ADDIS ABABA UNIVERSITY COLLEGE OF HEALTH SCIENCES,

SCHOOL OF MEDICINE, DEPARTMENT OF BIOCHEMISTRY

EVALUATION OF HEAVY METAL COMPOSITION OF DRINKING WATER SUPPLIED BY PIPE IN DIFFERENT PARTS OF ADDIS ABABA TOWN.

BY

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A THESIS SUBMITTED TO ADDIS ABABA UNIVERSITY, GRADUATE STUDIES, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (MSC) IN MEDICAL BIOCHEMISTRY

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Declaration Sheet

This is to certify that this master's thesis entitled: Evaluation of heavy metal composition of drinking water supplied by pipe in different parts of Addis Ababa town, a cross sectional study was conducted by Anemut Tilahun Mulu, and Submitted to the department of Biochemistry for partial fulfillment of the requirements for the degree of Master of science in Medical Biochemistry complies with the regulation of the university and meet acceptance standards with respect to originality and quality.

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ABBREVIATIONS AND ACRONYMS

AAWSA- Addis Ababa water and sewerage authority

ATSDR- Agency for toxic substance and disease registry

Cd- Cadmium

Cr- Chromium

FMOH- Federal ministry of Health

G.C- Gregorian calendar

GHC- Global healing center

ICP-OES- inductively coupled plasma-optical emission spectroscopy

Km^3- Kilometer cube

MAL- Maximum admissible limit

MCL- Maximum contaminant level

Mn- Manganese

Pb- Lead

PI- Principal Investigator

PPM- parts per million

PVC- poly vinyl chloride

SWTP- Surface water treatment plant

UNCSD- United nations conference on sustainable development

USA- united States of America

USEPA- United states environmental protection agency

WHO- World Health Organization

ABSTRACT

Background- Compromised drinking water quality due to accumulation of heavy metals is becoming a serious concern for many countries, including Ethiopia. Chronic exposure to heavy metals such as lead, cadmium, chromium and manganese has been shown to have harmful effects on the health of human beings. The presence of high levels of heavy metals in drinking water brings a potential threat to the health of consumers.

Aim of the study- The aim of this study is to determine the levels of heavy metals in drinking water supplied by pipe to Addis Ababa city.

Methodology- The study was conducted in Addis Ababa town from April 2018 to December 2018 G.C. A community based cross-sectional study design was employed. Water samples were collected from both surface and ground drinking water sources. Inductively coupled plasma-optical emission spectroscopy (ICP-OES) was used to measure the concentration of heavy metals in drinking water samples. Data was entered using the software SPSS version 20.

Result-This study showed that the highest concentration of lead was recorded in water samples taken from Gefersa, Asko and Kolfie areas (0.06mg/l, 0.06 mg/l and 0.05 mg/l respectively). Cadmium concentration was below the detection limit in all water samples except those taken from Asko and Kolfie areas. The result of this study also showed that there was a statistically significant difference in the mean levels of lead among water samples taken from different treatment plants and their respective catchments (0.02±0.002 mg/l in Akaki deep well, 0.01±0.001 mg/l in Legedadi surface water treatment plant and 0.05±0.001 mg/l in Gefersa surface water treatment plant) (p-value <0.01).

Conclusion- The mean lead levels of water samples taken from different areas of Addis Ababa town was higher than the maximum admissible limit of lead in drinking water set by WHO in 2011. The mean levels of cadmium concentration was higher than the maximum admissible limit of cadmium in drinking water set by WHO in 2011 in water samples taken from the Gefersa surface water treatment plant and it's catchment area. The mean levels of lead, cadmium, chromium and manganese in water samples were lower than their respective maximum contaminant level set by USEPA in 2010.

Keywords- Drinking water quality, Heavy metals, Addis Ababa.

1. INTRODUCTION

1.1 BACKGROUND

At present Addis Ababa City Administration is supplied with surface water from the Legadadi, Dire and Gefersa reservoirs, and groundwater has been pumped from Akaki well field located to the south of Addis Ababa and other wells and springs located within the city. The current total daily water production for the city is estimated to be 599,000m3. (AAWSA, 2018). Addis Ababa is the capital city of Ethiopia and the African continent. The city consists of so many governmental and non-governmental organization offices, institutions and several commercial and industrial companies. The first modern water supply provision for Addis Ababa was introduced 15 years after the establishment of the city. During that time, the selected source was groundwater which served the city for almost 58 years. Then the first surface water development with treatment plant at Gefersa has been established in 1930 with the objective of meeting the increased demand of the population (AAWSA, 2011).

Water is essential for survival. Our existence is intimately connected with the quality of water available to us. Safe drinking water is pivotal for human health. Drinking water can be obtained from two types of natural sources; Surface water and ground water. The major source of fresh drinking water is found under the Earth's surface. Groundwater and surface water are the two reservoirs mostly used by humans because of their accessibility. Fresh groundwater is about 100 times more plentiful than fresh surface water, but we frequently use more surface water since it is easily accessible. Much of the total groundwater volume lies deep in the crust and too saline for most uses (Fetter, 1988).

Despite the importance of assuring the quality of drinking water, less attention has been given to water quality monitoring in Ethiopia. Additionally, there are limited studies in the area of water quality monitoring in the country (FMOH,2007).

Drinking water can be contaminated by different contaminants which can have a negative impact on the health and economic status of consumers. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt might find their way into water supplies due to inadequate disposal and treatment of waste (Singh and Mosley, 2003). The rapid population growth, industrialization and

urbanization are the main causes of ground water contamination. The contamination of ground water is difficult to restore. Therefore, it is mandatory to assure quality of ground water.

The contamination of water is directly associated with the degree of contamination of our environment. Rainwater collects impurities while passing through the air. Streams and rivers collect impurities from surface run off and through the discharge of sewage and industrial effluents; these are carried to the rivers, lakes or reservoirs that supply our drinking water (Singh and Mosley, 2003). All of the chemicals generated by man will eventually end up in joining our water supplies. These dangerous products from industry, agriculture and other human activities enter the rivers, lakes, and underground water, and can ultimately contaminate our drinking water (Singh and Mosley, 2003). According to World health organization (WHO), 80% of diseases arise due to contamination of ground water. A significant portion of the world's population is facing shortage of water.

A heavy metal is a metal of relatively high density (specific gravity more than 5) or of high relative atomic weight. Heavy metals become of particular interest in recent decades in the area of environmental investigation (Ghaedi *et al*., 2005). Medical geology is a subfield of geology that studies the effects of chemicals in the environment, especially trace elements, on the health of humans and other animals. Human beings are always exposed to the natural levels of trace elements. Under normal conditions, the body can control the amount of these metals. However, continuous exposure to elevated levels of heavy metals could end up with serious illness or death (Sanayei *et al.,* 2009). If levels of these metals are higher than the recommended limits, their roles change to a harmful dimension. Drinking water is the main source for heavy metals for humans. Heavy metals can accumulate in the human body and other living organisms over a long period and may cause adverse effects on human health. The main contamination sources of heavy metals in drinking water include heavy metal leakage through iron pipes in distribution systems and geological contamination of the water source (Ghaedi *et al*., 2005). Presence of heavy metals in water as a contaminant is an indication of global industrialization attributed to large scale of inappropriate disposal and untreated wastewater containing heavy metals from anthropogenic sources (UNCSD, 2010). Most of drinking water sources from surface water and groundwater are susceptible to heavy metal pollution due to natural occurrence and anthropogenic activities. Heavy metals naturally found in the soil will infiltrate into the water body. Anthropogenic activities such as mining, industrial and agricultural activity also contribute

to heavy metal pollution in the water body due to improper waste water management and run off from fertilizer. However, most of heavy metals from surface water and ground water are usually removed during water treatment process (khan *et al*, 2013).

Heavy metals and their compounds can accumulate in body tissues; such as bones or nerves. They can cross the placenta and harm the unborn child in pregnant women. Children are the most susceptible to health problems caused by heavy metals, because their bodies are smaller and still developing (UNCSD, 2010). The health impacts imposed by heavy metals depend on the level and the length of exposure.

1.2 LITERATURE REVIEW

1.2.1 Health benefits of water

Water is vital for survival. Human health is closely associated with the quality of drinking water. About 25% of the human body is comprised of solid matter while the remaining 75% is water (WHO,2011). Therefore, if water is not supplied in adequate amounts, our body becomes dehydrated and vital organs will deteriorate. Water also acts as a purifying agent in our body. If humans do not consume water in enough amounts, they may not be able to properly flush out their kidneys and liver and unable to expel bowels properly and completely. This keeps harmful toxins in the body. The longer the toxin remains in the body, the more the body reabsorbs the toxin back into the bloodstream. Consequently, the toxins make their way through the human body causing poisoning and spreading infections (GHC, 2010).

Water is at the heart of life. This is why a human being can survive no longer than few days without water**.** Many scholars recommend drinking water every day and at regular intervals as part of a healthy lifestyle (WHO,2011). A healthy sedentary adult should drink at least 1.5 liters of water per day. This level of water intake balances water loss and keeps the body properly hydrated. The water consumed through food and drinks follows a precise route to arrive in your cells, of which it is an essential component. After reaching the stomach, water enters the small intestine, where it is largely absorbed in the duodenum and jejunum. The rest passes into the colon. It crosses the intestinal mucous membrane into the bloodstream, then into the interstitial tissues to arrive in the cells (Peronnet, 2012).

Water is an important component of Blood, which transport nutritional elements such as minerals, vitamins, protein components, lipids and carbohydrates to the cells. Water is essential for cells to function properly: it enters into the composition of the cells. As a key player in hydrolysis reactions, water is very essential in the biochemical breakdown of what we eat (proteins, lipids and carbohydrates) (Peronnet, 2012). Water also serves as a carrier, which helps to remove waste products through urine. Water has a large heat capacity, which helps limit the changes in body temperature in a warm or a cold environment. Water enables the body to release heat when the environmental temperature is higher than the body temperature; we begin to sweat and evaporation of water from the skin surface cools down the body very efficiently (Peronnet , 2012). Water, along with other viscous molecules, forms lubricating fluids for joints. It also aids in gastric, intestinal and airways mucus secretion in the digestive and respiratory system respectively. By maintaining cellular shape, water also acts as a shock absorber during walking or running. This function is especially important for the brain and spinal cord (Ganong, 2005).

Water quality is determined by physical, chemical and microbiological properties of water. These water quality characteristics throughout the world are characterized with wide variability. Therefore the quality of natural water sources used for different purposes should be established in terms of the specific water-quality parameters that most affect the possible use of water. That is why the aim of this chapter is to provide an overview of water quality characteristics - Physical, Chemical, Microbiological, and Biological characteristics (WHO, 2011).

Table 1 - Physical and chemical parameters of palatable drinking water

Parameters	**WHO Permissible limits**
Temperature	30^0 c
Odor	Odorless
PH	6.5-8.5
Hardness	500 mg/l
Total dissolved solids	1500 mg/l
Turbidity	5 NUT
Conductivity	120 YS/cm^3
Chloride ion	250 mg/l
Alkalinity	100 mg/l
Color	15 TCU
Appearance	Clear
Bacteriological	
Coliform	Nil/100ml
E. Coli	Nil/100ml

*Source- WHO drinking water quality standards, 2011

1.2.2 Uses of Heavy metals

Heavy metals are important components of building materials, vehicles, appliances, computers, highways, bridges, railroads, airports, electrical utilities and food production and distribution. Natural and consumer products contain small concentrations of different heavy metals. Cadmium is mainly found in batteries, plastics, cigarette smoke, in shellfish and vegetables. Cadmium is used industrially as an anti-friction agent, as a rust-proofer, in plastic manufacture, in alloys and in alkaline storage batteries. Mercury is found in batteries, dental amalgam, vacuum pumps and valves. Arsenic is high in seafood and may be found as a contaminant in animal foods. It is also present in wood preservatives, herbicides, corrosion inhibitors, in lead and copper alloys. Chromium is found in fresh foods and copy machine toner (ATSDR,1999). Copper is essential to all living organisms and has a wide range of effects depending on concentration and chemical

formulation. It is used in the electrical industry in alloys such as brass, in chemical catalysts and in wood-preservatives. Lead has been used in batteries, electronic equipment's, petrol, toys and paint. Lead has been used as fuel additive in many countries for several years, although this practice has been stopped in many countries because of the health implications of lead. Manganese compounds are used in manufacturing of products such as batteries, steel and unleaded petrol. Manganese dioxide is commonly used in the production of dry-cell batteries, matches, fireworks, porcelain and glass-bonding materials. Manganese chloride is a precursor of other manganese compounds. It is used as a catalyst in chlorination of organic compounds. Manganese sulfate is used as a fertilizer, livestock nutritional supplement and in ceramics (ATSDR,1999).

1.2.3 Human exposure to heavy metals and associated health impacts

Heavy metals exhibit toxic and persistent characteristics. They can enter into food chains and the ecosystem where they pose adverse impact on the biotic and abiotic components of ecosystem. since water serves as a medium of transport for pollutants, heavy metal contamination can have a negative effect on the well-being of individuals and the environment as a whole (ATSDR, 1999).

1.2.3.1 Lead

Lead has an atomic number of 82 with chemical symbol of Pb and situated in group 14 of the Periodic Table. It is a soft, malleable, ductile, bluish-white, dense metallic and poor electric conductivity element. Lead is also classified under heavy metals that have high toxicity. It causes long term irreparable impact to human health even at very low concentrations. Lead is primarily used in the acid battery industry. Furthermore, it is extensively used in manufacturing of ammunition, pipes, cable, alloy and paint. Lead is not essential as trace elements to nutrition in human or animals (USEPA, 2011). It can poison humans even in low concentrations. Lead Contamination of water and consumer products result in the absorption of lead into human body. Concentration of lead and duration of exposure are key factors in the measurement of lead toxicity (ATSDR, 1999). Acute poisoning occurs when one is exposed to high concentrations of lead for a short period of time and the adverse effect is pronounced and more severe. Acute poisoning is associated with seizure, coma and death. while, long-term and low level exposure leads to chronic poisoning which is commonly associated with diseases such as anemia, neurotoxicity, haemo-toxicity, nephrotoxicity and toxic metabolic encephalopathy. Furthermore,

lead toxicity cause brain damage and mental retardation especially in children (DEAT & DME 2003)

Lead activates the secretion of the chemokine IL-8 and affects mitogen-dependent activation by increasing the secretion of the pro-inflammatory cytokines IL-6 and TNF-α and chemokine IL-8. Lead also affects the pattern of gene expression, affecting major cellular functions including metallothionein expression, expression of cellular metabolic enzymes and protein kinase activity (Gillis *et al*,2012). Cellular responses to lead correlated with blood lead levels and were significantly altered in individuals with higher lead content resultantly affecting the nervous system, the negative regulation of transcription and the induction of apoptosis. The affected pathways were G-protein mediated signaling, gap junction signaling, synaptic long-term potentiation, neuropathic pain signaling as well as CREB signaling in neurons (Gillis *et al*,2012).

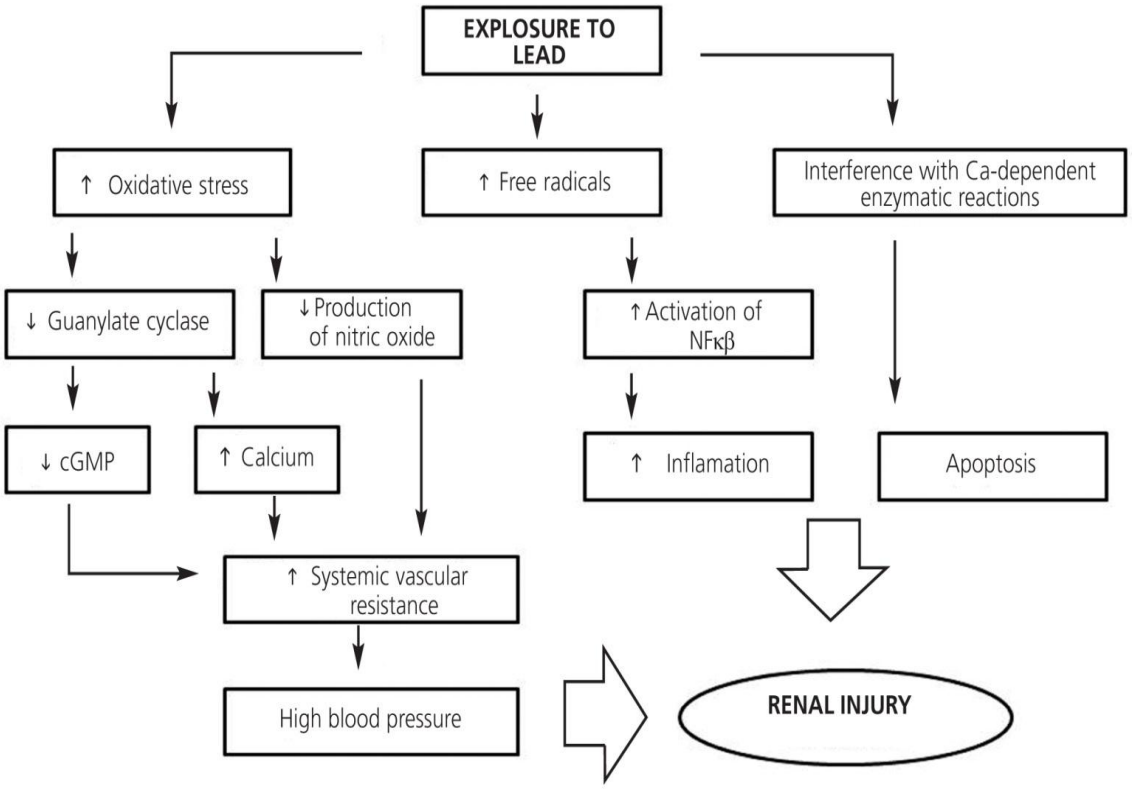

Figure 1: Harmful Health outcomes of prolonged lead exposure (ATSDR, 1999)

1.2.3.2 Cadmium

Cadmium (Cd) and its compounds are very toxic at all levels and tend to accumulate inside organisms and ecosystems. Cadmium is Bio-persistent and, once absorbed by an organism, it may accumulate for many years (ATSDR, 1999).

Long-term exposure to cadmium is associated with renal dysfunction, obstructive lung disease and lung cancer. Cadmium may also be implicated in bone abnormalities such as osteomalacia and osteoporosis. Soon after ingestion Cadmium is first transported to the liver where it binds with many proteins to form complexes. These complexes then are transported to the kidneys, ultimately affecting the filtering mechanism (ATSDR, 1999). This causes the excretion of important proteins and sugars, further damaging the kidney function. It takes a very long time for cadmium that has accumulated in kidneys to be excreted from the human body. Other possible health effects associated with cadmium poisoning are diarrhea, stomachache, severe vomiting, bone fracture, reproductive failure and even infertility (ATSDR, 1999). In general, frequent exposure to Cadmium affects the central nervous system, the immune system, psychological behavior and also be implicated in DNA damage or cancer development. Cadmium poisoning was responsible for the pathogenesis of "itai-itai" disease, a name derived from the painful screams in Japanese language due to severe pain in the joints and the spine. The disease arose from increased uptake of cadmium in locally consumed rice grown in paddy fields irrigated with cadmium-contaminated river water (ATSDR, 1999).

1.2.3.3 Chromium

Chromium (Cr) is used in metal alloys and pigments for paints, cement, paper and rubber. Low-level exposure to Cr can irritate the skin and cause ulceration. Long-term exposure can cause kidney and liver damage, and also circulatory and nerve defects (ATSDR, 1999). Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium (Singh and Mosley, 2003).

The level of chromium in drinking water is usually low, but contaminated well water may contain dangerous chromium (IV) or hexavalent chromium. Uptake of too much chromium (III) can cause skin rashes. Chromium (VI) is very toxic and is real threat for human health (Katz and Salem, 1994). Frequent exposure to hexavalent chromium can result in skin rashes, gastrointestinal upsets and ulcers, respiratory problems, weakened immune function, kidney and

liver damage, alteration of genetic material and development of lung cancer (Katz and Salem, 1994).

1.2.3.4 Manganese

Manganese (Mn) is considered an essential trace element for animals. Manganese is involved in many enzyme systems and in electron transport. In solution, it occurs as the Mn2+ ion. Under oxidizing conditions, most of the manganese precipitates as insoluble Mn02. Prolonged exposure of high levels of manganese negatively affects the central nervous system, visual reaction time, hand steadiness and eye-hand coordination (ATSDR, 1999)

Cellular effects of heavy metals

The toxicity of metals is often explained on the basis of their ability to cause the generation of oxygen and nitrogen-based reactants. Iron, chromium, aluminum, copper, vanadium and cobalt (Co) undergo redox cycling reactions thereby permitting massive free radical production. Mercury, Cadmium and Nickel have the ability to deplete the important endogenous antioxidant glutathione, and also to bind to sulfhydryl groups on proteins. Studies indicate that multifactorial mechanisms might be involved in metal-induced toxicity and it is evident that one of the prime mechanisms is metal-induced generation of reactive oxygen species (Sigel, 1999).

In a previous study conducted in Addis Ababa town, the total heavy metal levels in water samples taken from boreholes was higher when compared to that of water samples taken from springs from the same formation. This may be due to more residence time of the groundwater samples taken from boreholes. The movement of a particular metal into solution during weathering depends on the intensity of chemical weathering and the chemical strength of the particular water to dissolve the heavy metal. This is because of prolonged residence time and high degree of water-rock interaction (Alemayehu *et al*, 2005).

In a study conducted in Akaki River, Wide variations in the level of heavy metals were obtained spatially along the course of the river. The variability from upstream to downstream of the river could be due to the direct solid and liquid waste discharge from industrial, municipal and domestic activities, natural geologic deposits and wastes from agricultural practices which contribute significantly to the potential toxic elements load of the river. Most of elemental concentrations were decreased in the downstream sampling sites. These could be due to the

River water being diverted for irrigation purposes at different locations and input of unpolluted water from some of the tributaries that play a dilution role (Abdul *et al*, 2012).

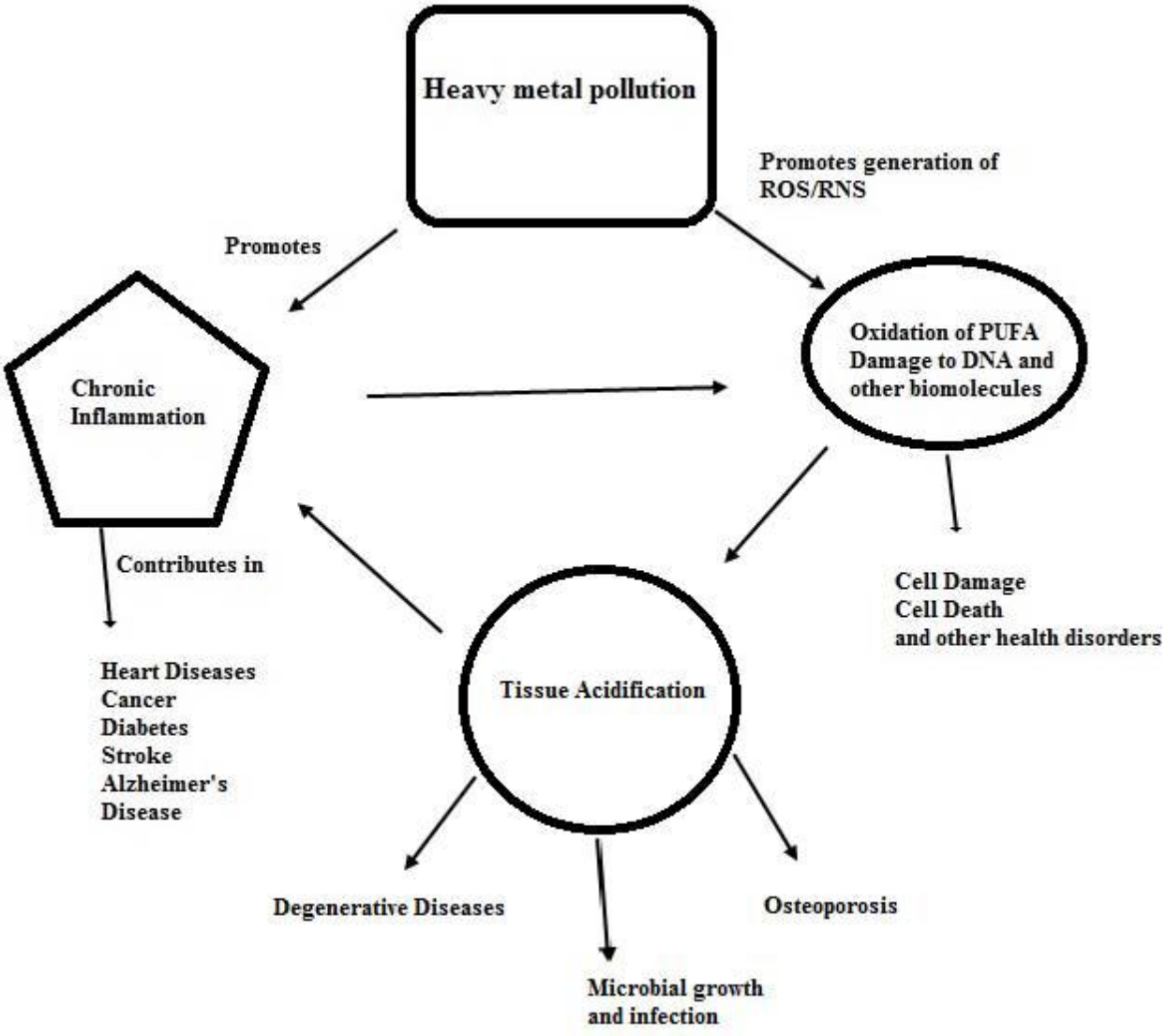

Figure 2- Cellular effects of heavy metal exposure (Fournie *et al*, 2001)

1.2.4 Principles of ICP-OES

The analysis of water samples by ICP-OES requires Decision to make regarding sample preparation, wavelength selection, preparation of standard solution and consideration of potential interferences. Once the samples and standards are prepared, the hardware is set up properly and the computer is programmed, the analysis can be started. The analyst usually starts by

introducing the first standard solution to the plasma and pressing a key on the computer. Assuming everything is found to be working properly, the analyst continues by introducing further standards (if used) and a blank solution to complete the calibration of the instrument (Dickensson and Fassel, 1969).

To generate plasma, first argon gas is supplied to the torch coil and high frequency electric current is applied to the work coil at the tip of the torch tube. Using the electromagnetic field created in the torch tube by the high frequency current, argon gas is ionized and plasma is generated. When plasma energy is given to the sample from outside, the component elements (atoms) are excited. When the excited atoms return to the low energy position, emission rays are released and the emission rays that correspond to the photon wavelength are measured. The type of element is determined based on the position of the photon rays. This plasma has high electron density and temperature (10000K) and this energy is used in the excitation-emission of the sample. Solution samples are introduced into the plasma in an atomized state through the narrow tube in the center of the torch tube. In OES, the intensity of the light emitted at specific wavelengths is measured and used to determine the concentrations of the elements of interest (Hasegawa and Hareguchi, 1992).

The advantages of OES over other spectroscopic techniques is that high temperature sources used in OES can populate a large number of different energy levels for several different elements at the same time. All of the excited atoms and ions can then emit their characteristic radiation at nearly the same time. This brings in the flexibility to choose from several different emission wavelengths for an element and the ability to measure emission from several different elements simultaneously (Hasegawa and Hareguchi, 1992).

Drinking water guidelines

Safe drinking-water, as defined by the Guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Those at greatest risk of waterborne disease are infants and young children, people who are debilitated and the elderly, especially when living under unsanitary conditions. Those

who are generally at risk of waterborne illness may need to take additional steps to protect themselves against exposure to water-borne pathogens (WHO, 2011).

Table 2: Guideline values of heavy metals in drinking water

Metal Name	USEPA (Maximum contaminant level)	WHO guideline value	BIS (Permissible limit)
Arsenic	0.01	0.01	0.05
Aluminum	0.05-0.2	NM	0.2
Boron	----	2.4	1.0
Cadmium	0.005	0.003	0.003
Chromium	0.1	0.05	0.05
Copper	1.3	2.0	1.5
Iron	0.3	NM	0.3
Lead	0.015	0.01	0.01
Mercury	0.002	0.006	0.001
Manganese	0.05	NM	0.3
Nickel	----	0.07	0.02
Selenium	0.05	0.04	0.01
Zinc	5.0	NM	15.0

*Values were expressed in mg/l. NM-- Not mentioned

* Source- Joint USEPA and WHO water quality standards, 2011

1.3. STATEMENT OF THE PROBLEM

The presence of high levels of heavy metals in drinking water has negative consequences on the health and wellbeing of human beings. Only a very small percentage (2.5%) of earth's total water coverage is clean and suitable for human consumption (Mendie, 2005). Heavy metals are the primary toxic pollutants which affects the quality and safety of drinking water (Nouri *et al*., 2006). Drinking water pollution due to accumulation of heavy metals is becoming a big problem in many countries. Frequent exposure to very low levels of heavy metals such as lead, cadmium

and chromium have been shown to have a cumulative adverse effects on humans because there is no any homeostatic mechanism that regulates the levels of these toxic substances. The quality of drinking water has now become a major area of concern worldwide (Peronnet, 2012).

Despite its immense role in human life, water is also a potential target for the transmission of a wide variety of human diseases. The pathogenesis of a broad range of human diseases such as; cholera, dysentery, typhoid fever, ring worms, skin irritation, and other illnesses is associated with the consumption and use of poor quality water supplies (Carter and Fernando, 1979).

Addis Ababa has a high population number and there is a growing concern over the quality of surface and ground drinking water. So, the presence of high levels of heavy metals in drinking water poses a potential threat to the health of the city residents due to extreme toxicity associated with these heavy metals (FMOH, 2007).

1.4 SIGNIFICANCE OF THE STUDY

Many literatures noted that accumulation of heavy metals in drinking water is one of the basic factors which compromise the quality of drinking water. Heavy metals in drinking water are very toxic to humans even in a very small concentration. Therefore, it is mandatory to assure the quality of drinking water in main distribution systems with regard to the concentration of these toxic heavy metals before the water is distributed to the general public. This study will provide scientific explanation about the concentration of toxic heavy metals in drinking water supply systems of Addis Ababa town. Furthermore, this study will provide baseline information for other researchers who are interested to conduct research regarding this topic.

2. OBJECTIVE

2.1 General objective

The general objective of this study is to determine heavy metal composition of drinking water supplied by pipe in different parts of Addis Ababa town, Ethiopia in 2010 E.C

2.2 specific objectives

- ✓ To determine the levels of heavy metals (Pb, Cd, Cr and Mn) in drinking water samples of Addis Ababa town.
- ✓ To compare the heavy metal composition of water samples of ground and surface water sources.
- ✓ To compare the heavy metal concentration between water originating from different treatment plants.
- ✓ To compare heavy metal composition of water samples taken from major treatment plants with those taken from household pipes.

3.0 METHODOLOGY

3.1 STUDY AREA

The study was conducted in Addis Ababa city administration. Addis Ababa is the capital city of the democratic republic of Ethiopia and the African continent. It is the center for many national and international organizations and institutions. Administratively it comprises of 10 sub- city administrations. Namely; Addis ketema, Lideta, Kirkos, Kolfe, Yeka, Bole, Gulele, Arada, Nefas silk Lafto and Akaki kality. Addis Ababa gets surface water supplies from the Legedadi, Gefersa and Dire dams. It also gets ground water supplies from the Akaki deep well system and other wells.

This study was conducted from April 2018 to December 2018 G.C.

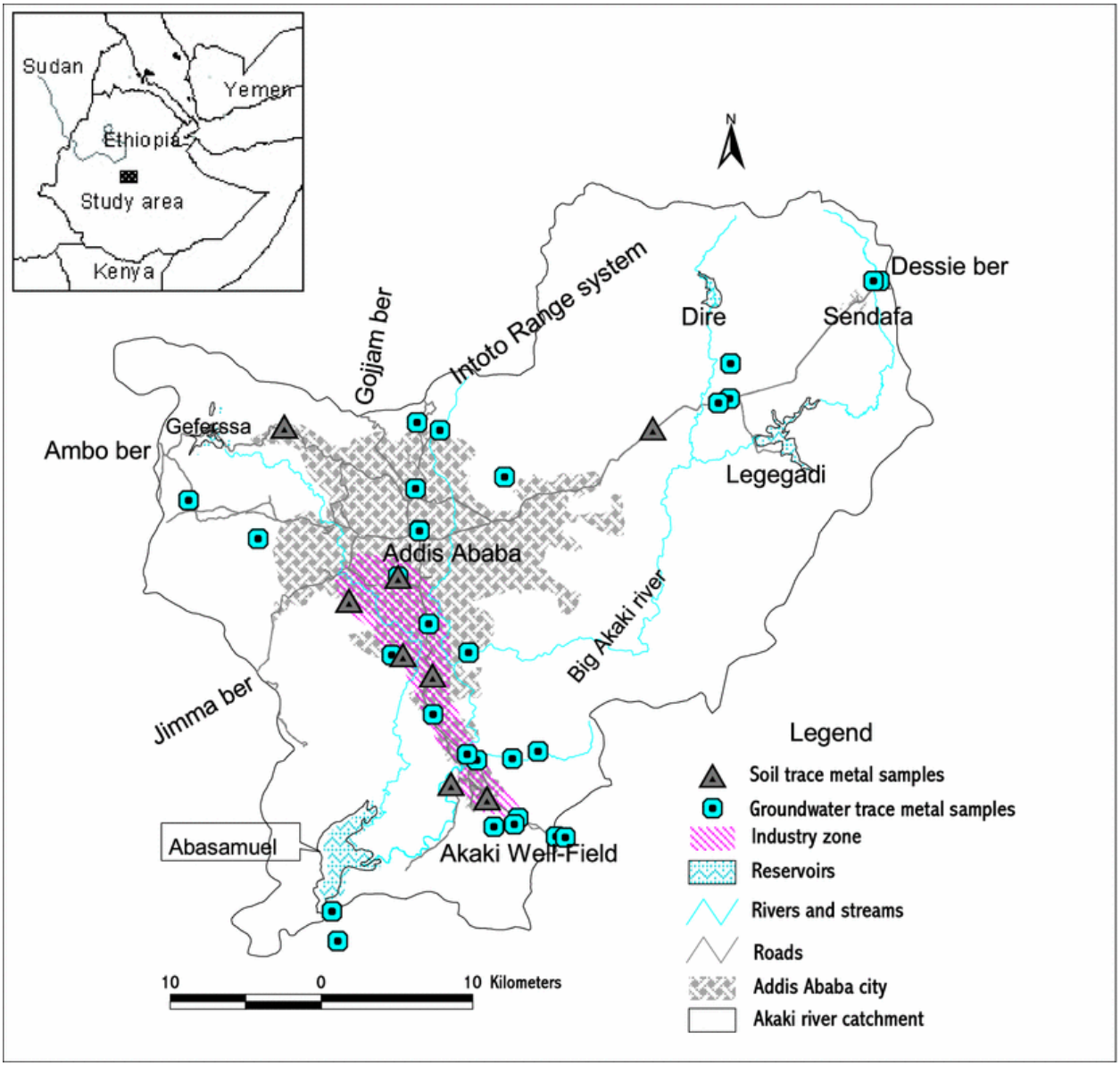

Figure 3: Geographic map of the study area (source; AAWSA, 2011)

3.2 Study design

A Community based cross-sectional study was conducted in order to investigate the heavy metal composition of drinking water supplied by pipe in different parts of Addis Ababa town with in the study period.

3.3 Sample population

Surface water Samples were collected from the Gefersa and the Legedadi reservoir dams and their respective catchments. Ground water samples were collected from the Akaki deep- well system and it's catchment area.

3.4 Sampling technique

Cluster sampling technique was used to collect water samples from reservoir sites and household pipes.

3.5 Sample size determination

A total of 12 drinking water samples were collected. 3 of the samples were collected from the 3 main treatment plants that supply almost the entire population of the town. The rest 9 representative samples were collected from household pipes at 9 different sites of the town.

3.6 Study variables

3.6.1 Dependent variables

- Concentration of heavy metals such as lead, cadmium, chromium and manganese in ground and surface water samples.

3.6.2 Independent variables

- Source of drinking water

3.7 Methods of data collection and processing

3.7.1 Methods of data collection

Water samples were collected from surface water of Gefersa and Legedadi reservoirs and ground water of the Akaki deep-well system and Legedadi reservoir well. Tap water samples were collected from different clusters of Addis Ababa town. Sampling was accomplished through pouring water samples in to a sterile small glass. Sample collection was mainly performed by the principal investigator.

Samples were contained in glass containers. To avoid potential contamination, sample containers were thoroughly washed with detergent and tap water.

For preservation purpose the samples were acidified with the addition of nitric acid and hydrochloric acid. After acidification, water samples were kept in a refrigerator at $4\ ^{0}_{C}$.

3.7.2 Laboratory tests

Inductively coupled plasma- optical emission spectroscopy (ICP-OES) was used to measure the concentration of heavy metals in drinking water samples collected from different parts of Addis Ababa town. Standard solutions of known metal concentrations in water were prepared in water with a matrix similar to that of the sample. Stock solutions of standards in concentrations above 500 mg/L were prepared and stored in a refrigerator.

3.7.2.1 Determination of Pb, Cd, Cr and Mn levels in water samples using ICP-OES

The concentrations of Pb, Cd, Cr and Mn metals were analyzed by using ICP-OES (Agilent 700 series, USA) with the main gas supply argon used as to the plasma, nebulizer and optics interface purge and also required to purge the poly-chromatic assembly with its purity: 99.996% and regulated with recommended flow rate: 0.7 to 0.32 L/min. 8 ml concentrated nitric acid and 2 ml concentrated hydrogen peroxide were added to the digestion tube containing the blank solution and the sample solution and digested in milestone start D microwave digester (Switzerland) with maximum temperature of $250\ ^{0}_{c}$ and pressure of 1200 psi for 15 minutes. Then the sample was diluted into 50ml Erlenmeyer flask and made up to the mark with 2% nitric acid solution. Then it was filtered through 0.45 micro meter pore diameter membrane filter to avoid any possible contamination. The samples were analyzed using the ISO 11885:2014 test method. Standard solutions were prepared from 99.99%, ICP grade standard. Six standard solutions were prepared (blank solution (0 ppm), 1ppm, 2ppm, 3ppm, 5ppm and 10ppm) by plotting calibration curve with recommended wavelength for each metal. The wavelength used was 226.499 for cadmium, 205.560 for chromium, 220.305 for lead and 257.610 for manganese. Due to its sensitivity and overall acceptability, the spectral interference was corrected and the prepared samples were run into the machine.

The instrument we used was highly sensitive. It has the ability to detect lead concentration up to 50 µg/l. It has a detection limit of 5µg/l for Cadmium, Chromium and Manganese. But the instrument can not detect these metals at concentrations below their respective detection limits mentioned above. Under such circumstances the result is reported as ‘’Below detection limit’’ for the metal under consideration.

3.7.2.2 Method validation

Sensitivity, limit of quantification, precision, linear dynamic range and interference corrections were established for each individual target analyte. Hence, the certified reference material has been used to observe accuracy. Analytical performance as accuracy was considerable high since the concentrations of all the element analyzed fell within in the range of given certified value. validation of the method was evaluated from precision experiments. Uncertainty of balance was calculated from data obtained from calibration certificates (declared uncertainty) and by repeatable weighing. After estimation, all sources of uncertainty were combined according to the law of propagation of uncertainties. A validated and accurate ICP – OES method was developed to estimate lead, cadmium, Chromium and manganese in drinking water samples. The method has been validated in terms of specificity, precision, linearity, accuracy and limit of quantification. The validated method can be used to estimate the level of lead, cadmium, chromium and manganese in water samples.

Table 3 - operating conditions for ICP-OES

Parameter	Condition
Plasma	Argon
Flow- rate	0.32- 0.7 L/min
Temperature	250 $^{0}_{c}$
Pressure	1200 psi

3.8 Data analysis

The collected quantitative data were coded, entered in a computer, processed, edited and analyzed using SPSS version 20. The results of heavy metal concentration in each sample were compared with the WHO recommended values.

3.9 Ethical consideration

Ethical clearance was obtained from Research and Ethics Committee of the Department of Biochemistry, School of Medicine, College of Health Sciences (meeting No. DRERC 08/18 and protocol No.: M.Sc. 02/18). Formal letter calling for collaboration from concerned bodies was written by the department.

3.10 Data quality assurance

Special emphasis was given to data quality assurance starting from data collection, laboratory testing, data entry and statistical analysis. The water samples were taken in a clean and neat manner. The sample containers were made free from any source of contamination in order to assure validation of results. The laboratory reagents and the instruments used were of standard quality. Results were checked for completeness on a daily basis by the principal investigator.

4. RESULTS

4.1 distribution of water samples based on main treatment plant

A total of 12 drinking water samples were taken from different parts of Addis Ababa town. 4/12(33.33%) of the samples were taken from the Akaki-deep well system (1) treatment plant and its catchment area (3), and 4/12(33.33%) of the samples were taken from the Legedadi surface water treatment plant (1) and its catchment area (3), while the rest 4/12(33.33%) samples were taken from the Gefersa surface water treatment plant (1) and its catchment area (3).

Table 4: Distribution of water samples based on catchment of actual main treatment plant, Addis Ababa, Ethiopia, 2018

Main treatment plant & catchment	**Number of samples**	**%**
Akaki deep-well system	**4**	**33.33**
Legedadi SWTP	**4**	**33.33**
Gefersa SWTP	**4**	**33.33**
Total	**12**	**100**

*SWTP= surface water treatment plant

4.2 Concentration of heavy metals (Lead, Cadmium, Chromium and Manganese) in water samples

4.2.1 Concentration of Lead

Lead concentration was measured in water samples collected from different parts of Addis Ababa town as depicted in figure 4. Lead concentration was 0.01 mg/l in Kirkos, 0.03mg/l in both Torhailoch& Bole, 0.04mg/l in both Alem bank & Merkato, 0.02mg/l in Megenagna, 0.06mg/l in both Gefersa treatment plant &Asko, 0.05mg/l in Kolfie. Lead concentration was below the detection limit in Akaki deep-well, Legedadi treatment plant and Piassa areas.

The mean level of Lead concentration was 0.028±0.003 mg/l in water samples collected from different parts of Addis Ababa town.

4.2.2 Concentration of Cadmium

Cadmium concentration was measured in water samples taken from different parts of Addis Ababa town as depicted in figure 4. Cadmium concentration was 0.01mg/l in samples from kolfie and Asko areas. Cadmium concentration was below the detection limit in samples taken from Akaki deep-well, Torhailoch, Alem bank, Legedadi, Piassa, Megenagna, Bole, Gefersa, Kolfie and Merkato areas.

The mean level of Cadmium concentration was 0.002±0.0003 mg/l in all water samples collected from different parts of Addis Ababa town.

4.2.3 Concentration of Chromium

Chromium concentration was measured in water samples taken from different parts of Addis Ababa town as depicted in figure 4. Chromium concentration was 0.01mg/l in samples from Akaki deep-well, Alem bank, Kolfie & Asko areas. Chromium concentration was below the detection limit in samples from Kirkos, Torhailoch, Legedadi, Megenagna, Piassa, Bole, Gefersa and Merkato areas. The mean level of Chromium concentration was 0.003±0.0004 mg/l in water samples collected from different parts of Addis Ababa town.

4.2.4 Concentration of Manganese

The concentration of manganese was measured in water samples taken from different areas of Addis Ababa town as shown in figure 4. Manganese concentration was 0.01mg/l in water samples of Megenagna and Merkato, 0.02 mg/l in water samples taken from Alem bank, Gefersa and Kolfie areas. Manganese concentration was below detection limit in water samples taken from Akaki deep-well, Kirkos, Torhailoch, Legedadi, Bole, Piassa &Asko areas. The mean level of manganese concentration was 0.007±0.0007 mg/l in water samples collected from different parts of Addis Ababa town.

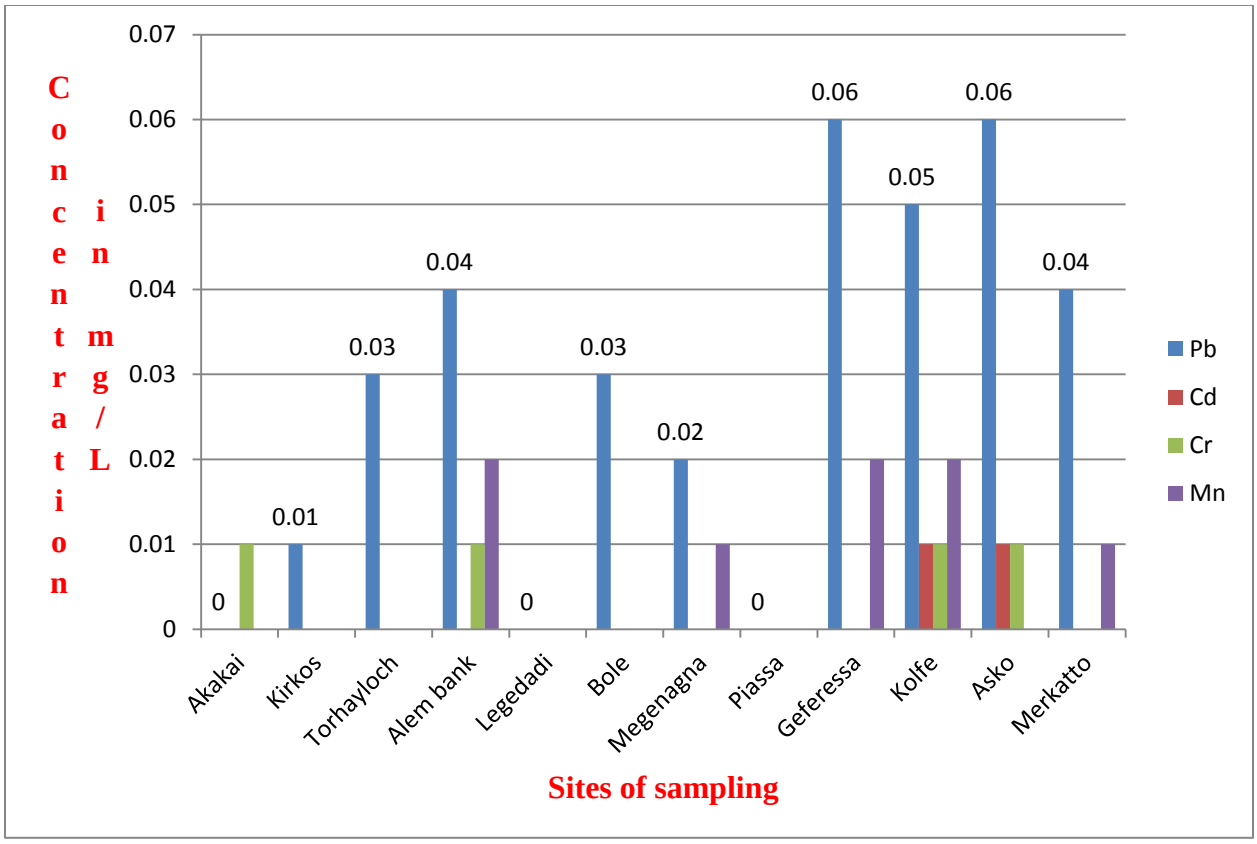

Figure 4: Bar chart showing concentration of heavy metals in different sampling sites of Addis Ababa, Addis Ababa, Ethiopia, 2018.

4.3 Estimation of the levels of heavy metals in ground and surface water samples

4.3.1 Comparison of Lead levels in ground and surface water samples

The level of lead was compared in ground and surface water samples. The mean concentration of lead in ground water samples was 0.02±0.009 mg/l and 0.03±0.008 mg/l in surface water samples (Table 5).

Independent sample t-test showed that there is no statistically significant difference in the mean levels of lead between ground and surface water samples (p-value>0.39)

Table 5: Comparison of lead levels in ground and surface water samples, Addis Ababa, Ethiopia,2018

Parameter	**Ground water samples (mean ±SD)**	**Surface water samples (mean ±SD)**	**p-value**
Pb (mg/l)	**0.02±0.009**	**0.03±0.008**	**0.39**

All values are expressed as mean ±Standard deviation. Pb = lead. Mg/l = milligram per liter

4.3.2 Comparison of Cadmium levels in ground and surface water samples

The level of cadmium was compared between ground and surface water samples. The mean concentration of cadmium was below the detection limit in ground water samples and 0.002±0.001 mg/l in surface water samples (Table 6).

Independent sample t-test showed that there is no statistically significant difference in the mean levels of Cadmium between ground and surface water samples (p- value>0.31)

Table 6: Comparison of cadmium levels in ground and surface water samples, Addis Ababa, Ethiopia,2018

Parameter	**Ground water samples (mean ±SD)**	**Surface water samples(mean ±SD)**	**p-value**
Cd (mg/l)	**BDL**	**0.002±0.001**	**0.31**

Values are expressed as mean ±Standard deviation. Cd = Cadmium. Mg/l = milligram per liter. BDL-Below detection limit

4.3.3 Comparison of Chromium levels in ground and surface water samples

The mean level of chromium was compared between ground and surface water samples. The mean concentration of chromium was 0.005 ±0.0002 mg/l in ground water samples and 0.002±0.0001 mg/l in surface water samples (Table 7).

Independent sample t-test showed that there is no statistically significant difference in the mean levels of chromium between ground and surface water samples (p- value>0.43).

Table 7: Comparison of Chromium levels in ground and surface water samples, Addis Ababa, Ethiopia, 2018

Parameter	Ground water samples(mean ±SD)	Surface water samples (mean ±SD)	p- value
Cr (in mg/l)	**0.005 ±0.0002**	**0.002±0.0001**	**0.43**

Values are expressed as mean ±Standard deviation Cr = Chromium. Mg/l = milligram per liter

4.3.4 Comparison of Manganese levels among ground and surface water samples

The mean manganese concentration was compared between ground and surface water samples. The mean concentration of manganese was 0.005 ±0.0001 mg/l and 0.007±0.0003 mg/l in surface water samples (Table 8).

Independent sample t-test showed that there is no statistically significant difference in the mean level of manganese concentration between ground and surface water samples (p- value>0.67).

Table 8: Comparison of Manganese levels in ground and surface water samples, Addis Ababa, Ethiopia,2018

Parameter	Ground water samples (mean ±SD)	Surface water samples(mean ±SD)	p- value
Mn (in mg/l)	**0.005 ±0.0001**	**0.007 ±0.0003**	**0.67**

Values are expressed as mean ±Standard deviation. Mn= Manganese. Mg/l= milligram per liter

4.4 Comparison of concentration of heavy metals in water samples taken from different treatment plants

4.4.1 Comparison of lead concentration in water samples of different treatment plants

The mean level of lead was compared between water samples taken from different treatment plants & respective catchment areas. The mean level of lead was 0.02±0.0018 mg/l in water samples taken from the Akaki deep well and its catchment area, 0.01±0.001 mg/l in water samples taken from the Legedadi surface water and its catchment area and it was 0.05±0.001 mg/l in water samples taken from the Gefersa surface water and its catchment area (Table 9).

Analysis of variance showed that there is a statistically significant difference in the mean levels of lead between water samples taken from major treatment plants and their respective catchments (p- value< 0.01).

Table 9: Analysis of variance of concentration of Lead in water samples taken from different treatment plants, Addis Ababa, Ethiopia, 2018

Parameter	**Akaki deep-well& catchment area(mean ±SD)**	**Legedadi SWTP& catchment area (mean ±SD)**	**Gefersa SWTP& catchment area (mean ±SD)**	**ANOVA P- value**
Pb (in mg/l)	**0.02±0.0018**	**0.01±0.001**	**0.05±0.001**	**0.01**

Values are expressed as mean ±Standard deviation. Pb= Lead. SWTP= Surface water treatment plant Mg/l= milligram per liter

4.4.2 Comparison of Cadmium concentration in water samples taken from different treatment plants

The mean levels of Cadmium were compared between water samples taken from different treatment plants & their respective catchment areas. The mean level of Cadmium was below the detection limit in water samples taken from the Akaki deep well system and its catchment area and in water samples taken from the Legedadi surface water and its catchment area and it was 0.005±0.0004 mg/l in water samples taken from the Gefersa surface water and its catchment area (Table 10).

Analysis of variance showed that there is no statistically significant difference in the mean levels of Cadmium between water samples taken from different catchment areas of major treatment plants (p- value> 0.1)

Table 10: Analysis of variance of concentration of Cadmium in water samples taken from different treatment plants, Addis Ababa, Ethiopia, 2018

Parameter	Akaki deep-well& catchment (mean ±SD)	Legedadi SWTP& catchment (mean ±SD)	Gefersa SWTP& catchment (mean ±SD)	ANOVA P-value
Cd (in mg/l)	**BDL**	**BDL**	**0.005±0.0004**	**0.1**

Values are expressed as mean ±Standard deviation. Cd= Cadmium. SWTP= Surface water treatment plant. Mg/l= milligram per liter. BDL= Below detection limit

4.4.3 Comparison of Chromium concentration in water samples taken from different treatment plants

The mean levels of Chromium were compared between water samples taken from different treatment plants & their respective catchment areas. The mean level of Chromium was 0.005±0.0004 mg/l in water samples taken from the Akaki deep well system and its catchment area. The Mean level of chromium was below the detection limit in water samples taken from the Legedadi surface water &its catchment area and it was 0.005±0.0002 mg/l in water samples taken from the Gefersa surface water and its catchment area (Table 11).

Analysis of variance showed that there is no statistically significant difference in the mean levels of Chromium between water samples taken from different catchment areas of major treatment plants (p- value> 0.27)

Table 11: Analysis of variance of Chromium concentration in water samples taken from different treatment plants, Addis Ababa, Ethiopia, 2018

Parameter	Akaki deep-well& catchment (mean ±SD)	Legedadi SWTP& catchment (mean ±SD)	Gefersa SWTP& catchment (mean ±SD)	ANOVA P-value
Cr (in mg/l)	**0.005±0.0004**	**BDL**	**0.005±0.0002**	**0.27**

Values are expressed as mean ±Standard deviation. Cr= Chromium. SWTP= Surface water treatment plant. Mg/l= milligram per liter. BDL-Below detection limit

4.4.4 Comparison of Manganese concentration in water samples taken from different treatment plants

The mean levels of Manganese were compared between water samples taken from different treatment plants & their respective catchment areas. The mean level of manganese was 0.005±0.0001mg/l in water samples taken from the Akaki deep well system and its catchment area. The Mean level of Manganese was 0.002±0.0004 in water samples taken from the Legedadi surface water &its catchment area and it was 0.01±0.001 mg/l in water samples taken from the Gefersa surface water and its catchment area (Table 12).

Analysis of variance showed that there is no statistically significant difference in the mean levels of manganese between water samples taken from different catchment areas of major treatment plants(p- value> 0.27)

Table 12: Analysis of variance of concentration of Manganese in water samples taken from different treatment plants, Addis Ababa, Ethiopia, 2018

Parameter	**Akaki deep-well& catchment (mean ±SD)**	**Legedadi SWTP& catchment (mean ±SD)**	**Gefersa SWTP& catchment (mean ±SD)**	**ANOVA P-value**
Mn (in mg/l)	**0.005±0.0001**	**0.002±0.0004**	**0.01±0.001**	**0.27**

*Values are expressed as mean ±Standard deviation. Mn= Manganese. SWTP= Surface water treatment plant Mg/l= milligram per liter.

4.5 Comparison of heavy metal concentrations between water samples taken from major treatment plants and pipe water samples in Addis Ababa.

4.5.1 Comparison of Lead concentration

The level of concentration of lead was compared between water samples taken directly from major treatment plants and tap water samples taken from individual households. The mean concentration of lead was 0.02±0.003 mg/l in water samples taken from major treatment plants and 0.03±0.002 mg/l in tap water samples taken from household pipes (Table 13).

Independent sample t- test showed that there is no statistically significant difference in the mean levels of lead between water samples taken from major treatment plants and water samples taken from household pipes(p-value>0.4).

Table 13: Comparison of Lead levels between water samples of major treatment plant and tap water samples, Addis Ababa, Ethiopia, 2018

Parameter	**Samples of treatment plants (mean ±SD)**	**Tap water samples (mean ±SD)**	**p- value**
Pb (mg/l)	**0.02±0.003**	**0.03±0.002**	**0.4**

Values are expressed as mean ±Standard deviation. Pb= Lead. Mg/l= milligram per liter.

4.5.2 Comparison of Cadmium concentration

The level of Cadmium was compared between water samples taken directly from major treatment plants and tap water samples taken from individual households. The mean level of Cadmium was below the detection limit in water samples taken from major treatment plants and 0.002±0.0001 mg/l in water samples taken from household pipes (Table 14).

Independent sample t- test showed that even though the mean level of cadmium in tap water sample is higher than water samples of major treatment plants, there is no statistically significant difference in the mean levels of Cadmium between water samples taken from major treatment plants and water samples taken from household pipes(p-value>0.4).

Table 14: Comparison of Cadmium levels between water samples of major treatment plant and tap water samples, Addis Ababa, Ethiopia, 2018

Parameter	**Samples of treatment plants (mean ±SD)**	**Tap water samples (mean ±SD)**	**p- value**
Cd (mg/l)	**BDL**	**0.002±0.0004**	**0.4**

Values are expressed as mean ±Standard deviation. Cd= Cadmium. Mg/l= milligram per liter. BDL= below detection limit

4.5.3 Comparison of Chromium concentration

The level of Chromium was compared between water samples taken directly from major treatment plants and tap water samples taken from individual households. The mean level of Chromium was 0.003±0.0003 mg/l in water samples taken from major treatment plants and 0.003±0.0005 mg/l in tap water samples taken from household pipes (Table 15).

Independent sample t- test showed that there is no statistically significant difference in the mean levels of Chromium between water samples taken from major treatment plants and water samples taken from household pipes (p-value>0.9).

Table 15: Comparison of Chromium levels between water samples of major treatment plant and tap water samples, Addis Ababa, Ethiopia, 2018

Parameter	**Samples of treatment plants (mean ±SD)**	**Tap water samples (mean ±SD)**	**p- value**
Cr (mg/l)	**0.003±0.0003**	**0.003±0.0005**	**0.9**

*Values are expressed as mean ±Standard deviation. Cr= Chromium. Mg/l= milligram per liter.

4.5.4 Comparison of Manganese concentration between water samples of major treatment plant and tap water samples.

The level of Manganese was compared between water samples taken directly from major treatment plants and tap water samples taken from individual households. The mean level of Manganese was 0.006±0.001 mg/l in water samples taken from major treatment plants and 0.007±0.002 mg/l in tap water samples taken from household pipes (Table 16).

Independent sample t- test showed that there is no statistically significant difference in the mean levels of Manganese between water samples taken from major treatment plants and water samples taken from household pipes(p-value>0.9).

Table 16: Comparison of concentration of Manganese between water samples of major treatment plant and tap water samples, Addis Ababa, Ethiopia, 2018

Parameter	**Treatment plants**	**Tap water**	**p- value**
Mn in (mg/l)	**0.006±0.001**	**0.007±0.002**	**0.9**

5. DISCUSSION

Water is one of the natural resources that support the existence of human beings and other living Organisms on earth (Musa *et al*, 2013). Water pollution is the leading worldwide cause of deaths and disease and it accounts for the deaths of more than 14,000 people daily (Larry, 2006). Accumulation of heavy metals in living organism can be toxic and carcinogenic due to their non-biodegradable nature. So, water quality management and assessment with regard to levels of heavy metal is of prime importance. The overall water quality status and identification of source of origin of heavy metals are required for water quality management (Bodaghpour *etal*,2012).
In this study the levels of heavy metals such as lead, cadmium, chromium and manganese in drinking water samples were determined in order to evaluate the quality of drinking water in Addis Ababa town. The levels of lead, cadmium, chromium and manganese were determined in 12 water samples taken from ground and surface water sources of Addis Ababa town.

Lead is the most significant of all the heavy metals because it is toxic and very common and harmful even in small amounts. Lead is a toxic metal whose high potency makes it a dangerous environmental threat to human health (Gregoriadou *et al*., 2001).

In the present study the mean lead concentration of the total water samples was 0.028 mg/l. This finding is in line with Ullah *et al*. (2009) and Mebrahatu and Zerabuk (2011). Ullah and his colleagues (2009) reported lead level of 0.81mg/l in water samples taken from industrial area of Pakistan (Ullah *et al*., 2009). Another study done in Tigray region, Ethiopia, by Mebrahatu and Zerabuk, (2011) has found lead levels of 1.347 mg/l in drinking water samples taken from indasilase (Mebrahatu and Zerabuk, 2011). However, our finding is higher than the Maximum admissible limit(MAL) of lead in drinking water set by WHO of 0.01mg/l (WHO, 2011), but lower than the USEPA maximum contaminant level(MCL) of 0.1mg/l(USEPA, 2010).The possible explanation for this finding may be due to the elevated concentration of Lead ion as a result of composed manure deposited on the farms around the study area or it might be as a result of used littered petrol in cars and water pumps (Jarup, 2003, Barbee and Prince, 1999). Rajkovic and his colleagues (2008) suggested that high concentration of lead in the stream could be due to weathering and leaching of lead from waste rock and dumps (Rajkovic *et al*, 2008). Nkansah and his colleagues (2011) also suggested that the Source of lead in water sources could be from

inappropriate disposal of waste from lead-acid batteries, metallic alloy, lead-based paints, used oil, waste incineration, scrap and junk auto parts (Nkansah *et al*, 2011).

In our study, even though it is not statistically significant, the mean level of lead in surface water samples(0.03 mg/l) was higher than the mean lead levels of ground water samples of 0.02 mg/l (p-value>0.39) . Our finding agreed with studies done by Nkansah *et al.*, (2011) ; Nouri *et al*., (2006) and mokuku *et al*.,(2002). However, both surface and ground water lead levels are higher than the Maximum admissible limit set by WHO at 0.01 mg/l (WHO, 2011), but lower than the USEPA Maximum contaminant level of 0.1 mg/l (USEPA, 2010).
The possible explanation for this finding may be due to junk auto spare parts that are coated with oil or grease, which may contain lead residues that create harmful storm water runoff and leachates from these wastes via storm water run-off may be released directly into the streams(Nouri *et al*., 2006). Mokuku and his colleagues, (2002) also suggested that the relatively high levels of lead in surface water may be due to mobilization of lead from sediments and leaching of lead from waste rocks (mokuku *et al*, 2002).

In the present study a statistically significant difference in the mean lead levels of major treatment plants & respective catchments was observed (p- value<0.01). The mean lead levels of the Gefersa surface water treatment plant and its catchment area (0.05 mg/l) was higher than that of samples of the Akaki deep well system & catchment (0.02 mg/l) and Legedadi surface water treatment plant and its catchment (0.01 mg/l). This finding is in line with Barbee and Prince (1999) and Obioha *et al* (2010). Mean lead levels of Akaki deep well system and the Gefersa surface water treatment plant and their catchments area are higher than the MAL of lead in drinking water by WHO at 0.01 mg/l, but the mean lead level of the Legedadi surface water treatment plant and its catchment is similar to the WHO Maximum admissible limit of lead in drinking water (WHO, 2011), but all the three values are below the USEPA maximum contaminant level of lead in drinking water at 0.1 mg/l (USEPA, 2010).

The possible justification for high levels of lead in the catchment area may be due to the practice of mining and other anthropogenic activities in the catchment area (Obioha *et al*, 2010). Barbee and prince, (1999) also stated that the high concentration of Lead in the study area may be a

result of composed manure deposited on the farms around the study area (Barbee and Prince, 1999). Alemayehu and his colleagues also suggested that prolonged residence time and high degree of water-rock interaction may be responsible for higher level of heavy metals (Alemayehu *et al*, 2005).

In this study even though it is not statistically significant, the mean lead levels of tap water samples taken from household pipes (0.03 mg/l) is higher than the mean lead levels of water samples taken directly from major treatment plants of 0.02 mg/l (p-value>0.4). Our finding agreed with Sartor *et al*., (1981) and Wongsasuluk *et al*., (2014). The mean lead levels of both tap water samples and water samples of the major treatment plant are higher than the Maximum admissible limit of lead in drinking water by WHO at 0.01 mg/l (WHO, 2011), but these values are below the maximum contaminant level set by USEPA at 0.1 mg/l lead levels in drinking water (USEPA, 2010).

Sartor and his colleagues, (1981) suggested that Lead pipes used in the older parts of the study area may be the possible cause of elevation of lead levels in tap water (sartor *et al,* 1981). They also stated that in households which use plastic pipes, plastic pipes which are in close contact with their domestic rubbish dumps may be responsible for the increase in lead concentrations in tap water (sartor *et al,* 1981). Salem and his colleagues, (2000) suggested that Lead in pipe borne water sources could be due to breakages and leakages in PVC piping which allows lead-containing leachate into pipe borne water within the study area (Salem *et al*. 2000).

Frequent exposure to Cadmium can lead to obstructive lung disease and has been linked to lung cancer and may result in bone defects. Cadmium exposure is also associated with kidney damage (Adelekan and Abegunde, 2011)

In this study the mean level of cadmium in water samples collected from different parts of Addis Ababa town was 0.002 mg/l. This value is lower than the maximum admissible limit of cadmium in drinking water set by WHO at 0.003 mg/l (WHO, 2011) and the USEPA maximum contaminant level of cadmium in drinking water at 0.005 mg/l (USEPA, 2010). This finding is in agreement with Kodom *et al*., (2009); Espeby and Gustafsson, (2001) and Kithiia, (2006). The possible justification for this finding may be due to dilution effect from run off as well as absorption by sediments in surface waters (kithiia, 2006). Kodom and his colleagues (2009) also

suggested that lower levels of cadmium in hand dug wells and hand pump wells may be due to adsorption processes occurring in soil surfaces (Kodom *et al*., 2009).

In our study even though it is not statistically significant, the mean level of cadmium in surface water samples(0.002 mg/l) was higher than the mean level of cadmium in ground water samples(p- value>0.31). The mean level of cadmium in ground water samples was below the detection limit. The meal levels of cadmium in both surface and ground water samples are lower than the maximum admissible limit of cadmium in drinking water set by WHO at 0.003 mg/l (WHO,2011) and below the USEPA maximum contaminant level of cadmium in drinking water at 0.005 mg/l (USEPA, 2010). Our finding agrees with Espeby and Gustafsson, (2001); Asubiojo *et al*., (1997) and Kodom *et al*., (2009). The possible reason for lower levels of cadmium may be due to the effect of surface adsorption of cadmium in ground water sources (Kodom *et al*., 2009).

In the present study although there is no statistically significant difference between the cadmium levels in different treatment plants, the mean levels of cadmium concentration of the Gefersa surface water treatment plant &its catchment area is higher than that of the Akaki deep well and the Legedadi surface water treatment plant and their catchments (p- value >0.1)). The mean levels of cadmium were below the detection limit for samples of the Akaki deep well and the Legedadi surface water treatment plant and their respective catchment areas. However, the mean level of cadmium was 0.005 mg/l in water samples of the Gefersa surface water treatment plant and respective catchment area, which is higher than the maximum admissible limit of cadmium in drinking water set by WHO at 0.003 mg/l (WHO,2011) but congruent with the USEPA maximum contaminant level of cadmium in drinking water at 0.005 mg/l (USEPA, 2010). This finding is in agreement with studies done by Asamoah and Boateng, (2009) and Duruibe *et al*., (2007). The possible justification for our finding may be due to the disposal of waste and industrial effluents containing cadmium and cadmium related compounds, waste batteries and paints to the study area (Kodom *et al*., 2009). Nassef and his colleagues, (2006) also suggested that industrial activities such as electroplating, pigments, plastics, stabilizers and battery industries may be the possible causes of elevation of cadmium levels in water samples of the study area (Nassef *et al*. 2006).

In this study the mean level of cadmium in water samples taken directly from the treatment plants was below the detection limit. The mean level of cadmium concentration of tap water samples taken from individual households was 0.002 mg/l.

There was no statistically significant difference in the mean levels of cadmium between water samples taken directly from treatment plants and tap water samples taken from individual households (p-value>0.4) . The mean level of cadmium in both treatment plants and tap water samples was lower than the maximum admissible limit of cadmium in drinking water set by WHO at 0.003 mg/l (WHO,2011) and are also lower than the USEPA maximum contaminant level of cadmium in drinking water at 0.005 mg/l (USEPA, 2010). This finding is in agreement with a study done by Mebrahtu and Zerabruk, (2011) in Tigray region Ethiopia, which reports a cadmium level of 0.002 mg/l in drinking water. This finding is also in line with a study done by Selinus and alloway, (2005).

The possible justification for this finding may be due to dilution effect from surface run off as well as absorption by sediments in surface waters (kithiia, 2006). Kodom and his colleagues, (2009) also suggested that lower levels of cadmium in hand dug wells and hand pump wells may be due to adsorption processes occurred in soil surfaces (Kodom *et al*., 2009).

Sub chronic and chronic exposure to chromium can cause dermatitis and ulceration of the skin. Long-term exposure can cause kidney, liver, circulatory and nerve tissue damages. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high level of chromium (Pandey et al., 2010).Chromium in drinking water is mainly a result of industrial waste. However, natural sources have been reported by a number of investigators (Ball and Izbicki, 2004).

In our study we have found that the mean level of chromium in water samples collected from different parts of Addis Ababa town was 0.003 mg/l. This value of chromium is below the maximum admissible limit of chromium in drinking water set by WHO at 0.05mg/l (WHO,2011) and it is also lower than the USEPA maximum contaminant level of chromium in drinking water set at 0.1mg/l (USEPA, 2010). Our finding is in line with a study done by Raji *et al*., (2010). It also agreed with a study done by Adelekan and Abegunde ,(2011) in Ibadan, Nigeria which showed that chromium concentration in hand-dug wells were lower than the limits set by WHO

guideline for drinking water (Adelekan and Abegunde ,2011). This finding is also in agreement with studies done by Mebrahatu and Zerabruk, (2011) in Tigray region, Ethiopia. They found that chromium concentration was below the WHO maximum admissible limit in water samples taken from Indasilase, Axum, Adwa, and Enticho towns (Mebrahatu and Zerabruk, 2011). The possible explanation for this finding may be the limited extent of industrial activity in the study area(Adelekan and Abegunde, 2011).

In this study although it is not statistically significant, the mean level of chromium concentration of ground water samples (0.005mg/l) was higher than 0.002 mg/l of surface water samples (p-value>0.43). The mean level of chromium for both ground and surface water samples was below the maximum admissible limit of chromium set by WHO at 0.05mg/l(WHO,2011) and is also below the USEPA maximum contaminant level of chromium in drinking water set at 0.1 mg/l(USEPA, 2010). Our finding is in agreement with Dayan and Paine, (2001) and Mebrahatu and Zerabruk, (2011).

The possible justification for the relative increment of chromium levels in ground water samples compared to that of surface water samples may be due to infiltration of surface water which results in the leaching of heavy metals through the soil and finding their way into underlying groundwater (Jarup *et al*, 1998).

In the present study there is no statistically significant difference in the mean levels of chromium among water samples taken from the major treatment plants and their respective catchment area (p-value>0.27). The mean levels of chromium was 0.005mg/l in water samples taken from the Akaki deep well& it's catchment, 0.005 mg/l in water samples taken from the Gefersa surface water treatment plant& it's catchment and it was below the detection limit in water samples taken from the Legedadi surface water treatment plant& it's respective catchment area. These values of chromium are below the maximum admissible limit of chromium in drinking water set by WHO at 0.05 mg/l(WHO, 2011) and are also below the USEPA maximum contaminant level of chromium in drinking water set at 0.1 mg/l(USEPA,2010). This finding is in agreement with studies done by Adelekan and Abegunde, (2011) and Yadav *et al.,(*2011).

The possible justification to this finding may be due to limited extent of industrial activity in the study area (Adelekan and Abegunde, 2011).

In our study we have found that there is no statistically significant difference in the mean levels of chromium in water samples directly taken from treatment plants and tap water samples taken from individual households(p- value>0.9). The mean level of chromium was 0.003mg/l for both water samples of major treatment plants and tap water samples. These values are found to be lower than the maximum admissible limit of chromium in drinking water set by WHO at 0.05mg/l(WHO,2011) and are also lower than the USEPA maximum contaminant level of chromium in drinking water set at 0.1 mg/l (USEPA, 2010). Our finding is in line with Adelekan and Abegunde ,(2011); Yadav *et al.,(*2011); Bakraji and Karajo, (1999) and a study done by Mebrahatu and Zerabruk, (2011) in Tigray region of northern Ethiopia showed chromium concentration of below MAL of chromium in drinking water by WHO (Mebrahatu and Zerabruk, 2011).

The possible reason for this finding might be due to limited availability of Ophiolite rocks in the study area which are capable of generating a wide range of chromium and chromium derivative compounds (Fantoni et al., 2002). Adelekan and Abegunde, (2011) also suggested that the limited extent of industrial activity and limited extent of industrial wastes in the study area might be responsible for the decreased level of chromium in water samples (Adelekan and Abegunde, 2011).

Manganese is an essential micronutrient required by living organisms and is essential in glucose utilization (WHO, 2011). Concentrations of greater than 0.1 mg/l in drinking water can cause undesirable taste but the WHO has a 0.4 mg/l health based guideline value and at concentrations above 0.4 mg/l, manganese can be toxic and exposure to high concentrations may lead to neurological impairment (WHO, 2011).

In this study the mean level of manganese in water samples taken from different areas of Addis Ababa town was 0.007mg/l. This value is below the maximum admissible limit of manganese drinking water set by WHO at 0.4 mg/l (WHO,2011). This value is also lower than the USEPA maximum contaminant level of manganese in drinking water set at 0.05 mg/l (USEPA, 2010). This finding is in agreement with studies done by Jarup, (2003) and Mebrahatu and Zerabruk, (2011).

The possible justification for Low levels of manganese in this study may be due to dilution of dissolved manganese in surface and ground water sources (Anita *et al.,* 2010).

In the present study it has been found that no statistically significant difference in the mean levels of manganese exists between ground water samples and surface water samples (p-value>0.67). The mean level of manganese was 0.005 mg/l for ground water samples and 0.007 mg/l for surface water samples. The mean levels of manganese of both ground and surface water samples were found to be below the maximum admissible limit of manganese in drinking water set by WHO at 0.4 mg/l (WHO,2011) and are also lower than the USEPA maximum contaminant level of manganese in drinking water set at 0.05 mg/l (USEPA,2010). This finding is in agreement with studies done by Ademoroti, (1996) and Mebrahatu and Zerabruk, (2011). The possible explanation for this finding might be due to the influence of water waves in surface waters and rainfall in both surface and ground water resulting in extensive dissolution of manganese ions (Anita *et al.,* 2010)

In this study we found that no statistically significant difference in the mean levels of manganese exists between water samples taken from major treatment plants and their respective catchment areas (p-value>0.27). The mean levels of manganese was 0.005 mg/l in Akaki deep well& it's catchment; 0.002 mg/l in Legedadi surface water treatment plant and it's respective catchment and it was 0.01 mg/l in Gefersa surface water treatment plant and it's catchment area. These mean values of manganese concentration in water samples of major treatment plants and corresponding catchment area were found to be below the maximum admissible limit of manganese concentration in drinking water set by WHO, which is 0.4 mg/l (WHO,2011) and also lower than the USEPA maximum contaminant level of manganese in drinking water set at 0.05 mg/l (USEPA,2010). This finding is in agreement with studies done by Wachira, (2007); Alaa and Osman, (2010) and Mebrahatu and Zerabruk, (2011). Alaa and Osman, (2010) reported manganese concentration of 0.033-0.14mg/l in water samples taken from Nile river (Alaa and Osman, 2010). The possible explanation for this finding might be due to oxidation of manganese at adsorption sites because removal of manganese is facilitated by passing water through high surface area adsorbent (Lloyd *et al*., 1983).

In the present study it has been found that there is no statistically significant difference in the mean levels of manganese between water samples taken directly from major treatment plants and tap water samples taken from individual households (p-value>0.9).The mean level of manganese was 0.006 mg/l for water samples directly taken from treatment plants and 0.007 mg/l for tap water samples taken from individual households. The mean levels of manganese in both water samples of treatment plants and tap water samples were found to be below the maximum admissible limit of manganese in drinking water set by WHO at 0.4 mg/l (WHO,2011) and also lower than the USEPA maximum contaminant level of manganese in drinking water set at 0.05 mg/l (USEPA,2010). This finding is in agreement with studies done by Wachira, (2007); Alaa and Osman, (2010) and Mebrahatu and Zerabruk, (2011). The possible justification for lower levels of manganese in both water samples of treatment plants and tap water samples may be due to oxidation of Manganese by chlorine during the process of water treatment in treatment plants and other distribution systems (Lloyd *et al*., 1983).

6. CONCLUSION

The present study demonstrated the heavy metal composition of water samples taken from different areas of Addis Ababa town. This study showed that the mean levels of lead in water samples taken from different areas of Addis Ababa town was higher than the maximum admissible limit of lead in drinking water set by WHO in 2011. The mean lead levels of both water samples taken from the ground and surface water sources were found to be higher than the maximum admissible limit of lead in drinking water set by WHO in 2011.

There was a statistically significant difference in the mean levels of lead in water samples taken from major treatment plants and their respective catchment areas ($p\text{-value}<0.01$). The mean lead level was higher than the maximum admissible limit of lead in drinking water set by WHO in 2011 in water samples taken from both the Akaki deep well and the Gefersa surface water treatment plant and respective catchment areas.

The mean lead levels of water samples taken directly from treatment plants and tap water samples taken from individual household pipes were higher than the maximum admissible limit of lead in drinking water set by WHO in 2011.

The mean levels of cadmium concentration was higher than the maximum admissible limit of Cadmium in drinking water set by WHO in 2011 in water samples of the Gefersa treatment plant and it's respective catchment area.

This study also showed that the mean levels of lead, cadmium, chromium and manganese in water samples taken from different areas of Addis Ababa town were lower than the maximum contaminant level of lead, cadmium, chromium and manganese set by USEPA in 2010.

7. RECOMMENDATION

We would like to recommend the Addis Ababa water and sewerage authority and other responsible authorities to develop reliable and sustainable drinking water treatment techniques and strategies which can reduce the current levels of heavy metals.

We also would like to recommend Addis Ababa water and sewerage authority to perform water quality monitoring and evaluation regarding possible contaminants, including heavy metals as frequent as possible.

We would like to recommend Addis Ababa city administration to design and implement safe and healthy waste handling and disposal strategies in order to prevent potential contamination of drinking water sources.

It is also recommended that routine environmental investigation including frequent supervision of distribution systems and check up and maintenance of pipe-line breakages and controlling and managing the waste disposal systems of factories and industries is of prime importance for the provision of safe drinking water.

Furthermore, we would like to recommend further that a thorough study should be conducted regarding other physical, chemical and biological parameters of drinking water.

8. STRENGTH AND LIMITATIONS OF THE STUDY

8.1 Strength of the study

Evaluation of heavy metal levels in drinking water supplied by pipe in different parts of Addis Ababa town was attempted for the first time in Addis Ababa.

Therefore, this study will provide baseline information for further study on heavy metal composition of drinking water in Addis Ababa and other areas of the country.

8.2 Limitations of the study

Financial constraint was the major limitation in this study affecting the sample size considered and the numbers of heavy metals analyzed.

The present study does not evaluate the physical, chemical and biological parameters of drinking water.

The sample size considered was small and cross-sectional. The cost of reagents and laboratory analysis were expensive, so that we have limited ourselves to 12 water samples and the number of heavy metals that would have been analyzed were also proportionately limited.

Seasonal variation of heavy metals in drinking water sources was not evaluated.

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10. ANNEXES

10.1 Declaration

I, Anemut Tilahun Mulu, declare that this research paper entitled ‘Evaluation heavy metal composition of drinking water supplied by pipe in different parts of Addis Ababa town, which I hereby submit for the degree of master of science in medical Biochemistry at Addis Ababa University, is my original work and has not previously been submitted for any degree in any other University. All sources of materials used for this research have been fully acknowledged.

Anemut Tilahun Mulu

Signature_____

Date_____