "Primary virgin metal production" which accounts 28% of the total release and then Waste incineration and burning accounted for 15% of the total release. The annual release figure corresponding to "waste incineration and burning " is mainly accounted for by uncontrolled batch combustion without employing automatic pollution control system (APCS), of medical/hospital waste, which is comprised of incinerating of medical waste generated from hospitals, health centers, clinics, drug stores, and burning of expired medicines. According to the inventory land air, water are the main vectors of the release which accounts 37%, 34% and 10% of the total release respectively and the other three together accounted for the 19% of the total release.

The inventory generally showed mercury added products such as batteries with batteries with mercury, thermometers and electrical switches and relays with mercury are widely used for both household consumption and hospital use and open dumping and burning of waste is very common practice which followed by informal waste burning and this resulted the highest mercury release into the atmosphere.

2.3. Empirical Literature review

Under this section, empirical literature reviews on management practices of mercury in developed and developing country are presented.

2.3.1. Foreign countries Experiences and initiatives

In recent years the potential risks of mercury to the environment and human health have gained a considerable attention worldwide. As such, regulatory control and measures are proposed to protect human health, the ecosystem, and the environment.

2.3.1.1. North America

The North American Agreement on Environmental Cooperation (NAAEC), which was signed by Canada, Mexico, and the United States in 1994, established the Commission for Environmental Cooperation (CEC) to address and advance cooperation among the three countries regarding environmental issues related to the North American Free Trade Agreement (NAFTA).

North American Regional Action Plan on Mercury from inception in 1995 until formal close-out in 2010. The activities were summarized in six key action items: Management of atmospheric emissions of mercury, Management of mercury in processes, operations and products, Mercury waste management approaches, Research, monitoring, modeling, assessment and inventories., Communication activities to increase public awareness and share best management practices and Implementation and compliance implementation of NARAP objectives and compliance with national commitments.(CEC 2013)

2.3.1.2. Asia Pacific Mercury monitoring Network

The Asia Pacific Mercury Monitoring Network (APMMN) is the platform responsible for implementing the International Environmental Partnership's (IEP) mercury monitoring program. The APMMN was created to establish a harmonized network of air and rainwater mercury monitors in the Asia-Pacific region. Currently, 18 Asia-Pacific countries participate in APMMN. It is supported by a central mercury testing laboratory, standard operating procedures for field operations, laboratory analysis, and quality assurance, and data sharing agreements. In 2017, APMMN received international recognition as a model regional network at the International Conference on Mercury as a Global Pollutant. (USEPA 2017)

2.3.1.3. Europe

In June 1998, under the auspices of the United Nations Economic Commission for Europe (UNECE), the Executive Body of the convention on long range Transboundery air pollution Protocol on Heavy metals adopted the protocol on heavy metals. This legally-binding agreement went into effect in December 2003. The United States is a party to this agreement. The Protocol targets three heavy metals cadmium, lead and mercury.The Protocol Aims to cut emissions from industrial sources (iron and steel industry, non-ferrous metal industry), combustion processes (power generation, road transport), and waste incineration. Includes strict limit values and deadlines for emissions reductions for new and existing stationary sources and suggests Best Available Techniques (BAT) for these sources. The other measures to reduce emissions from heavy metals and other products such as leaded gasoline and mercury in batteries, through the mandatory phase-out of leaded gasoline and mandatory mercury concentration limits for certain types of batteries were been utilized (USEPA 2017).

2.3.1.4. UNEP initiative in reducing Mercury release

The UNEP Governing Council decision GC 24/3 IV identified seven priority areas for action to reduce the risks from releases of mercury, two of which are: i. To reduce the global mercury supply, including considering curbing primary mining and taking into account a hierarchy of sources; and i. To find environmentally sound storage solutions for mercury. Even more recently, the UNEP Governing Council decision GC 25/5 (paragraph 34) mandated member governments to take further international measures including the elaboration of a legally binding instrument

on mercury, which could include both binding and voluntary approaches, as well as a range of interim activities, to reduce risks to human health and the environment. For South Africa to evaluate its status in global mercury emission it is necessary to look at the mercury inventory and the models used to determine such data. Such situation analysis could be of significant importance in coming up with a national inventory based UNEP toolkit developed in 2005 [UNEP, 2005].

2.3.1.5. Management practice of mercury release in Ethiopia

The management practice of the mercury release is week and there has not been got enough attention. Thus, the existing legal and institutional arrangements are none specifically for the management of mercury or heavy metals. (MIA 2016)

The waste incineration, the consumer product such as cosmetics, batteries, electric switch and mineral extraction such as gold has major contribution for the mercury release in the country, nevertheless there reduction of consumption, alternative utilization of materials End- of pipe techniques which included in BAT to minimize the release of mercury are not started at company or national level. (MIA 2016)

2.3.1.6. Conceptual framework mercury release, quantification and management

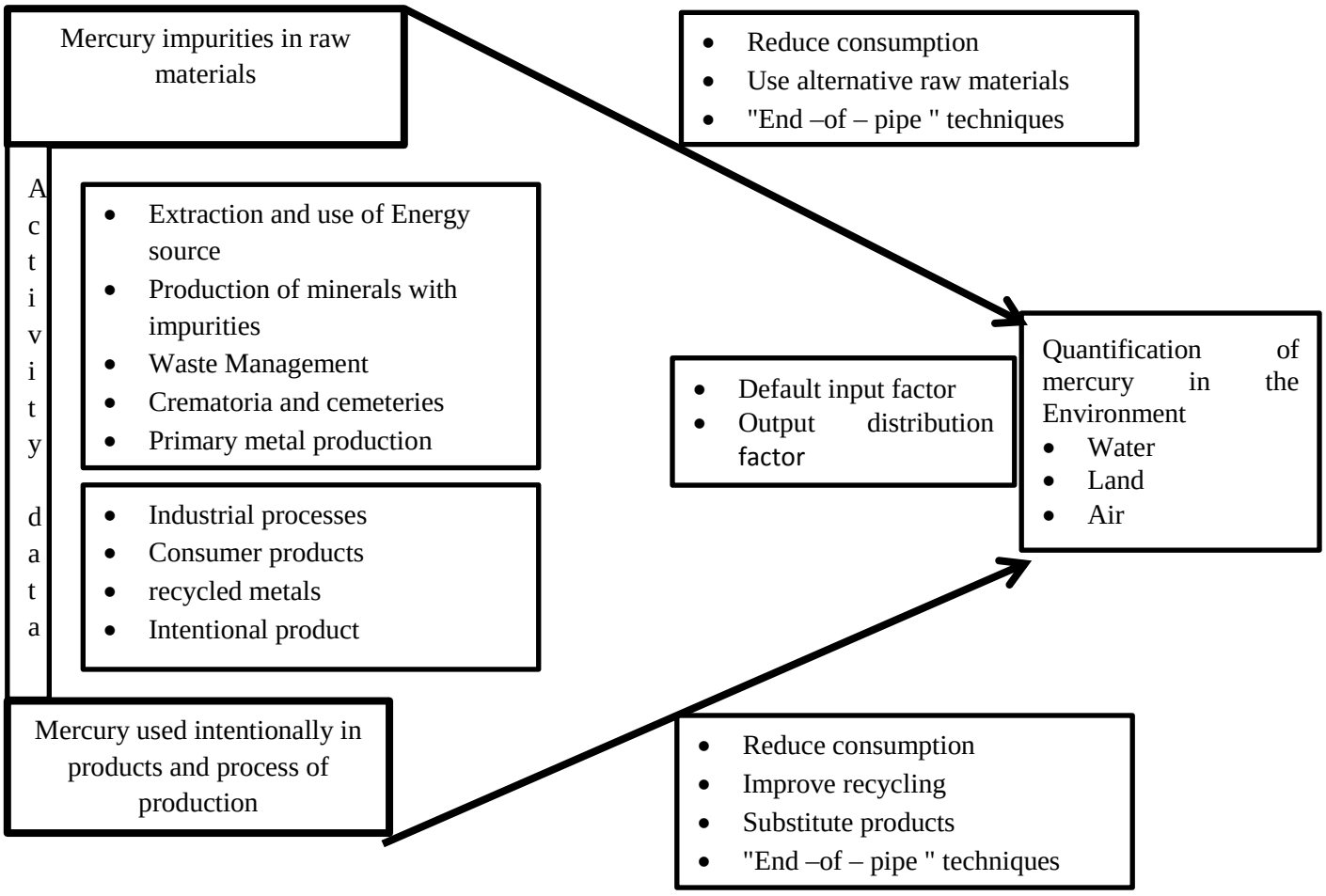


Figure 2- 1 Main source of anthropogenic Hg release to the Environment, method of main control options and method of quantification in the main environmental media (Modified UNEP toolkit 2017)

The conceptual framework **figure 2-1** above illustrate the potential anthropogenic Mercury (Hg) source (UNEP toolkit, 2017), the mercury input factor or a unit of feed material processed or product relevant for the individual mercury source type, the output distribution factors or the relative shares of the inputs that follow the output pathways relevant in the individual mercury source, activity rate or activity data (usually per year) a row data and its parameter describing the volume of the activity in the sub-category in question per unit of time and more over in area of approach where the management practices can be effective or fail (UNEP toolkit, 2017).

CHAPTER THREE

RESEARCH DESIGN AND METHOD

3.1. Description of the study area

Addis Ababa was established in 1886 and according to the 2007 population census; the city has a total population of 3,384,569 inhabitants. And one of the oldest and largest cities in Africa found at an average altitude of 2400 meters, Being the capital of a non-colonized country in Africa, it has been playing a historic role in hosting the regional organizations such as the African Union, and the Economic Commission for Africa, which contributed to the decolonization of African countries, and later bringing Africa together. (World Bank Group Ethiopia Urbanization Review 2016)

The city lies at an elevation of 2,300 meters (7,500 ft) and is a grassland biome, located at 9°1′48″N 38°44′24″ECoordinates: 9°1′48″N 38°44′24″E. The city lies at the foot of Mount Entoto and forms part of the watershed for the Awash. From its lowest point, around Bole International Airport, at 2,326 meters (7,631 ft) above sea level in the southern periphery, the city rises to over 3,000 meters (9,800 ft) in the Entoto Mountains to the north. The city is divided into 10 sub-cities. (World Bank Group Ethiopia Urbanization Review 2016)

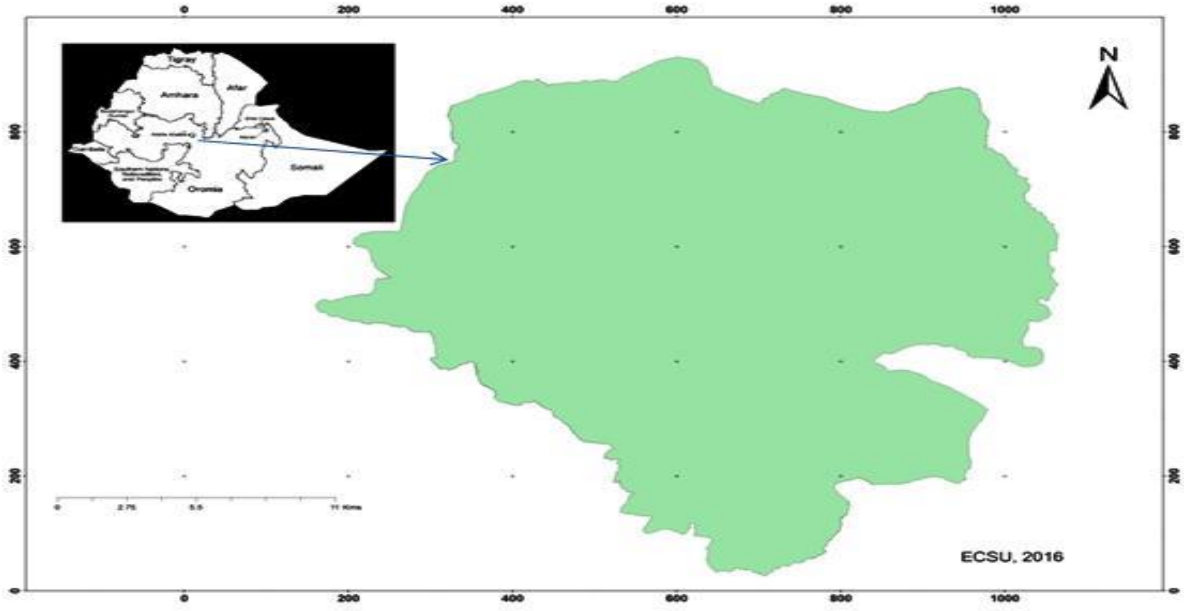


Figure 3- 1 Map of Addis Ababa

Source of Location Map (ECSU, 2016)

3.1.1. Climate

The city has a complex mix of highland climate zones, with temperature differences of up to 10 °C (18 °F), depending on elevation and prevailing wind patterns. The high elevation moderates temperatures year-round, and the city's position near the equator means that temperatures are very constant from month to month. (World Bank Group Ethiopia Urbanization Review 2016)

3.1.2. Demographic situation

Based on the 2007 census conducted by the Ethiopian national statistics authorities the population of Addis Ababa is 3,384,569 million; all of the populations are urban inhabitants. For the capital city, 662,728 households were counted living in 628,984 housing units, which results in an average of 5.3 persons to a household. (World Bank Group Ethiopia Urbanization Review 2016)

3.1.3. Economy

The economic activities in Addis Ababa are diverse. According to official statistics from the federal government, some 119,197 people in the city are engaged in trade and commerce; 113,977 in manufacturing and industry; 80,391 homemakers of different variety; 71,186 in civil administration; 50,538 in transport and communication; 42,514 in education, health and social services; 32,685 in hotel and catering services; and 16,602 in agriculture.. The city has recently been in a construction boom with tall buildings rising in many places. Its geographic location is in the center of Ethiopia that has combined with a lack of development policies in other urban centers have given the capital the majority of social and economic infrastructure in the country. As a result, it has been a melting pot to hundreds of thousands of people, coming from all corners of the country in search of better employment opportunities and services. This high rate of rural-urban migration accounts for about 40 percent of the growth. Coupled with rapid natural population growth, Addis Ababa one of the fast growing cities in Africa, posing critical challenges, including a high rate of unemployment, housing shortage, and environmental deterioration.(Addis Ababa Finance and Economy Bureau Annual report 2016.)

3.2. Method

According to Kothaire(2004), research design is a plan or roadmap strategy of the study to obtain an answer to the research question. It specifies method and procedure for collecting, processing and analyzing the required data. And According to Willian (2011), methods of collecting data by using questioners is said to be surveyed, descriptive survey method is used to conduct the study at Addis Ababa because the data that will be collected from the respondent through prepared questionnaires and this method is efficient to collect data

3.2.1. Research techniques

Following topic selection and its approval, a literature review was compiled. Appropriate and relevant literature were selected and reviewed. Following the preparation of a research proposal and identification of data sources, the researcher prepared an appropriate instrument for data collection. The data collection task has been undertaken. Primary data was collected using observation, questionnaire and key informant interview. Other relevant information has been then compiled from government and private organization reports, research articles, UNEP toolkit for identification and quantification of mercury, websites, etc. Then the collected primary and secondary data were fed into UNEP MODEL Mercury release identification and quantification toolkits excel sheet and SPSS. Finally, the result summarized and presented using tables.

3.2.2. Research approach and type

The study was conducted on the management practices of anthropogenic mercury release. Therefore, it intended to look at the source categories of Mercury and current management practice using a qualitative research approach and also to quantify the release of mercury in the city quantitative research approach were conducted. Thus, both qualitative and quantitative research approaches were used to collect, analyze and interpret the collected data. And in this study descriptive, research type has been employed because it is more appropriate to describe what actually exists or current condition and management practices of mercury release of mercury at Addis Ababa.

3.2.3. Time dimension

The researcher conducted the research only once and the data was gathered from the selected, sample size at one point in time from November 23, 2018 –April 30, 2019. Thus, cross-sectional time dimension was used to undertake the research.

3.3. Sources of Data

The data for quantification of mercury release in the city is collected from relevant organizations and to obtain Information for evaluation of the management practice of anthropogenic source of mercury release both primary and secondary data were used. Close and open-ended questionnaires were dispatched to collect primary information from the sample respondent. Key informants were interviewed about the institutional policy and the regulatory framework for the management practices of mercury release and also directs observation were done to see practically how the management looks like in the sampled government and Non -governmental organization. And also secondary data were gathered from documents like books, previous works, annual activity report of different activity, internet and other published and unpublished materials were been utilized.

3.4.Toolkit and Excel program for identification quantification of mercury release

The mercury release from each sector and into all media for the year 2017 was carried out using the mercury Toolkit 2017. "Toolkit for identification and quantification of mercury releases", version 1.0, March 2017 (UNEP, 2017a; UNEP, 2017b) with separate electronic Excel spreadsheets (UNEP, 2017c; UNEP, 2010d) were used for calculations. The Toolkit provides a methodology, associated input factors and output distribution factors for estimating mercury releases into all media (air, water, land, products and wastes). Mercury release estimation by Toolkit is divided into two levels. Simplified and standardized methodology (Inventory Level 1) and Inventory Level 2 provides more detailed emission inventory estimation. Mercury emissions were estimated using Toolkit Level 2 based on distribution factors from real measurements in facilities in operation. Further, comparative study of mercury release between the estimation was made based on the Toolkit Level 2 output distribution factors.

3.5. Steps for Identification and quantification of mercury release

There are four major steps for identification and quantification of mercury release (UNEP toolkit 2017) Apply screening matrix developed by UNEP to identify main source categories, investigate and identify existing descriptions of mercury sources in the city, classify main source categories further into sub-categories and gather additional qualitative information to identify existing activities and sources of mercury releases in the city, gather detailed quantitative information on the identified sources, and quantify releases with source specific data or default mercury input and output distribution factors from the Toolkit and apply city wide to establish full inventory and report results using guidance given in the standard format for identification and quantification of mercury release to the environmental media.

3.6. Methods of Data Collection

Different data gathering tools were used to collect data. The data collection tools were dispatched to the sample organizations. A closed and open-ended questionnaire, interview and direct nonparticipant observation were used to collect primary data. Document such as organizational annual report review for the calculation of activity data, to decide the input and output mercury factor including were used to gather data and quantify the mercury released to the environmental media.

3.7. Sampling design

According to Kothari (2004), sample design is a definite plan for obtaining a sample from a given population. Accordingly, the population of the study, sampling frame, sampling unit and sampling techniques of the study described as followed.

3.7.1. Population of the study

Population refers to the total items about which information is desired (Kothari, 2004).In this study, government and private organization such as energy source providers, waste generators and institutes working on waste management, consumer product importers, Heath care facilities, metal recycling industries, cement industry, organizations working on cemeteries responsible for the release of mercury were taken a population of the study.

3.7.2. Sampling frame and Sampling Unit

The sampling frame is the list from which the sample is drawn. And thus for this study, the sample frames were 648 private and 436 governmental organizations. And the unit of analysis was governmental and private organization found in Addis Ababa.

3.7.3. Sampling Technique

Probability sampling technique namely of multi-layer stratified random sampling techniques was used by the researcher for selecting respondents for both questionnaires and interview. Mercury releasing /emitting organizations were first stratified; the target samples then calculated according to its number of the total population. Following this, the calculated number of samples purposively further stratified to private and government. Finally, the representative samples from each category were taken randomly. This technique helped the researcher to get representative diverse information from all mercury releasing organizations. And the sampling methodology adopted here is enabled the researcher to generalize the findings.

3.7.4. Sample Size Determination

According to Singh and Masuku (2013), there are many approaches to determine the sample size of the study. These include using a census for a small population, limiting a sample size of similar studies, using published tables, and also applying formulas to calculate the sample size. The sample size in this study is determined by using scientific formula; a method which is explained by Cochran (1977).

Use of mineral oil, Cement production, consumer products with intentional use of mercury such as thermometer with mercury, electric and electric switches light source with mercury, cosmetics, and related products, Dental mercury amalgam fillings, manometers, and gauges, laboratory and chemicals and equipment's, medical waste incineration, informal dumping of general waste and crematoria are potential source of mercury release Frank Pinto (2004)

Thus the total number of this population is 1084. Cochran formula is used to determine the sample size. The representative number of samples that determine by Cochran under considering 90% confidence level (z= 1.645 and 0.01% margin of error) is 67.6 = 68

$$n = \frac{Z^2 P (1-P)}{d^2}$$

Where

n= the required sample

Z^2 Standardized Normal variable (90%= 1.645

P= the estimated proportion of an attribute that is present in the population and variables responsible for emission (governmental and non-governmental organization) which was 50% =0.5, q= (1-p)

d^2= degree of accuracy express as proportion= 0.01

$$n = \frac{(1.645)^2.(0.5)(1-0.5)}{(0.01)^2} = 67.6 = 68$$

Accordingly, 68 organizations were selected. However, some organizations which have lower sample ratio in **Table 3.2 below,** the original number of their population was taken as a sample. Hence, the total number of 78 sample organizations were selected and conducted.

Table 3- 1 Sample size determination

No	Source Categories	Population	Sample population ratio	Sampled population from each group
1.	Extraction and use of fuels/energy sources	2	2*68/1084	0.125
2.	Primary (virgin) metal production	0	0*68/1084	0
3.	Production of other minerals and materials with mercury impurities	2	2*68/1084	0.125
4.	Intentional use of mercury in Industrial processes	0	0*68/1084	0
5.	Consumer products with intentional use of mercury (whole life cycle)	1	1*68/1084	0.062
6.	Other intentional product/process use*2	3	3*68/1084	0.188
7.	Production of recycled metals	1	1*68/1084	0.06
8.	Waste incineration and burning	1073	1073*68/1084	67.3
9.	Waste deposition/landfilling and waste water treatment	1	1*68/1084	0.062
10.	Crematoria and cemeteries	1	1*68/1084	0.062
		1084		68

3.8. Methods of data analysis

The collected data were organized according to the variables, source categories, quantities and management practices of mercury release. Three variables like identification, quantities, and management practices were organized from the respondent viewpoints. Both qualitative and quantitative methods of data analysis were used to explain the condition of mercury release and management practices. Simple quantitative statistical tools including frequency, percentage, chart, and tables were used. SPSS (Statically package for Social Science). UNEP standard default factor for identification and quantification of mercury release Excel program were employed to analyze the data.

3.9.Data presentation

The data obtained using different data collection method were analyzed and presented differently. The analyzed and interpreted data were presented in the form of tables, figures, and narration and included in the report.

3.10. Ethical consideration

The primary data was collected by communicating the responsible different government and private organizations for the release of mercury through a formal letter from Environment Forest and Climate change Commission and Addis Ababa University. The collected data were analyzed without any biases and exaggeration. Those data taken from any other secondary sources and previous studies were cited and acknowledged.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter includes the presentation, analysis and interpretation part of the data collected from both primary and secondary sources. The main objective of this study was evaluating the management practices of mercury release in Addis Ababa. Herby to fulfill the intended objectives of the study, the researcher collected data through questionnaire and interview, field observation from the organization in the study area. In addition, Statically package for social sciences SPSS, UNEP toolkit and Excel program which help the researcher to convert the activity data of the organization into environmental release have been applied to analyze the data.

4.2. Response Rate

As it is described in the methodology part, primary data are used for this study were gathered from the organizations. The following table summarized the respondent rate along with the returned.

Table 4- 1 Response rate of the questionnaire

Respondent	Distribution questionnaire	Returned questionnaire	Response rate %
78	78	78	100

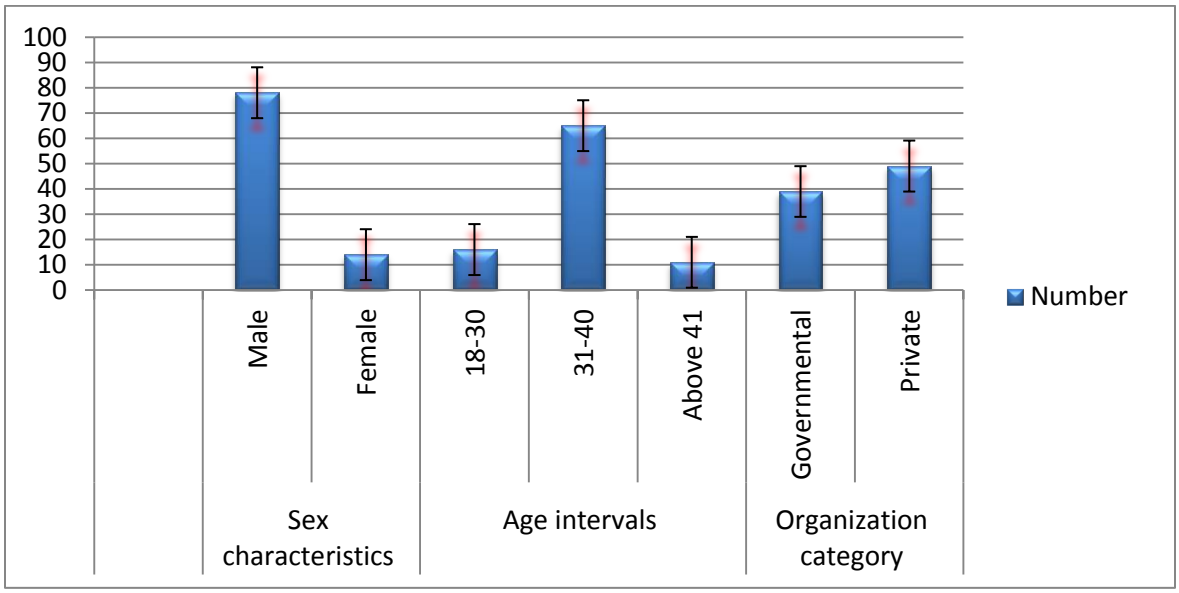
Source: Field survey (2019)

The above **table4.1.**demonstrate that from the total of 78 respondents, 100% of respondent returned the questionnaire, this indicates that the returned questionnaires are sufficient enough to carry out the analysis.

4.3. Demographic data

Knowing sex, age, and organization of the respondents help to set their composition and flexibility and their inclination to change. The following table present the demographic composition of the respondent directly related to the activities emitters organization.

Figure 4- 1Sex, age and organization characteristics of the respondent



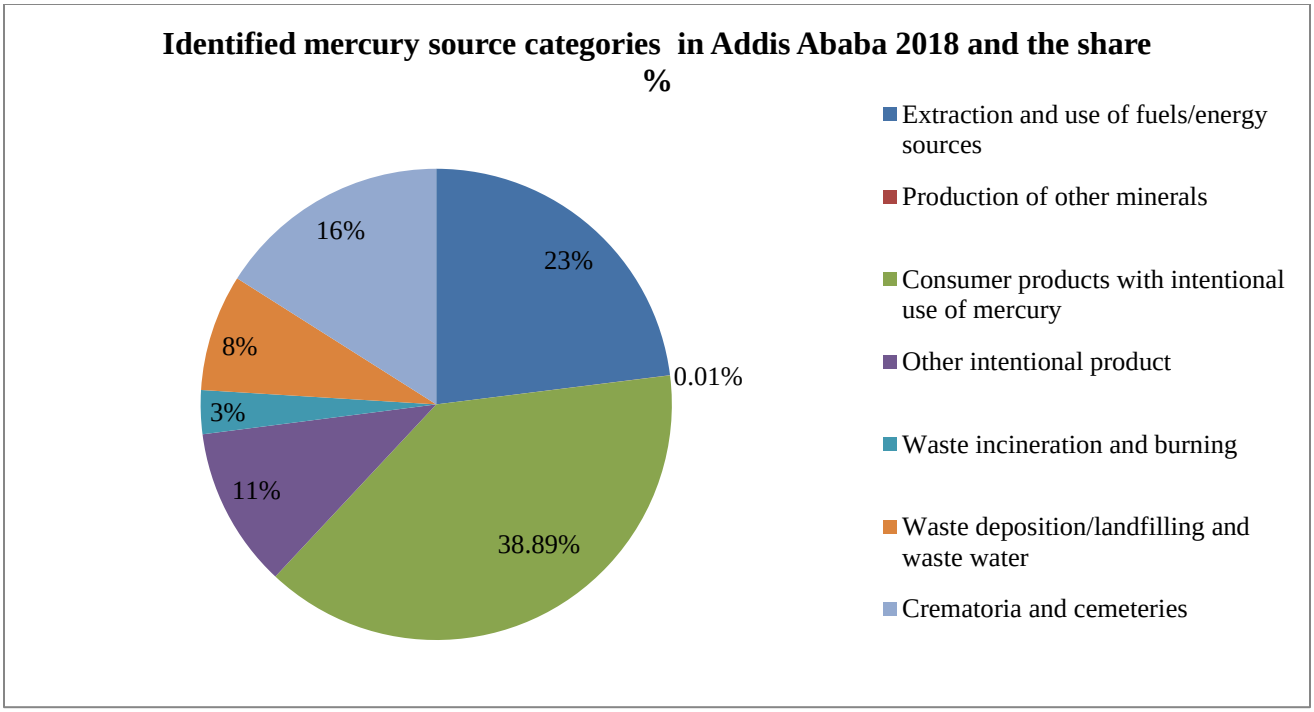
As it was seen in **Figure 4** above 78 or 84.7% of the respondents were Male and 14 or 15.2 % were females and regarding their age 16 or 17.3 of the respondent were under the age group of 18-30 years and 65 or 70.65 % were under the age group of 31-40 and the remaining 11 or 11.9 % were grouped age of above 41. From the same table 42 or 45.6 respondents were from government and 50 or 54.3 % were from private organizations.

4.4. Source of Mercury in Addis Ababa

Other than the natural phenomena, the anthropogenic activities undertaken at a particular place might have a significance effects on the presence or absence of mercury in different media at that particular place. This resulted in it impossible to found all source categories in all cities at the same level. Which means the difference depends on the economic activities production process and waste management of city.

UNEP Chemical and industries division in its manual for the management of anthropogenic source of mercury encourages cities or countries to identify and categorize their mercury source so as to make their effort more effective in the management of mercury (UNEP 2017)

Therefore the source categories identification in the study area undertaken by comparing anthropogenic activities (Production process, service process and remains of residue process) in the city with the source listed in the toolkit for identification quantification of mercury as a result it is fund that **seven (7)** out of **ten (10)** main categories such as Extraction and use of fuels/energy source, Production of other minerals and materials with mercury impurities, Consumer products with intentional use of mercury, Other intentional products/process uses, Waste incineration, Waste depositions/landfilling and wastewater treatment and crematoria and cemeteries main sources categories were identified as the source of Mercury release in the city.



Source survey 2019

Figure 4 1 Mercury source in Addis Ababa

From the **figure 4.2** above the bulk of the release of mercury or 38.89% of the release in the city Addis Ababa in 2018 were from consumer products with intentional use of mercury followed by extraction and use of fuel as energy source which accounts 23% of the total release and crematoria and cemeteries which accounts 16% of the total release. Similarly main category (5.6) other intentional products, waste deposition, waste incineration and production of other minerals main categories release 11,8,3 and 0.01 % of mercury release in to the environmental media.

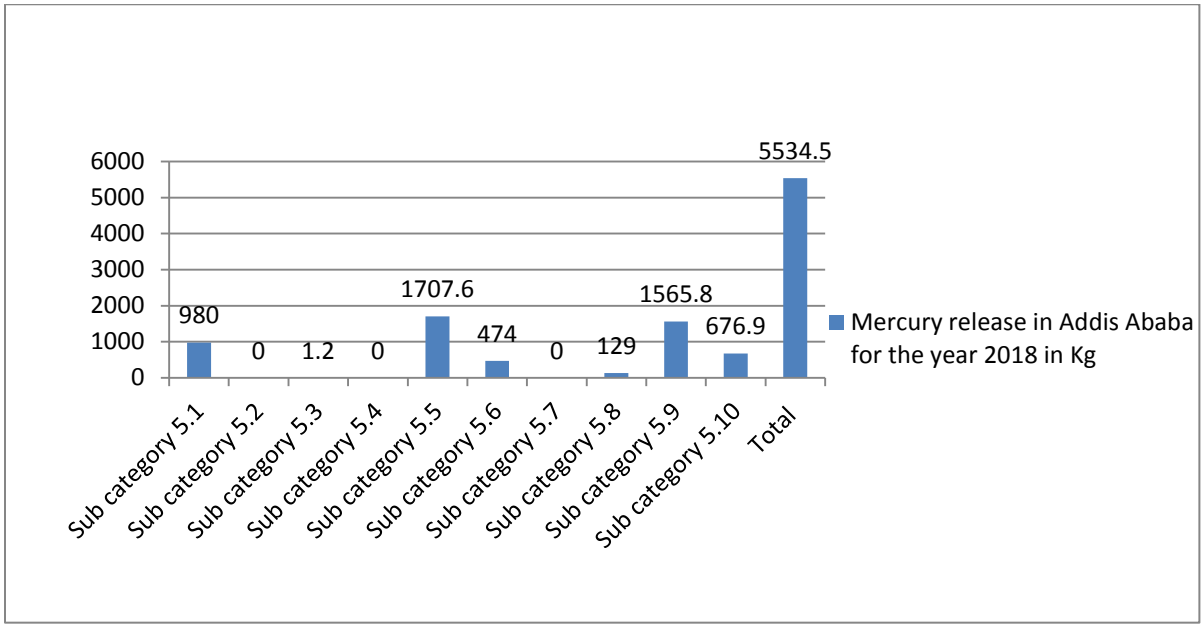
4.5. The quantities of mercury exist in the Environmental Media.

After carrying out the identification of the source categories, Inventory of mercury release have been conducted. To quantify the annual release of mercury in the study area mercury input factor and output distribution factor in the UNEP toolkit for quantification of mercury have been used. The result found that **5534.5 kg** of estimated mercury were relased in to air, water , land environmetal media and by- product, general and sector specifice waste.

Of the total mercury released to the environmtal media and general and sector specific waste **1707.6 Kg** of mercury were relased from source catgory 5.6 or consumer products with intentional use of mercury then followed by waste deposition/landfiling or source catgory 5.9 which accounted **1565.8Kg** of mercury and source catgory 5.1 or Extraction and use of fuels for energy source accounted 980Kg of mercury.

The remaining source catgory founded in the city such as crematoria and cemeteries or source catgory 5.10, other intetional product or source catgory 5.6, Waste incineration and burning or source catgory 5.8 and Production of other minirals or source catgory 5.3, acounted **676.9 Kg**, **474 Kg, 129 Kg and 1.2 Kg** respectively.

Figure 4. 2 Summary Estimated mercury release in Addis Ababa for the year 2018



Source filed survey 2019

The study also found that for the source category 5.1 or Extraction and use of fuels/energy source three sub categories such as Biomass Fired Power and Heat production, other coal combustion sub category and Extraction, refining and use of mineral oil sub category contributed **931, 31** and **4 Kg** of mercury for the total main source category. For the source category 5.3 or production of other minerals and materials with mercury only cement production sub category contributed **1.8Kg** of mercury release to the environmental media.

On the other hand for source category 5.5 or Consumer products with intentional use of mercury, six sub categories such as Thermometers with mercury sub category, Electrical and electronic switches, Light sources with mercury, Batteries containing mercury Polyurethane with mercury catalysts and Cosmetics and Related Products with Mercury contributed **82, 474, 20, 75, 57.87** and **750 Kg** of mercury to different environmental media.

For source category 5.6 or other intentional products/ process uses, three subcategories such as Dental amalgam fillings sub category contributed the largest portion of mercury **(677 Kg)** Manometers and Gauges with Mercury **10Kg** and the remaining Laboratory chemicals and equipment with Mercury sub category contributed **96.46 Kg** of mercury.

Source category 5.7 or production of recycled metals comprises three production processes and the mercury release from these source categories in the city was from production of recycled ferrous metal and it accounted **0.55Kg** production of other recycled metals. Regarding the source category 5.8 or the waste incineration and burning the medical waste incineration sub category found in the city and released an estimated **6 Kg** of mercury and informal burning of waste release **123 Kg** and contributed for the main source group.

Source category 5.9 or Waste disposal deposition/landfilling the sub category, Informal dumping of general waste and Waste water system/treatment released **138.9 Kg and 176 Kg** of mercury finally for the source category 5.10 or Crematoria and Cemeteries only the cemeteries activity accomplished in the city released **67.69Kg** of mercury to the environmental media.

And the research also found that which environmental media has received more mercury release from the anthropogenic activities which are practicing in the city. The table below illustrates more.

Table 4- 2 Overall release of Mercury in Addis Ababa per each vector.

No	Environmental media	Release of Mercury Kg/y	%
1	Air	1284.3	23.21
2	Water	1130	20.4
3	Land	1826.2	33.00
4	By products and Impurities	0.6	0.011
5	General Waste	1118.8	20.22
6	Sector specific treatment	174.6	3.15
	Total	**5534.5**	**100**

Source :Field survey (2019)

As it was seen in **Table 4.3:** due to the anthropogenic source of mercury listed on source identification part, most of the activities or release of mercury become high on the vector of land which accounts **1826.2 Kg** or **33%** from other vectors, following the land, the release of mercury was high on **air** vector which was accounted **1284.3 Kg** or **23.21%** and release of mercury to the **water** media become third which accounted for about **1130 kg or 20.4**% preceding this mercury release to by product and impurities and treatment/ disposal and **land** had been registered very insignificant and have 0.011 and 3.15% share.

4.6.Current Management Practices of Mercury in Addis Ababa

According to the Minamata Convention, countries who signed the convention towards the management of mercury have to design management Systems like BAT and BEP (best available technology and best environmental practice) to reduce and eliminate the release of mercury. This agreement is not easily applicable in a country like Ethiopia because our economy is still in progress and it has a major related impact during the developmental activities. Especially, in Addis Ababa social and economic demand have a load to the city environment and human wellbeing.

Therefore, this study was focused on evaluating the management practice of mercurey release by taking a sample of 92 respondents from the population of 1623 through Questionnaires and Field observation from the identified and source categories for release of mercury in Addis Ababa City. The following discussion has shown how the management practice looks like in the organizational activities of the suspected emitters.

4.6.1.1. Extraction and use of fuels/ Energy source

- **The management practice in coal use**

As it can be seen from the table 4.4 below50 % respondent indicated that they used coal for their energy source the rest of 50 % respondent indicated their organization does not have used coal for their energy source. Moreover, 100% of the respondent said their furnace does not have air pollution system and mercury monitoring system. So this implies that the overall management practice of mercury in coal using industries according to the respondent was very weak.

Table 4- 3 Coal use mercury management practices

Variables	Response	Frequency	Percentage
Utilization of technology for mercury management	Yes	0	0
	No	2	100
	Total	2	100

Source: filed survey (2019)

- **The management practice in mineral oils use**

As it is shown in **Table 4.5:** 2 or 100 % of respondents indicated that their organizations were used oil for heating and power generation, 100% of respondent responded that they use oil combustion facility with no emission control to thus 100% of respondent response their production activities are not environmental sound. However, the respondent do not aware of their production process is emitting mercury to the environment. This implies that the statuses of mercury emission management from mineral oil using facilities were not properly implemented.

Table 4- 4 Mineral oils use mercury management

Variables	Response	Frequency	Percentage
Utilization of oil for power generation	Yes	2	100
	No		
	Total	2	
Oil combustion facility with no Emission control	Yes	2	100
	No		
	Total	2	100
Oil Combustion Facility with PM control using an ESP	Yes		
	No	2	100
	Total	2	100
Power plants with ESP and FGD	Yes		
	No	2	100
	Total	2	100

Source; Filed survey (2019)

- **The management practice in Biomass fired power plant and heat production**

Table 4- 5 Biomass fired power plant and heat production mercury management

Variables	Response	Frequency	Percentage
Utilization of biomass for heat generation	Yes	1	50
	No	1	50
	Total	2	100
Aware of mercury emission from utilization of biomass	Yes		100
	No	2	
	Total	2	100

Source; Filed survey (2019)

As shown in **table 4.6:** above 50% of respondent responded that they are using charcoal and wood for heating and energy source at home and 100% of the respondent they don't aware of mercury release from materials which they are using an energy source.

4.6.1.2. Production of other minerals and materials with mercury Impurity

- **Management practices Cement production**

Table 4- 6 Mercury emission management from cement production

Variables	Response	Frequency	Percentage
Production of cement with no filters	Yes		100
	No	2	
	Total	2	
Production of cement with simple practice control	Yes	2	100
	No		
	Total	2	100
Production of cement with optimized practical control	Yes		
	No	2	100
	Total	2	100
Production of cement with Very efficient Hg Control	Yes		
	No	2	100
	Total	2	100
Aware of contribution of mercury emission from the industry	Yes		
	No	2	100
	Total	2	100

Source: Filed survey (2019)

As shown in the **table 4.7:** 100% of the respondent indicated that the cement production which is undertaking in their organization was carried out under some simple practice control, more of dust control. And 100% of the respondent indicated that they are not aware of cement production industries contribute for mercury emission. This indicated that mercury emission from cement production was not properly managed.

4.6.1.3. Consumer products with intentional use of mercury

- **Management practices in thermometer with mercury**

As shown in the **table 4.8:** below 100 % of respondent indicated they used thermometers for examination at health care facilities and 75% of the respondent responded the health care facilities do not have a separate waste collection as well as management system for mercury-containing mercury while broken and only 50% of the respondent responded that they were aware of the mercury release from thermometers while broken and contrite to the environmental media.

Table 4- 7 Mercury management in thermometer utilization

Variables	Response	Frequency	Percentage
Thermometer utilization health care facilities	Yes	4	100
	No		
	Total	4	
Separate waste collection while broken	Yes	3	75
	No	1	25
	Total	4	100
Aware of contribution of mercury emission	Yes	2	50
	No	2	50
	Total	4	100

Source: Filed survey (2019)

- **Electrical switches and relay with mercury**

As shown in the **table 4.9:** below 2 or 100% respondent indicated the waste generated from electric equipment at their home discarded without segregation and 100 % of the respondent they don't aware of the contribution of electrical switch and relay for the mercury emission contribution. This indicated that the mercury release from electric and switch relay was not properly managed

Table 4- 8 Mercury management in Electrical switch and relay with mercury

Variables	Response	Frequency	Percentage
Separate waste collection while discarded for being out of use	Yes		
	No	2	100
	Total	2	100
Aware of contribution of mercury emission	Yes		
	No	2	100
	Total	2	100

Source: Filed survey (2019)

- **Light source with mercury**

As shown in the **table 4.10:** below 2 or 100% respondent indicated the waste generated from light source at their home discarded without segregation and 100 % of the respondent they don't aware of the contribution of light source for the mercury emission contribution. This indicated that the mercury release from light source was not properly managed.

Table 4- 9 Mercury management in light source with mercury

Variables	Response	Frequency	Percentage
Separate waste collection while discarded for being out of use	Yes		
	No	2	100
	Total	2	100
Aware of contribution of mercury emission	Yes		
	No	2	100
	Total	2	100

Source: Filed survey (2019)

- **Batteries with mercury**

As shown in **table 4.11:** below 2 or 1000f respondent indicated they have used batteries for a light source and for remote control and 100% respondent indicated the waste generated from Batteries discarded without segregation, However, 100 % of the respondent they don't aware of the contribution of batteries for the mercury emission contribution. This indicated that the mercury release from batteries was not properly managed.

Table 4- 10 Mercury management in Batteries mercury

Variables	Response	Frequency	Percentage
Use of batteries for light source and remote control and others	Yes	2	100
	No		
	Total	2	100
Separate waste collection while discarded for being out of use	Yes		
	No	2	100
	Total	2	100
Aware of contribution of mercury emission	Yes		
	No	2	100
	Total	2	100

Source: Filed survey (2019)

- **Polyurethane with mercury catalyst**

As shown in **table 4.12:** regarding the management practice of mercury from Polyurethane, 100 % of the respondent indicated they use Polyurethane containing shoes and 100% responded they haven't practice waste segregation while discarding the shoe sole and others like. However, 100% respondent they do not aware of the mercury release from Polyurethane source. This indicated that the mercury release from Polyurethane was not properly managed.

Table 4- 11 Mercury management in Polyurethane with mercury

Variables	Response	Frequency	Percentage
Use of polyurethane for shoes sole	Yes	2	100
	No		
	Total	2	100
Separate waste collection while discarded for being out of use	Yes		
	No	2	100
	Total	2	100
Aware of contribution of mercury emission	Yes		
	No	2	100
	Total	2	100

Source: Filed survey (2019)

- **Cosmetics and related products with mercury**

Table 4- 12 Mercury management in Cosmetics and related products with mercury

Variables	Response	Frequency	Percentage
Utilization skin whitening cram, mascara and others cosmetics	Yes	2	100
	No		
	Total	2	100
Aware of some containing mercury and contribute for emission of mercury	Yes		
	No	2	100
	Total	2	100

Source: Filed survey (2019

As shown in **table 4.13:** above 100% respondent indicated at list one type of cosmetics and 100 % respondent they do not aware some of the cosmetics they have mercury in it. And the researcher has undertaken a discussion with expertise working in Ethiopian Food Medicine and Health care administration, as observed from the discussion there is no specific standard or limit the content of mercury on cosmetics. This indicated that the mercury release from cosmetics utilization was not properly managed.

4.6.1.4. Other intentional products/process use

- **Dental mercury-amalgam fillings**

As shown in **table 4.14:** below100% respondent indicated mercury amalgam fillings were undertaken at the clinic and only dental chair filters are used in the clinics for the filling purpose. This indicated that the mercury release from cosmetics utilization was not properly managed.

Table 4- 13 Mercury management in dental mercury amalgam flings

Variables	Response	Frequency	Percentage
Mercury amalgam fillings in the clinic	Yes	2	100
	No		
	Total	2	100
Is the clinic equipped with high efficiency amalgam filters	Yes		
	No	2	100
	Total	2	100
Only dental chairs filters are used	Yes	2	100
	No		
	Total	2	100

Source: Filed survey (2019

- **Manometers and gauges with mercury**

Table 4- 14 Mercury management in manometers and gauges with mercury

Variables	Response	Frequency	Percentage
Blood pressure gauges utilization health care facilities	Yes	2	100
	No		
	Total	2	
Separate waste collection	Yes	1	50
	No	1	50
	Total	2	100

Source: Filed survey (2019

As shown in the **table 4.15:** above 100% respondent indicated they have used manometers gauges with mercury in the health care facilities and 50% of the respondent indicated their facilities do not have separate waste collection and disposal mechanisms. This indicated that the mercury release from manometer and gauges was not properly managed.

- **Laboratory chemicals and equipment with mercury**

As shown in the **table 4.16:** below 100% respondent indicated they do not have waste treatment facility for mercury and 50% respondent was aware of the release of mercury from chemicals and reagents used in the laboratory, However, this showed as the management practice in laboratories was not good enough to manage the release of mercury.

Table 4- 15 Mercury management in laboratory chemicals and equipment with mercury

Variables	Response	Frequency	Percentage
Separate waste treatment for mercury in the facility	Yes		
	No	2	100
	Total	2	
Aware of mercury emission contribution	Yes	1	50
	No	1	50
	Total	2	100

Source: Filed survey (2019

4.6.1.5. Production of recycled metals (secondary metal production)

- **Management practices in Production of recycled ferrous metals (iron and steel)**

Table 4- 16 Mercury management practices production of recycled ferrous metals

Variables	Response	Frequency	Percentage
Cleaned and dirty iron and steel scrap melting via furnace	Yes	2	100
	No		
	Total	2	100
The furnace has air pollution control system	Yes		
	No	2	100
	Total	2	100

Source: Filed survey (2019)

As it is shown in **Table 4.17:** 2 or 100% of respondent indicated their organization iron and steel factories have used the furnace for heating and melting purpose of the dirty and cleaned raw materials during the production activities, 100% of respondent response that they do not have an air pollution control system related to this 100% of respondent response their production activities are not environmentally sound. This showed as the management practice in recycled ferrous production was not good enough to manage the release of mercury.

4.6.1.6. Waste Incineration

- **Management practices in Incineration of medical waste**

As it can be seen from **table 4.18:** 52.3% respondents indicated that they used furnace during medical waste incineration the rest of 47.7% respondent indicated their organization does not have used a furnace Moreover, 100% of respondent said their incinerator does not have an emission reduction device and the medical waste incineration activity was not environmentally sound.

And the researcher was undertaken field observation one from governmental and one from private hospitals as observed from the field their incineration activity were done by simply in the small box specially private hospital. In black lion hospital, they have an incinerator which was not work properly without Air pollution control system and they managed the bottom ash simply by disposing around the incinerator area.

Table 4- 17 Mercury management practice in medical waste incineration

Variables	Response	Frequency	Percentage
Waste incinerated via furnace	Yes	23	52.3
	No	21	47.7
	Total	44	100
The incinerator has emission reduction device	Yes		
	No	44	100
	Total	44	100

Source: Filed survey (2019)

- **Informal waste burning**

Table 4- 18 Management of mercury from informal waste burning

Variables	Response	Frequency	Percentage
Waste burning as a method of waste disposal	Yes	6	75
	No	2	25
	Total	8	100
Waste segregation for dumping	Yes	1	12.5
	No	7	87.5
	Total	8	100

Source: Filed survey (2019)

As depicted in **Table 4.19:** the management practices of mercury from informal waste burning 6 or 75% of respondent revels that they have used burning as waste disposal method the rest 25% gives it to Medium and small scale enterprise for disposal and only 12.5% of the respondent responded that they have to do segregation at home before disposal the rest 87.5 % they doing nothing on segregation of waste for disposal. Generally, the management's practices were very weak.

4.6.1.7. Waste deposition/ Landfilling and waste water treatment

- **Management practices in Informal dumping of general waste**

As depicted in **Table 4.20:** below the management practices of mercury from the dumping of general waste 1 or 12.5 % of respondent indicated they have practice segregation of general waste and 7 or 87.5% of respondent revels that they do not practice any segregation practice of waste at all. Moreover, 1 or 12.5 % of respondent indicated they are aware of mercury release from the dumping of general waste and 7 or 87.5% do not aware of the mercury release from the dumping of general waste. This indicates that the management practice of mercury from the dumping of general waste was very poor.

Table 4- 19 Management of mercury from informal dumping of general waste

Variables	Response	Frequency	Percentage
Waste segregation for dumping	Yes	1	12.5
	No	7	87.5
	Total	8	100
Aware of mercury release from waste dumped	Yes	1	12.5
	No	7	87.5
	Total	8	100

Source: Filed survey (2019)

- **Management Practices in Waste water treatment**

Table 4- 20 Mercury management practice from waste water treatment

Variables	Response	Frequency	Percentage
Applied treatment to wastewater to reduce mercury release	Yes		
	No	2	100
	Total	2	100
Mechanical and biological (activated sludge) treatment;	Yes	2	100
	No		
	Total	2	100

Source field survey (2019)

As indicated in the **table 4.21:** above 2 or 100% of respondent indicated their organization does not take to reduce mercury release from the wastewater treatment plant, Moreover 2 or 100% respondent responded their institution is using Mechanical and biological (activated sludge) treatment method for treating the wastewater. This indicates that the management practice of mercury from the dumping of general waste was very poor.

4.6.1.8. Crematoria and cemeteries

- **Management practices Cemeteries**

Table 4- 21 Mercury management practice from cemeteries

As it can be seen from **table 4.22:** 100% respondents indicated that there was no applied method to reduce the release of mercury from cemeteries activities in the city

Variables	Response	Frequency	Percentage
Applied method to reduce mercury release	Yes		
	No	2	100
	Total	2	100

Source field survey (2019)

4.5.Interpretation and discussion of the study

The interpretation and discussion part focuses on the major findings of the study. Hence, in this section the interpretation and discussion of the source categories of mercury, quantification of Mercury release to environmental media and current management practices of mercury from source categories were presented.

4.5.1. Identification of source categories for the release of mercury

The findings of the study carried out on the anthropogenic source of mercury were listed on UNEP toolkit guideline 2017. The Minamata Convention on mercury encourages countries to identify the source of their mercury release. This is because the management plan or strategies will be designed based on the data obtained from the identification of activities. Regarding Ethiopia the first Minamata Initial Assessment (MIA) was developed in 2015 and before the Minamata Initial Assessment (MIA) identification of mercury release is the first activities that have been undertaken.

Thus, according to the MIA (2016) in Ethiopia, there are about **9** main source category and **26** subcategories were been identified as a source of mercury release but, there is no any study conducted on the issues of mercury release. Thereby, this study tried to look at the national activities at regional level. In the same procedure **7** main source categories and **19** sub categories were identified in Addis Ababa.

The difference, For instance, min source category two Primary (Virgin) metal productions, Source category three productions of other minerals and materials with mercury impurities were been identified as a source of mercury during the national identification and quantification and intentional use of mercury in an industrial process is one of the main category which was not been identified as a source of release both at national and at the city level among the 10 main categories listed in the toolkit.

4.5.2. The quantities of mercury release in the Environmental Medias in Addis Ababa

The UNEP Governing Council decision GC 24/3 IV identified seven priority areas for action to reduce the risks from releases of mercury, two of which are:

I. To reduce the global mercury supply, including considering curbing primary mining and taking into account a hierarchy of sources;
II. To find environmentally sound storage solutions for mercury.

These activities are undertaken with after the identification of source categories have accomplished. Therefore this study tried to the inventoried the amount of mercury release in the capital city of Ethiopia.

The first inventory of mercury release was undertaken since in 2015 and this inventory was national wide and the finding showed that source group seven or consumer products with intentional use of mercury which accounted for **22198 Kg** or **33%** of the total release to Air, water land and general waste, secondly; source category two, Primary (Virgin) metal production which accounted 1875 Kg or 28% of the total release to air water land and by-products and impurities thirdly; medical waste incineration and open burning of waste under the main category eight which accounted 9810 Kg release to air media.

The rest six main categories ranged from 4th -9th and other intestinal products 6470 kg or 10% of the total release, extraction, and use of fuel/energy source 5739kg or 9% of the total release, cemeteries 1802 kg 3% of the total release, deposition /landfilling and wastewater treatment 7121 Kg or 2% of the total release production of other minerals and materials with mercury impurities, 602Kg or 1% of the total release and production of recycled metals waste respectively.

However, the finding of this study was varied from the national inventory, thus, this Study finds out **Seven (7)** main source categories and **nineteen (19)** subcategories were identified and quantified, thus the findings were quietly different from the national level. it means, In the study area the source category five consumer products with intentional use of mercury was the first anthropogenic activities for the release of mercury which was accounted **1707.6 Kg** of mercury to air, water land and general waste environmental media. Waste disposal and land filing the second source for mercury release which accounted **1565.8 Kg** or **28.29 %** of the total

release. Extraction and use of fuels/ energy source The third anthropogenic source was other intentional products/process release **980 Kg** or **17.7%** of the total release of mercury to air, water, general waste and sector-specific treatment/ disposal environmental media. The rest four source categories such as crematoria and cemeteries, other intentional products with mercury, waste incineration and burning and production of other minerals and source categories accounted 12.23 %, 8.56% ,2.33 % and 0.022% respectively.

4.5.3. Release amount of mercury through Environmental Media

The research result indicated that the release of mercury have released into the six environmental vectors such as air.water, land, by-product and impurities, general waste and sector-specific tremnte or disposal. The source categories like extraction and use of fuel/energy source and waste incineration and burning, the emission of mercury was released via the air vector, source categories such as consumer products with intentional use of mercury, other intentional product / process and waste deposition land feeling and waste water treatment dominates the air water and land environmental media.

Regarding the release to the by-Products and impurities, general waste and sector specific treatment of waste/disposal environmental media the research found that main source categories such as other intentional use of Mercury, consumer product with intentional use of mercury and waste disposal main categories are the main source.

4.5.4. Management practices of mercury in Addis Ababa

4.5.4.1. Extraction and use of fuels/Energy

- **Management practices in other coal use**

Domestic heating and other coal uses are very common in most countries. Compared to the amount of coal used in the city, the mercury released from these subcategories was significant. The research finding that about coal utilization was undertaken with uncontrolled way and the technology used is poor. Due to this mercury has released to environmental media and it harms the health of the society.

- **Management practices Mineral oils extraction and use**

Mercury released in the life-cycle of mineral oil, such as heating, power production, use in transportation, synthesis of chemicals and polymers, carbon black production, (UNEP Toolkit 2019)

The research found that the utilization of oil for residential purpose and other oil combustion facilities was undertaken without any control majors.

- **Management practices in Biomass fired power plant and heat production**

Heating and cooking with biomass in residential households are common practice in many countries. And the research also found that significant amount of mercury was released to air environmental media compared to other sub categories and there nothing has done to reduce the emission of mercury from these sub categories.

4.5.4.2. Production of other minerals and Materials with Mercury Impurity

- **Management practices in cement production**

The mercury released from Cement production is resulted from mercury in lime, waste as fuel and other feedstock materials. (UNEP toolkit 2017)

The research found that only one production plant in the city, however the technology applied in the facility was uncouple to limit the release of mercury

- **Management practices in thermometers with mercury**

Thermometers containing mercury, including medical thermometers, other glass thermometers (used in laboratories, for educational purposes, etc.) and other mercury thermometers (industrial, marine diesel engines, etc.) are common source of mercury release in most countries.

The research found that the type and number of mercury contenting thermometers and the amount of mercury released to the environmental media was very large. However the management practices to limit the release of mercury to the environment while the thermometers are broken and discarded was not installed all health care facilities in the city and generally the management practices was very poor.

- **Management practices in Electrical switches and relay with mercury**

Level switches in sewer pumps, water pumps, car boot lids (lighting), car ABS sensors, car ride-control systems, freezers lids, fall alarms for the elderly, railway signals, lights in children's shoes, etc. are common and potential source of emission mercury (UNEP toolkit 2017)

The research found that the amount of electric switches and relays with mercury that the city used remain unknown and the electrification rate of the city is about 57% and the mercury released from these sub categories was very significant, The Poor waste segregation and management practices in the city contributed for its significance.

- **Management practices in Light source with mercury**

Linear fluorescent lamps, Compact bulbs (small energy saving fluorescent lamps), Street advertisement with fluorescent tubes, Other mercury-containing lamps (Hg-lamps and Na-lamps for street lighting, UV lamps for skin tanning, light source in LCD flat screens for TV and computers, laboratory atomic absorption spectrometry lamps, head lamps in some car brands are common sources of mercury release to different Environmental media in most countries.

The research found that fluorescent tubes (double end) compact fluorescent lamp (CFL single end), High pressure mercury vapor and UV light for tanning were very common and known light source in the city. Absence of collecting used light source for recycling or in the city as well as at country level is contributing for high amount of mercury from the sub sector to different environmental media.

- **Management practices in Batteries with mercury**

Batteries such as Mercury oxide batteries (cylindrical and button), Alkaline cylindrical cells (containing mercury), Button shaped cells of most types (containing mercury) are common source of release of mercury.

The research found that the waste management system, absence of segregation and recycling or reusing facility for batteries in the city was contributed significant amount of mercury release to different environmental media.

- **Management practices in Polyurethane with mercury catalyst**

Polyurethane is common sources of mercury release (UNEP Toolkit 2017), In Addis The amount of due to absence of registered data the amount Polyurethane being utilized remain unknown. However from the electrification and habitat in Addis the research found that little amount of mercury was released to air water and general waste environmental media and the amount released was aggravated by the poor waste management that the city have and absence of recycling facilities in the city.

- **Management practices Cosmetics and related products with mercury**

Cosmetics and related products, including skin lightening creams and soaps, preservation in eye cosmetics are source of mercury release (UNEP Toolkit 2017) Regarding the management practices of mercury from cosmetics utilization the research found that there was properly installed system or method of control to limit the product at city as well as country level as a result the management was very week.

4.5.4.3. Other Intentional Products/Process

- **Dental mercury- amalgam flings**

Dental amalgam fillings in dentist clinic is one of the source of mercury release (UNEP Toolkit 2017) .The research found that the filings of album in Addis Ababa was undertaken only using dental chair filters and the contribution of the release of mercury to different environmental media was very significant. This indicates the management practice was very poor.

- **Manometers and gauges with mercury**

Blood pressure gauges, other manometers/pressure controls for industrial uses, for educational purposes, district heating pressure valves (such pressure controls may contain hundreds of kilos of mercury per control valve (UNEP Toolkit 2017). In this regard the research found that the amount of manometers and gauges being used are not known, however from the adjustment electrification rate the release from manometers and gauges with mercury was significant. The existing Poor waste management especially absence of proper segregation might be aggravate the release from this subcategory.

- **Laboratory chemicals and equipment with mercury**

Laboratory chemicals and equipment, including Special laboratory apparatus (Coulter Counters etc.), Chemical reactants for COD analysis, Kjeldahl analysis (nitrogen analysis), Electrodes for physio-chemical measurements, such as calomel electrodes and others are common source of mercury release in many counties. In Addis due to lack of appropriate data the amount of such chemicals which being used for different purpose remain unknown. However, from the adjusted electrification rate for the subcategories the research found that significant amount of mercury was released to different environmental media and the management practices in this sub category was very poor.

4.5.4.4. Production of recycled metals

- **Management practices in production of recycled ferrous metals (iron and steel)**

In Addis Ababa city, there are two ferrous metals (Irons and steel) factory using melting with furnaces to produce iron and steel. Both iron and steel industries is highly material intensive industry with raw materials such as ores ,pellets ,scraps ,coal ,lime.the finding of this research was both the factories were no applied an air control pollution system as well as mercury emission control system.

4.5.4.5. Waste Incineration

- **Management practices in Incineration of medical waste**

Each country has various ranges of healthcare wastes produced from healthcare services. The generation of a comparatively large amount of potentially infectious and hazardous wastes have increased in healthcare services (i.e., hospitals, clinics, laboratories, pharmacies, and other supported healthcare facilities) every year. Each type of medical waste has required its own management process and treatment. There are 1073 governmental and Non-governmental hospitals, clinics, and health care institute found in Addis Ababa (AAHO, 2015) all the institution generates medical waste and incinerates it. The research finding that about the medical waste incineration was undertaken with uncontrolled way and the technology used being poor. Due to this the organic substances has released to environmental media and it harms the health of the society

- **Management practices in Informal waste burning**

Informal waste burning includes private or local informal waste burning in open fire, barrels, domestic heating ovens, and the research found that both open burning at disposal site and open dumping of general waste was a very common practice in most part of the city. Absence of segregation, reuse and recycle was among the factors which increase the amount of waste generated and this indicate that the mercury management in this sub categories was very poor.

4.5.4.6. Waste Deposition/Landfilling and Waste treatment

- **Management practices in Informal dumping of general waste**

Informal dumping of waste is uncontrolled, informal dumping of general waste diffusely or at informal waste dumps, the research found that both open burning at disposal site and open dumping of general waste was a very common practices in most part of the city. Absence of segregation, reuse and recycle was among the factors which increase the amount of waste generated and this indicate that the mercury management in this sub categories was very poor.

- **Management practices in Waste water treatment**

Waste water system/treatment, where any mercury in wastewater (Originating from all sorts of mercury uses, but often dominated by dental amalgam waste ends up in the sewage sludge, and to a lesser degree in the output water. The research found that there was no control method applied to manage mercury releases from this sub sector.

4.5.4.7. Crematoria and Cemeteries

- **Management practices in Cemeteries**

Cemeteries is common practices in most countries, the research found that the mercury release contribution in Addis Ababa is insignificant

4.5.5. Institutional policy and regulatory framework for mercury management

This research finds that, the management practices of mercury release including the intentional and the unintentional was very weak. There is no legislation, which is directly and wholly devoted to the management of mercury. However, there are several legislations, which are applicable to mercury release management in one way or another. Environmental Pollution Control Proclamation No.300/2002, Industrial pollution control regulation No 152/2008 and

Hazardous waste management proclamation No 1090/2018 are among the most important legislations for mercury management.

Under the interpretation and discussion part, several issues was interpreted and discussed with accordance of the study result. Thus, the anthropogenic source for the emission of mercury was identified in the study area and these source categories have variation with national level and then the amount of mercury released through different environmental media was inventor and it tried to compare with the national level inventory which undertaken since 2015 related with this the release amount of mercury in the environment media were discussed thereby air was the first environmental media were mercury released and finally both current emission reduction management practices of mercury and the regulatory frame were interpreted and discussed and then it conclude that mercury were not properly managed in the organization and regarding regulatory framework there is no relevant regulatory framework has formulated by the government towards the management practices of mercury under the Minamata convention.

CHAPTER FIVE:

CONCLUSION AND RECOMMENDATION

5.1. Introduction

In this chapter, conclusion obtained from the findings of the study and relevant recommendation to the finding of existing management practices of mercury including identification, quantification, and regulatory framework are presented.

5.2. Conclusion

The Minamata convention on mercury under article five articulated that each party should reduce the source released of mercury, or if it is possible to party should eliminate the emission of mercury. Therefore, this research was focused the management practice of mercury in Addis Ababa city. To obtain the required information, the writer was dedicated to seeing the listed specific objectives of the study. Those research questions were responded to different data source methods such as primary and secondary data source, data collection methods such as questionnaire, interview, field observation and data analysis such as statistical social package science, UNEP toolkit default emission factor with excel spreadsheet, tables and charts were employed by this research.

All this research content was digested to produce an outcome; therefore the following issues were concluded on the relay on the research question. Therefore, the first objective of the research is source identification for the release of mercury which is found in the city. This activity was the prior which enable the writer to make an inventory and to evaluate management practices of mercury management unless it is impossible to accomplished inventory and management evaluation of mercury release.

Based on this, source group identification for the release of mercury in the study area has been conducted using the UNEP toolkit Guide for identification and quantification of mercury release and MIA unpublished document. Therefore, the major sources for the release in the study area have generalized as followed, Seven **(7)** main source categories and nineteen **(19)** sub source categories. According to the UNEP toolkit, the main source category has been described in number (Example, category 5.1. Extraction and use of fuels/energy) at same categories sub source categories are described in number (example 5.1.1 coal combustion in power plant) followed by specific type of activities related to the sub source categories.

Then after the identified main source categories and sub source categories activities found in the study area was inventory. Thus, to quantify the release of mercury, activity rate data of the organization was taken and compiled. And the writer used the default model of input factor and output distribution factor prepared by UNEP to convert the annual activity rate data into annual release mercury in Kg for different environment media.

From the seven **(7)** main source categories of anthropogenic activity for release of mercury, a total of **5534.5 Kg** mercury was released and of this release **1284.2 Kg** to the air, **1130 Kg** to the water, **1826.2 Kg** to the Land, **0.6 Kg** to the Byproducts and impurities **1118.8 Kg** to the general waste and **174.6 Kg** to the sector-specific treatment/ disposal media. This expected to be higher in the coming few years as a result of many economic and service delivery in the city.

Regarding the management practice legal framework, Technology usage both in the service and production sector and the awareness of all the implementers in the management process was assessed and the result showed that the activities which done so far for the management of mercury release was absent or minimal.

5.3. Recommendation

While conducting this research, a number of gaps were identified in the management of mercury emission in Addis Ababa. Thus the following recommendation forwarded with respect to the objectives of the research for further improvement of the managements of mercury for the organizations as well as for the country.

- **Regulatory framework option**

Cities in general and facilities or organizations should take an action to control and reduce the release of mercury to the environment. Legal frameworks are very crucial to reduce the consumption of raw materials and products releasing mercury and substitution by non-mercury alternatives, end-of-pipe techniques and waste management. So therefore, to meet the objectives of the convention controlling and reducing the release of mercury from anthropogenic source in the city government has to work with collaboratively with Federal government on formulating of the regulatory framework the management of mercury.

- **Technology options or product substitutions**

The majority of mercury release is coming from the utilizations of consumer products which currently do have safer alternatives with poor production technologies; therefore technology advancement is a very crucial point that should be given an emphasis to reduce the emission of mercury through the environmental Medias. However some of the technology has need financial capacities, but this problem can be solved through participating different stakeholder like governmental and private sectors and others developmental partners body. Therefore the following points are recommended by under the technology option.

- Adoption of Best Available Technology and Best environmental Practices in medical waste incinerations, metal melting.
- Converting mercury contain thermometers to digital, electric lamp and others
- Removal of barrier of introduction of technologies that Minimize mercury release through environmentally sound management practices

Capacity building option

This is a very significant issue that helps to improve the management practices of mercury. The government should enhance to create demanding society; it helps to work it hard.

Demanding society will create from hardworking of capacity building. Therefore, to improve the management practices of mercury the following recommendation are listed

- Conduct awareness raising and establishing network for information exchange through Sensitizing the public and stakeholders on environmental and health impact of mercury
- Develop education and awareness materials on health and environmental effects of mercury.
- Establish free access web and database on mercury.

REFERENCES

Addis Ababa Water Sanitation and Sewerage Authority 2015, 2016 Annual Report.

Addis Ababa city Government, *Urban Development Indicators.* Finance and Economic Bureau August 2002.

Addis Ababa Health Office 2015,2016 Annual Report.

Addis Ababa Solid Waste Recycle and Disposal Project Office 2015, 2016 Annual Report.

Addis –Wikipedia, the free encyclopaedia, *http;//en.wikipedia.org/wiki/ Addis Ababa. 14/04/16*

AMAP/UNEP, 2008; Niksa and Fujiwara, 2009; Pacyna et al., 2010; Kim et al., 2011; Kumari, 2011; Al Razi and Hiroshi, 2012; Nelson et al., 2012; Won and Lee, 2012; UNEP, 2013b).

Clarkson T, The toxicology of mercury and its chemical compounds, Critical Reviews in Toxicology, 36, 2006, 609–662.

Diet, lifestyle, or environmental factors and disease G Taubes, 1995

Distribution of mercury in the sediments of some freshwater bodies in Ethiopia, Nigussie mekonnen, Kebede, Ataro Ambushe, Abayneh, Chandravanshi, B. 2012

European Commission standards for lead Cadmium and mercury, Commission Regulation (EC) No 1881/2006. Accessed on 23 July 2015:2006

Haley BE, Mercury toxicity: genetic susceptibility and synergistic effects, Medical Veritas, 2 (2), 2005, 535–42.

HenrikSelin, Susan Egan Keane, Shuxiao Wang, Noelle E. Selin, Kenneth Davis and Dominique Bally, Linking science and policy to support the implementation of the Minamata Convention on Mercury, Ambio, 47, 2, (198), (2018).

IARC, IARC monographs on the evaluation of carcinogenic risks to humans, Beryllium, cadmium, mercury, and exposures in the glass manufacturing industry, Lyon, International Agency for Research on Cancer, 58, 1993.

Kevin M.Rice Marshall University, Huntington Environmental mercury and its toxic effects. 2014

Kim,J.H.,Park,J.M.,Lee,S.B.,Pudasainee,D.,Seo,Y.C.,2010b.Anthropogenic mercury emission inventory with emission factors and total emission in Korea. Atmospheric Environment 44, 2714– 2721.

Mercury management for sustainable development UNEP, 2016

Millennial scale impact on the marine biogeochemical cycle of mercury from early mining on the Iberian Peninsula Serrano and A. Martínez Cortizas ,2013

Modeling of atmospheric dispersion of mercury from coal–fired power plants in Japan Al Razi, Khandakar Moritomi, Hiroshi 2012

Morais S, Costa FG, Pereira ML, Heavy metals and human health, in Environmental health – emerging issues and practice, Oosthuizen J. ed., 2012, 227–246.

National inventory of mercury release into different media UNEP, Mukherjee et al., 2000

Oehlenschlager J, Identifying heavy metals in fish In: Safety and Quality issues in fish processing, Bremner H.A, (Ed), Woodhead Publishing Limited, Cambridge, 2002, 95-113.

Patrick L, Mercury toxicity and antioxidants: Part 1: role of glutathione and alpha-lipoic acid in the treatment of mercury toxicity, Altern Med Rev., 7 (6), 2002, 456–471.

Reilly C, Pollutants in Food —Metals and Metalloids, In: Mineral Components in Foods, Szefer P, and Nriagu J.O, (Eds), 2007, 363-388.

Samet JM, Dearry A, Eggleston PA et al. Urban air pollution and health inequities: A workshop report. Environ Health Perspect 2001; 109 (Suppl. 3): 357–74.

Samet JM, Fine particulate air pollution and mortality 344 -347 2001

Taubes G. Epidemiology faces its limits. Science 1995; 269: 164–9 718-724.

Total Contents and Sequential Extraction of Heavy Metals in Soils Irrigated with Wastewater, Akaki, Ethiopia 2007 Fitamo, Daniel,Itana, Fisseha, Olsson, Mats

Trasande L, Landrigan PJ, Schechter C, Public health and economic consequences of methyl mercury toxicity to the developing brain, Environ Health Perspect., 113 (5), 2005, 590–596.

UNEP 2010d. Toolkit for Identification and Quantification of Mercury Releases, Calculation Spreadsheet Rev.1.1 (InventoryLevel2), http://www.unep.org/hazardous substances /Mercury/ Mercury Publications /Guidance Training Material Toolkits/ Mercury Toolkit/tabid /4566/ language/ en– US / Default .

UNEP,

UNEP,2011. Hg Toolkit inventory Report-Template-Rev Jan 2011.

WHO, Inorganic Mercury, Environmental Health Criteria, Geneva: World Health Organization, 118, 1991

ANNEX 1 Questionnaires for the key informant interview

Requested by: Girma Gemechu

Mobile Phone 0911077821

Office phone 01111704011

Email- girma.nahall@gmail.com

To:_____

Dear respondent, the main objectives of this questionnaires is to obtain data on identifying, characterizing, quantifying and prioritize sources of releases of mercury through evaluating the management practice of mercury release management in Addis Ababa city. The data will be analyzed to examine for potential and better improvement of the management practice in the city. Keep in mind that, the quality of the research work highly depends on your genuine responses. Therefore respond each question as much as possible. The writer would like to thank you in advance for your commitment and truthful responses,

Please return the completed questionnaire

to_____

Note. If it possible this study need the five year time series data but if not the activity data should be for the last 20117/18year (2010E.C)

1. **Extraction and use of fuels/energy sources- Coal use -Coal combustion**
   1.1. How many Industries in the city does using coal for their power consumption? ----------
   ----
   1.2. How much tons of Coal is used during the physical year of 2010 E.C----------
   ----
   1.3. Does this industries do have any technology to minimize the release of mercury ----------
   ----
   1.4. How much tones of heavy oil and petroleum coke does used in the city ----------
   ----
   1.5. How much tones of gasoline, diesel, light fuel oil, Kerosene LPG and other light distillates is used in the city ----------
   ----

1.6.How much tones of bio mass is fired in the city ----------

1.7.How much charcoal is fired in the city ----------

2. Primary or virgin metal production

2.1.Is there any production or extraction of primary metals **Gold, zinc Copper Lead , Aluminum , Other non-Ferrous and Primary ferrous metal** ----------

2.2. If yes how much tones primary virgin metals of each is extracted the past year --------

3. Production of other minerals and materials with mercury impurities

3.1.How many cement production industries does exist in the city ----------

3.2.How much tons of cement is produced by these industry by the past year ----------

3.3.How many Lime production and light weight aggregate kilns production industries does exist in the city ----------

3.4.How much tons of cement is produced by these industry by the past year ----------

4. Intentional use of mercury in industrial Process

4.1.Does exist any industry with production of Chlor-alkali production with mercury-technology and production of chemicals and polymers with mercury compounds as catalysts----------

5. Consumer products with intentional use of mercury

5.1.How many thermo meters with mercury does exist in health care facilities ----------

5.2.How many electronic switches, contacts and relays with mercury does exist in the city ----------

5.3.How many Light sources with mercury does exist /used in the past year in the city ----

5.4. How many Batteries containing mercury does existed/used in the past year in the city ----------

5.5. How much tones of Cosmetics and related products were used in the city in the past year ----------

6. Other intentional use

6.1. How many peoples have done dental amalgam filing in the past year ----------

6.2. How may manometers gauges are used in health institutes of the city during the past year ----------

6.3. What is the electrification rate of the city in the past year ----------

7. Production of recycled metals

7.1. How many industries does exist in the city which produce recycled ferrous metals ----------

7.2. How much tones of recycled ferrous metal is produced in the past year in the city ----------

8. Waste incineration -Medical waste Incineration

8.1. How many hospitals, health centers, clinics and others health institution does exist in Addis Ababa? ----------

8.2. How much tones of medical waste is generated in the cities from these health care facilities----------

8.3. What do you think about the by-product effect during the combustion? Is there any mitigation measure to reduce the effect of those by-products? Please mention the mitigation you take.----------

9. Waste deposition/landfilling and waste water treatment

9.1. How much tones of general waste is generated and dumped in the citiy in the past year ----------

9.2. What do you think about the type of waste dumped in the dumping site in terms of its content ----------

9.3. How much M^3 of waste water is treated and released in to the environment in the city ----------

9.4.What do you think about the kind of waste water treatment that the city is operating --
---

10. Cremation and cemeteries

10.1. How many peoples have died and cemeteries in the country by the past year-------
---

ANNEX 2 Questionnaires for the respondent (2018)

Requested by: Girma Gemechu

Phone 0911 077821

Office Phone 0111704011

Email: - *girma.nahall@gmail.com*

To:_____

Dear respondent , the main objectives of this questionnaires is to obtain data on identifying, characterizing, quantifying and prioritize sources of releases of mercury through evaluating the management practice of mercury in Addis Ababa city. The data will be analyzed to examine for potential better improvement of the management practice in the city. Keep in mind that, the quality of the research work highly depends on your genuine responses. Therefore respond each question as much as possible. The writer would like to thank you in advance for your commitment and truthful responses,

Please return the completed questionnaire

to_____

Extraction and use of fuels/energy sources

Sex Male ☐ Female ☐

Age 18- 30 ☐ 31 -40 ☐ above 41☐

Organization Governmental ☐ Private ☐

1. Does your organization use coal for power generation?

   Yes ☐ No ☐

2. Which type of coal you used for power generation?

   Hard coal ☐ bituminous brown coal ☐ Lignite brown coal ☐

3. What kind of technology is used by your organizations to prevent emission

   None ☐ Simple APC ☐ Particulate matter ☐ Efficient APC ☐

Primary or virgin metal production

Sex Male ☐ Female ☐

Age 18- 30 ☐ ☐ 31 -40 ☐ ☐ above 41 ☐ ☐

Organization Governmental ☐ Private ☐

1. Is there a primary virgin metal such as Mercury, Gold, and Silver, Zinc, Aluminum, Ferrous and non-Ferrous production in the city?

   Yes ☐ ☐ No ☐ ☐

Production of other minerals and materials with mercury impurities

Sex Male ☐ ☐ Female ☐ ☐

Age 18- 30 ☐ ☐ 31 -40 ☐ ☐ above 41 ☐ ☐

Organization Governmental ☐ ☐ Private ☐

1. Is there cement producing industry in the city?

   Yes ☐ ☐ No ☐ ☐

2. Does the cement production industry have any technologies to reduce the emission of mercury?

   Yes ☐ ☐ No ☐ ☐

3. If you have answered YES for question above what type of filters are using during production?

   With no filters ☐ with filters no dust recycling ☐ simple particle control ☐

Pulp and paper production

Sex Male ☐ Female ☐

Age 18- 30 ☐ 31 -40 ☐ above 41 ☐

Organization Governmental ☐ Private ☐

1. Is there pulp and paper production in the city?

   Yes ☐ No ☐

2. If you have answered YES for the above question what production technologies are most used in the industry?

   No filter ☐ PM control for the general ESP ☐

Production of lime and light weight aggregates

Sex Male ☐ Female ☐

Age 18- 30 ☐ 31 -40 ☐ above 41 ☐

Organization Governmental ☐ Private ☐

1. Is there a production of lime and light weight aggregates in the city?

   Yes ☐ No ☐

Intentional use of mercury in the industrial process

Sex Male ☐ Female ☐

Age 18- 30 ☐ 31 -40 ☐ above 41 ☐

Organization Governmental ☐ Private ☐

1. Is there an industry in the city which uses mercury for industrial process?

   Yes ☐ No ☐

Consumer products with intentional use of mercury

2. Is there a medical thermometer with mercury in the health service?

   Yes ☐ No ☐

3. Is there a handling system (procedure) for thermometers when it will be out of use?

   Yes ☐ No ☐

4. What do you think the waste management when the thermometer is broken

   No separate collection, waste handle controlled ☐

No separate collection, informal waste handle ☐

Separate collection, waste handle controlled ☐

5. Is there a handling system or procedure for electrical switches and relays when it will be out of use?

   Yes ☐ ☐ No ☐ ☐ ☐

6. What do you think the waste management when the electrical switches and relays out of use

   No separate collection, waste handle controlled ☐

   No separate collection, informal waste handle ☐

   Separate collection, waste handle controlled ☐

7. Is there a handling system or procedure for light source with mercury when it will be out of use?

   Yes ☐ ☐ No ☐ ☐ ☐

8. What do you think the waste management when the light source with mercury out of use

   No separate collection, waste handle controlled ☐

   No separate collection, informal waste handle ☐

   Separate collection, waste handle controlled ☐

9. Is there a handling system or procedure for Batteries with mercury when it will be out of use?

   Yes ☐ ☐ No ☐ ☐ ☐

10. What do you think the waste management when Batteries with mercury out of use ?

    No separate collection, waste handle controlled ☐

    No separate collection, informal waste handle ☐

    Separate collection, waste handle controlled ☐

11. Is there a handling system or procedure for cosmetics and related products with mercury when it will be out of use?

    Yes ☐ ☐ No ☐ ☐ ☐

Other intentional product/ process and use

1. Is there a method other than mercury amalgam fillings in the dental clinics?

   Yes ☐☐ No☐☒☐

2. What do you think the waste management in the dental clinics?

   No separate collection, waste handle controlled ☐

   No separate collection, informal waste handle ☐

   Separate collection, waste handle controlled ☐

Incineration of medical waste

Sex Male ☐☐ Female ☐ ☐

Age 18- 30 ☐☐ 31 -40 ☐ ☐ above 41☐☐

Organization Governmental ☐ ☐ Private ☐☐ ☐

1. Does your organization have management practices to reduce the emission of mercury?

   Yes ☐ ☐ No☐☒

2. What type of emission reduction devices are used in the incineration plant?

   No emission reduction device ☐

   PM reduce, simple ESP or Similar ☐

   Acid gas control with limestone ☐

   Mercury specific absorbance ☐

3. Is there informal burning of waste in the city?

   Yes ☐ ☐ No☐☒

Waste deposition/ and waste water treatment

Sex Male ☐ Female ☐

Age 18- 30 ☐ 31 -40 ☐ above 41☐

Organization Governmental ☐ Private ☐

1. Does the city have a waste water treatment plant?

   Yes ☐ No☐

2. Which type of treatment steps do the city is using for the waste water treatment?

Cremation and Cemeteries

Sex Male ☐ Female ☐

Age 18- 30 ☐ 31 -40 ☐ above 41☐

Organization Governmental ☐ Private ☐

1. Is there cremation practice in Addis Ababa?

   Yes ☐ No☐

2. Do you have any idea cemeteries practice release mercury?

   Yes ☐ No☐

3. Does your organization have management practices the release of mercury?

   Yes ☐ No☐

ANNEX 3 Checklist for Field Observation to evaluate the management Practice of mercury release in Addis Ababa (2017)

Requested by: Girma Gemechu

Phone 0911077821

Email- girma.nahall@gmail.com

Name of the Organization_____

Date of Observation_____

Time Of observations_____

	Issues to be Observed	**Responses from observation**	**Remarks**
1	Is there any policy , laws, regulations under the organization to manage the release of mercury		
2	Is there any technology application and what kinds of technology did they used during their production/process		
3	What are the existing management practices undertaking by the organizations?		
4	What are the management plan or strategies set by the organization to reduce mercury release		

ANNEX 4 Interview Questionnaires for Environment Forest and Climate Change Commission Reference Year 2017

Requested by: Girma Gemechu

Phone 0911077821

Office Phone 0111704011

Email- girma.nahall@gmail,com

Note: The activity data obtained from the organization , if it is possible for five-year activities unless it should be 2017/2018

For Environment, Forest and climate change Commission

1. What are the major activates done on the management of mercury release after the singing the Minamata convention?
2. What do you think about the management mercury release in Addis Ababa?
3. Is there any institutional policy and regulatory framework for emission reduction of mercury release from all sources?

Annex 5 Inventory Data of mercury release in Addis Ababa for year 2018.

ventory Level 2 spreadsheet of UNEP 's Toolkit for identification and quantification of mercury releases

ad "introduction" before starting

														Enter output distribution factors (unitless)						Calculated Hg output, Kg/y						
Su-C	Source category /phase	Exists? (y/n/?)	Default input factor	Unit	Enter input factor	Unit	Enter activity rate	Unit	Calculat. Hg input	Unit	"Output scenario (where relevant)	Enter Hg input	Unit	Air	Wate	Land	Products	General waste	Sector specific treatment/disposal	Air	Water	Land	Products	General waste	Sector specific treatment/disposal	Remarks
	Source category: Waste incineration																									
5.8.1	Incineration of municipal/general waste																			0.00	0.00	0.00	0.00	0.00	0.00	
			1-10	g Hg/t waste incinerated	5	g Hg/t waste incinerated		Waste incinerated, t/y	0	Kg Hg/y	No emission reduction devices		Kg Hg/y	1						0.00	0.00	0.00	0.00	0.00	0.00	
								2300000			PM reduc, simple ESP, or similar		Kg Hg/y	0.9					0.1	0.00	0.00	0.00	0.00	0.00	0.00	
								3400000			Acid gas control with limestone (or similar acid gas absorbent) and downstream high efficiency FF or ESP PM retention		Kg Hg/y	0.5					0.5	0.00	0.00	0.00	0.00	0.00	0.00	
								1700000			Mercury specific absorbents and downstream FF		Kg Hg/y	0.1					0.9	0.00	0.00	0.00	0.00	0.00	0.00	
5.8.2	Incineration of hazardous waste																			0.00	0.00	0.00	0.00	0.00	0.00	
			8-40	g Hg/t waste incinerated	24	g Hg/t waste incinerated		Waste incinerated, t/y	0	Kg Hg/y	No emission reduction devices		Kg Hg/y	1						0.00	0.00	0.00	0.00	0.00	0.00	
											PM reduc, simple ESP, or similar		Kg Hg/y	0.9					0.1	0.00	0.00	0.00	0.00	0.00	0.00	
											Acid gas control with limestone (or similar acid gas absorbent) and downstream high efficiency FF or ESP PM retention		Kg Hg/y	0.5					0.5	0.00	0.00	0.00	0.00	0.00	0.00	
											Mercury specific absorbents and downstream FF		Kg Hg/y	0.1					0.9	0.00	0.00	0.00	0.00	0.00	0.00	
5.8.3	Incineration of medical waste																			0.00	0.00	0.00	0.00	0.00	0.00	
			8-40	g Hg/t waste incinerated	24	g Hg/t waste incinerated		Waste incinerated, t/y	0	Kg Hg/y	No emission reduction devices		Kg Hg/y	1						0.00	0.00	0.00	0.00	0.00	0.00	
											PM reduc, simple ESP, or similar		Kg Hg/y	0.9					0.1	0.00	0.00	0.00	0.00	0.00	0.00	
											Acid gas control with limestone (or similar acid gas absorbent) and downstream high efficiency FF or ESP PM retention		Kg Hg/y	0.5					0.5	0.00	0.00	0.00	0.00	0.00	0.00	
											Mercury specific absorbents and downstream FF		Kg Hg/y	0.1					0.9	0.00	0.00	0.00	0.00	0.00	0.00	
5.8.4	Sewage sludge incineration		?	?	2	g Hg/t sludge incinerated		?	0	Kg Hg/y			Kg Hg/y	0.9					0.1	0.00	0.00	0.00	0.00	0.00	0.00	
5.8.5	Informal waste burning (open fire waste burning on landfills and infomally)		1-10	g Hg/t waste burned	5	g Hg/t waste burned		Waste burned, t/y	0	Kg Hg/y			Kg Hg/y	1						0.00	0.00	0.00	0.00	0.00	0.00	

					Enter output distribution factors (unitless)						Calculated Hg output, Kg/y											
Calculat. Hg input	Unit	Output scenario (where relevant)	Enter Hg input	Unit	Air	Water	Land	Products	General waste	Sector specific treatment/disposal	Air	Water	Land	Products	General waste	Sector specific treatment/disposal	Remarks	Fossil fuel amounts calculations for cement production (a			
3	Kg Hg/y	Cement production									0.00	0.00	0.00	0.60	0.00	0.60					
3	Kg Hg/y (incl. fossil fuel contributions)	**With no filters**		Kg Hg/y	0.8			0.2			0.00	0.00	0.00	0.00	0.00	0.00					
		With filters an no filter dust recycling:		Kg Hg/y														Mid-range fossil fuel amounts per t cement produced		Calculated fuel amounts used (estimated)	
0	Kg Hg/y (a	Simple particle control (ESP / PS / FF)	3	Kg Hg/y	0.6			0.2		0.2		0.00	0.00	0.60	0.00	0.60		0.09	t fuel/t cement	-	t petroleum coke/y
0	Kg Hg/y (a	Optimized particle control (FF+SNCR / FF+WS / ESP+FGD / optimized FF)		Kg Hg/y	0.4			0.2		0.4	0.00	0.00	0.00	0.00	0.00	0.00		0.11	t fuel/t cement	-	t hard coal/y
0	Kg Hg/y (a	Efficient air pollution control (FF+DS / ESP+DS / ESP+WS / ESP+SNCR)		Kg Hg/y	0.2			0.2		0.6	0.00	0.00	0.00	0.00	0.00	0.00		0.17	t fuel/t cement	-	t lignite/y
0	Kg Hg/y (a	Very efficient Hg pollution control (wetFGD+ACI / FF+scrubber+SNCR)		Kg Hg/y	0.04			0.2		0.76	0.00	0.00	0.00	0.00	0.00	0.00		0.07	t fuel/t cement	-	t fuel oil/y
0	Kg Hg/y (a	**With filters and filter dust recycling *2:**		Kg Hg/y														75.90	m³ gas/t cement	-	m³ gas/y
		Simple particle control (ESP / PS / FF)		Kg Hg/y	0.7			0.3			0.00	0.00	0.00	0.00	0.00	0.00					
		Optimized particle control (FF+SNCR / FF+WS / ESP+FGD / optimized FF)		Kg Hg/y	0.6			0.4			0.00	0.00	0.00	0.00	0.00	0.00					
		Efficient air pollution control (FF+DS / ESP+DS / ESP+WS / ESP+SNCR)		Kg Hg/y	0.5			0.5			0.00	0.00	0.00	0.00	0.00	0.00					
		Very efficient Hg pollution control (wetFGD+ACI/FF+scrubber+SNCR)		Kg Hg/y	0.04			0.5		0.46	0.00	0.00	0.00	0.00	0.00	0.00					
0	Kg Hg/y (incl. fossil fuel contributions)	**With no filters**		Kg Hg/y	0.8			0.2			0.00	0.00	0.00	0.00	0.00	0.00					
		With filters an no filter dust recycling:		Kg Hg/y														Mid-range fossil fuel amounts per t cement produced		Calculated fuel inputs	
0	Kg Hg/y (a	Simple particle control (ESP / PS / FF)		Kg Hg/y	0.6			0.2		0.2	0.00	0.00	0.00	0.00	0.00	0.00		0.09	t fuel/t cement	-	t fuel/y
0	Kg Hg/y (a	Optimized particle control (FF+SNCR / FF+WS / ESP+FGD / optimized FF)		Kg Hg/y	0.4			0.2		0.4	0.00	0.00	0.00	0.00	0.00	0.00		0.11	t fuel/t cement	-	t fuel/y
0	Kg Hg/y (a	Efficient air pollution control (FF+DS / ESP+DS / ESP+WS / ESP+SNCR)		Kg Hg/y	0.2			0.2		0.6	0.00	0.00	0.00	0.00	0.00	0.00		0.17	t fuel/t cement	-	t fuel/y
0	Kg Hg/y (a	Very efficient Hg pollution control (wetFGD+ACI / FF+scrubber+SNCR)		Kg Hg/y	0.04			0.2		0.76	0.00	0.00	0.00	0.00	0.00	0.00		0.07	t fuel/t cement	-	t fuel/y
0	Kg Hg/y (a	**With filters and filter dust recycling *2:**		Kg Hg/y														75.90	m³ gas/t cement	-	m³ gas/y
		Simple particle control (ESP / PS / FF)		Kg Hg/y	0.7			0.3			0.00	0.00	0.00	0.00	0.00	0.00					
		Optimized particle control (FF+SNCR / FF+WS / ESP+FGD / optimized FF)		Kg Hg/y	0.6			0.4			0.00	0.00	0.00	0.00	0.00	0.00					
		Efficient air pollution control (FF+DS / ESP+DS / ESP+WS / ESP+SNCR)		Kg Hg/y	0.5			0.5			0.00	0.00	0.00	0.00	0.00	0.00					
		Very efficient Hg pollution control (wetFGD+ACI/FF+scrubber+SNCR)		Kg Hg/y	0.04			0.5		0.46	0.00	0.00	0.00	0.00	0.00	0.00					
0	Kg Hg/y			Kg Hg/y							0.00	0.00	0.00	0.00	0.00	0.00					
		No filter		Kg Hg/y	1						0.00	0.00	0.00	0.00	0.00	0.00					
		PM control with general ESP, or PS		Kg Hg/y	0.9				0.1		0.00	0.00	0.00	0.00	0.00	0.00					
	Kg Hg/y										0.00	0.00	0.00	0.00	0.00	0.00					
	Kg Hg/y			Kg Hg/y							0.00	0.00	0.00	0.00	0.00	0.00					

			Enter output distribution factors (unitless)						Calculated Hg output, Kg/y						
"Output scenario"	Enter Hg input	Unit	Air	Water	Land	Impurity in p	General waste	Sector specific treatment/disposal	Air	Water	Land	Inpurity in p	General waste	Sector specific treatment/disposal	Remarks
									8.20	24.60	0.00	0.00	49.20	0.00	
/Production (a	0	Kg Hg/y	0.01	0.005	0.1		0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	
/Use+disposal:															
(a1) No separate collection. Waste handl. controlled	82	Kg Hg/y	0.1	0.3			0.6		8.20	24.60	0.00	0.00	49.20	0.00	
(a2) No separate collection. Informal waste handl. widespread		Kg Hg/y	0.2	0.3	0.2		0.3		0.00	0.00	0.00	0.00	0.00	0.00	
(a3) Separate collection. Waste handl. controlled		Kg Hg/y	0.1	0.3			0.3	0.3	0.00	0.00	0.00	0.00	0.00	0.00	
									47.40	0.00	47.40	0.00	379.20	0.00	
/Production			0.01	0.005	0.1		0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	
/Use+disposal:															
(a1) No separate collection. Waste handl. controlled	474		0.1		0.1		0.8		47.40	0.00	47.40	0.00	379.20	0.00	
(a2) No separate collection. Informal waste handl. widespread			0.3		0.4		0.3		0.00	0.00	0.00	0.00	0.00	0.00	
(a3) Separate collection. Waste handl. controlled			0.1		0.1		0.4	0.4	0.00	0.00	0.00	0.00	0.00	0.00	
									1.00	0.00	0.00	0.00	19.00	0.00	
/Production			0.01	0.005	0.1		0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	
/Use+disposal:															
(a1) No separate collection. Waste handl. controlled	20		0.05				0.95		1.00	0.00	0.00	0.00	19.00	0.00	
(a2) No separate collection. Informal waste handl. widespread			0.3		0.3		0.4		0.00	0.00	0.00	0.00	0.00	0.00	
(a3) Separate collection. Waste handl. controlled			0.05				0.8	0.15	0.00	0.00	0.00	0.00	0.00	0.00	
									0.00	0.00	0.00	0.00	754.00	0.00	
/Production (a		Kg Hg/y	0.005	0.005	0.1		0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	
/Use+disposal:															
(a1) No separate collection. Waste handl. controlled	754						1		0.00	0.00	0.00	0.00	754.00	0.00	
(a2) No separate collection. Informal waste handl. widespread			0.25		0.25		0.5		0.00	0.00	0.00	0.00	0.00	0.00	
(a3) Separate collection. Waste handl. controlled							0.6	0.4	0.00	0.00	0.00	0.00	0.00	0.00	
									5.79	2.89	0.00	0.00	49.19	0.00	
/Production															
/Use+disposal:															
(a1) No separate collection. Waste handl. controlled	57.87613		0.1	0.05			0.85		5.79	2.89	0.00	0.00	49.19	0.00	
(a2) No separate collection. Informal waste handl. widespread			0.2	0.1	0.4		0.3		0.00	0.00	0.00	0.00	0.00	0.00	
									0.00	0.00	0.00	0.00	0.00	0.00	
/Production		Kg Hg/y	0.01	0.005	0.1		0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	
/Use+disposal:															

Unit	Enter activity rate	Unit	Calculat. Hg input	Unit	"Output scenario (where relevant)	Enter Hg input	Unit	Air	Water	Land	Products	General waste	Sector specific treatment/disposal	Air	Water	Land	Products	General waste	Sector specific treatment/disposal	Remarks
														0.00	0.00	0.00	0.00	0.00	0.00	
g Hg/t waste		Waste landfilled, t/y	0	Kg Hg/y			Kg Hg/y	0.01	0.0001					0.00	0.00	0.00	0.00	0.00	0.00	
-		-	-	-				-	-	-	-	-	-	-	-	-	-	-	-	
g material, under det output path *sector specific treatment/disposal accompanied by a descriptive note; e.g. solid residues from waste incineration or metal extraction.																				
														0.00	0.00	0.00	-	-	-	
-		-	-	-			Kg Hg/y				-	-	-	0.00	0.00	0.00	-	-	-	
														138.98	138.98	1,111.83	-	-	-	
g Hg/t waste	277957	Waste dumped, t/y	1,390	Kg Hg/y		1,390	Kg Hg/y	0.1	0.1	0.8				138.98	138.98	1,111.83	-	-	-	
														0.00	88.00	0.00	0.00	52.80	0.00	
mg Hg/m3 waste water	33600000	Waste water, m3/y	176	Kg Hg/y	No treatment; direct release from sewage pipe		Kg Hg/y		1					0.00	0.00	0.00	0.00	0.00	0.00	
					Mechanical treatment only		Kg Hg/y		0.9			0.1		0.00	0.00	0.00	0.00	0.00	0.00	
					Mechanical and biological (activated sludge) treatment; no land application of sludge	176	Kg Hg/y		0.5			0.3		0.00	88.00	0.00	0.00	52.80	0.00	
					Mechanical and biological (activated sludge) treatment; 40% of sludge used for land application		Kg Hg/y		0.5	0.2		0.15	0.15	0.00	0.00	0.00	0.00	0.00	0.00	