ADDIS ABABA UNIVERSITY

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ASSESSMENT OF LEAD CONTAMINATION VIA SOIL AND TAP WATER IN ADDIS ABABA DAYCARES

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Assessment of Lead Contamination via Soil and Water in Addis Ababa Daycares

By: Eden Belete

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Abstract

Lead exposure can come from different environmental media soil, water and air impose negative health effects if ingested by humans, children's are the most vulnerable. The objective of the study were to investigate i) lead level in water and soil of daycares facilities in Addis Ababa, ii) lead level in water sources (both surfaces and ground water) that supply water sources to Addis Ababa city. Graphite Furnaces Atomic Absorption Spectroscopy were used to analyze the concentration of lead in soil and tap water of 28 day cares. Samples were taken from 11 sub cities, sample size were determined based on the number of daycares in each sub city. Sample from sources (ground and surfaces) of water supply were also analyzed. The result indicated that the mean level of lead in soil and water of day cares were 2.37 and 8.26µg/l are within the permissible value of 10µg/L according to WHO standard. The result from sources of water shows that the lead level in surfaces water sources before treatment were above the permissible value (10µg/L) whereas the ground water sources were within in the acceptable limits . Integrated exposure uptake bio-kinetic model were used to determine the blood lead level of children's below 4 year of age. The mean blood lead level were 1.78µg/dl. Even if the BLL were below the blood reference value of 3.5µg/dl (according to CDC) there is no safe blood lead level value low lead level can have adverse effects in children. Lead level in drinking water from daycare centers is greater than the lead concentration from water sources this shows that there is sources of lead in between water sources and daycare tap water.

KEY WORDS: Lead exposure, Blood Lead Level, Water, Soil, Daycare, Addis Ababa

Declaration

1. The undersigned declare that this thesis is my original work performed under the supervision of research advisor Dr. Zerihun Getaneh and has not been presented as a thesis for a degree in any other university in Ethiopia .All Sources of materials used for this thesis have also been duty acknowledged.

Name: Eden Belete

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And to my companion and husband Wendesen Seid, thank you for being in this Journey with me.

Abbreviation

AAWSA	Addis Ababa Water and Sewerage Authority
ADHA	Attention Deficiency Hyper Active Disorder
ASTRD	Agency for Toxic Substances and Disease Registry
BLL	Blood Lead Level
BMD	Bone Mineral Density
CDC	Center for Disease Control
CSA	Central Statistical Agency
Dl	deciliter
GFAAS	Graphite Furnaces Atomic Absorption Spectroscopy
HIC	High Income Countries
IARC	International Agency for Research on Cancer
IEUBK	Integrated Exposure Uptake Bio-Kinetic
IQ	Intelligences Quotient
Km	kilometer
LMICs	Low and Middle Income Countries
Ml	milliliter
PAHO	Pan America Health Organization
Pb	Lead
PH	Potential of Hydrogen
USEPA	United State Environmental Protection Agency
WHO	World Health Organization
µg	microgram

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Chapter One: Introduction

1.1. Background

Exposure to environmental hazards is a measure of health effects in children. The WHO estimates that over 30% of global disease in children can be caused by environmental hazards. Children, like adults, may be exposed to chemicals through the air they breathe, the water they drink, the foods they eat, and the surfaces and materials they contact. Children also have unique routes of exposure, through placental exposure for the developing fetus and ingestion of breast milk for infants. Because of their unique physiology and behavior, children’s exposures may be higher than those of adults; as a result, children may have greater health risks than adults in the same environments (WHO, 2006).

Lead is a naturally occurring heavy metal (bluish-grey in color, but it tarnishes quite easily in the air into a darker gray color) that can be found in the Earth's crust, especially where volcanic activities and geochemical weathering occur. Within the environment, lead can be found in atmospheric suspended particles, water, soil, and biota in general. It has a low melting point, is easily molded and shaped, and can be combined with other metals to form alloys. For these reasons, lead has been used by humans for decades and is widespread today in a multitude of products. Human activities related to lead release into the environment include, but are not limited to, mining, smelting, refining, and informal recycling of lead; use of leaded gasoline; production and recycling of lead-acid batteries and paints; soldering; ceramics manufacturing; electronic waste; and lead use in (old) water pipes (PAHO, 2013).

Children can be exposed to lead contamination from environmental media. This environmental medium can be Air, soil, dust, or drinking water. Lead found in the air might be from leaded gasoline that is used for vehicles; lead present in soil or dust might be from lead paints or from point sources such as smelters and recycling plants. Lead in drinking water could be found in plumbing fixtures, old pipes, and leaded pipes. But these are not the only contributing factors to lead contamination in canned foods and spices, which can also be sources of lead contamination in children.

The majority of African countries identified on-going lead-related public health concerns. These sources of lead contamination in African countries are: gasoline (lead gasoline), even if it was banned, it's still available for aviation purposes; lead paint; lead in toys; lead paint on playgrounds; occupational exposure to lead; for example, people who work in garages and mining fields are exposed to lead contamination; around 20 to 25 million tons of electronic waste (e-waste) annually produced in developed countries and transported to developing countries like Asia and Africa; this led to more contamination of lead in the content; traditional brews, foods, and cosmetics contribute to lead contamination (WHO, 2015).

Children from low socioeconomic backgrounds are commonly exposed to lead contamination. Children absorb 50% of the lead they ingest, but adults absorb only 10%. This will make children more susceptible to lead contamination than adults. A child's brain is more sensitive than an adult's because it is not fully developed yet, and exposure to lead may have an adverse effect on the child's development (Parhoudeh, 2018).

Several studies indicate that low blood lead levels will affect children less than five years old. It can have adverse effects such as lower intelligence, Attention-deficiency hyperactivity disorder (ADHA), and an increase in respiratory problems at an early age (Cheng et al., 2022; Vafaee-Shahi et al., 2022; Brown et al., 2022). Due to lead exposure, children are prone to reduced cognitive potential (loss of IQ), which will result in an economic loss of $134 billion for the African continent; the highest total loss in economic productivity is in Egypt and South Africa with $17.7 and $17.8 billion, respectively (Attiana et al., 2013).

Blood lead levels will affect the future of children in general and the future of the next generation. The aim of the current study is to determine lead contamination in drinking water and in soils in Addis Ababa city daycare facilities and to estimate blood lead levels found in children using environmental media data as an input. Lead levels in water sources were also determined to identify if there is a connection between tap water in daycares and sources of water.

1.2. Statement of the Problem

Preschool-age children and fetuses are usually the most vulnerable segments of the population for exposures to lead (ATSDR, 2020). This increased vulnerability results from a combination of factors including: 1) the developing nervous system of the fetus or neonate has increased susceptibility to the neurotoxic effects of lead; 2) young children are more likely to play in dirt and to place their hands and other objects in their mouths, thereby increasing the opportunity for soil ingestion (pica--the eating of dirt and other non-food items--is more likely to occur in children); 3) the efficiency of lead absorption from the gastrointestinal tract is greater in children than in adults; and 4) nutritional deficiencies of iron or calcium, which are prevalent in children, may facilitate lead absorption and exacerbate the toxic effects of lead.

Young children are more vulnerable because they absorb 4-5 times as much ingested lead as adults due to their age. Their hand-to-mouth behavior results in ingesting lead-contaminated dust, soil, and flakes. Exposure to mass lead contamination from battery recycling and mining has caused multiple children's deaths in Nigeria, Senegal, and other countries (WHO, 2022).

A study conducted on drinking water in a kindergarten school in Addis Ababa city shows that there is lead contamination in drinking water and predicts the blood lead level found in children (Debebe et al. 2018). Lead contamination is not only due to the water but also the air and soil, which contribute a lot to lead contamination.

Socio-economic development One's country affects the contamination of lead. In a country where there is low economic development, contamination will affect not only children but also adults. Compared to the mitigation cost of lead contamination and the health and social cost of lead, exposure to lead contamination will cost more. (Akoumianaki ,2017)

This study will assess the lead contamination of water and soil in a daycare facility in Addis Ababa city. The public water supplier (AAWSA) did not have data on the current lead contamination in water, and the local health offices don't have health protection activities concerning lead contamination. Children are still affected by this problem, and there is a gap in preventing and taking action to reduce lead contamination. Therefore, it is essential to show the severity of lead contamination in both water and soil and estimate children's exposure to lead contamination in daycare facilities. Moreover as lead affect the nervous system and the Intelligent of children it will affect the future of a child and the future of a generation.

1.3. Objectives

1.3.1. General Objectives

The general objective of this study is to estimate children exposure to lead contamination in soil and tap water in daycare facility

1.3.2. Specific Objectives

- Determine the amount of lead present in drinking water in child care center in Addis Ababa city
- Determine the amount of lead present in soil in child care center in Addis Ababa city
- Estimate the amount of lead that will present in human body due to exposure

1.4. Research Question

This study justify the following research question

- Does the lead present in childcare services provider's tap water in Addis Ababa is in allowable limit?
- Does the lead present in childcare services provider's soil in Addis Ababa is in allowable limit?
- Is there a link between the water sources and lead contamination?
- How much is blood lead level in children's in daycare centers?

1.5. Scope of Study

The scope of this research is taking representative samples from sources, and childcare facility (day care) in the study area. The samples size were determined from each sub cities, and depend on the number of day cares the sample size were determined. After sample collected from day cares and water sources the level of lead were determined in laboratory. The level of blood lead in children's less than 4 years of age were estimated using IEUBK model.

1.6. Significance of the study

In this study lead level in soil and water will be determined in Addis Ababa city Childcare (day care) centers. There are no adequate studies on the lead contamination and its effect in preschool and daycare center. Finding of this research will be help future researchers and AAWSA to conduct a follow up research and to make remediation plan. Policy makers to regulating law on safe drinking water and continuous test and mitigation measure of water supply and also to apply laws to ban possible sources of lead such as lead paints.

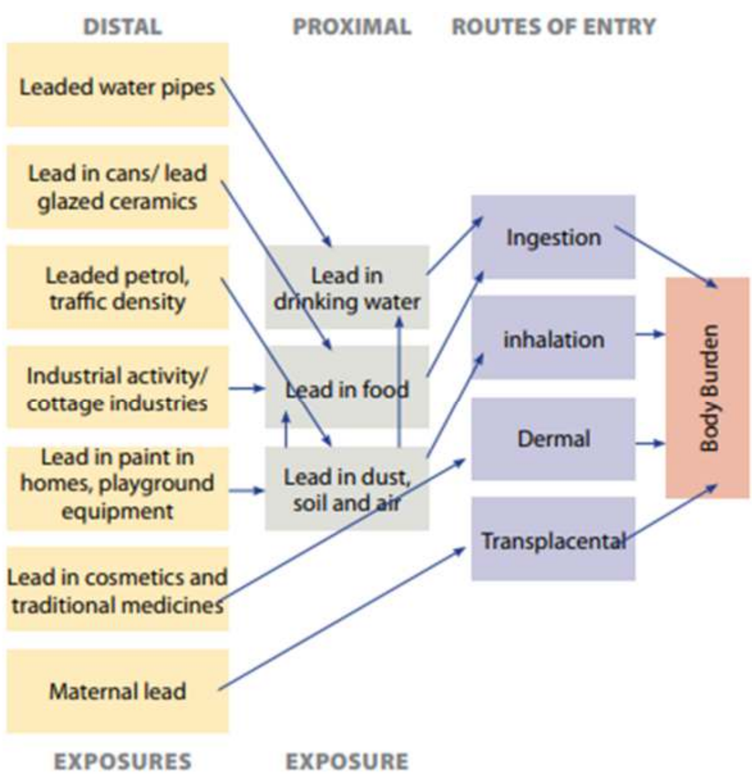
Ministry of Health can do further research to determine the lead blood level by testing blood of children's, this will help to identify what kind of mitigation measures to take for children's who are already exposed to lead contamination.

Chapter Two: Literature Review

Environmental contaminants tend to affect the organ system of human body rather than causing a disease. The effect of contaminants depend on the extent, duration of exposure, substance type. It Can be classified in to certain metals, persistent organic pollutant, pesticides, polyhalgenated byphenyls, airborne pollutants. Metals that are harmful for humans include lead, mercury, arsenic, cadmium, manganese. There are different methods to measure degree of possible human exposure to contaminants. These are ambient concentration, exposure modeling, personal monitoring and bio monitoring. Ambient concentration which gives information about how much amount of contaminant present in the environment but doesn't provide information about how many people come in contact with the contaminant. Exposure Modeling: estimate exposure by determining the amount of contaminant present in environment by taking people activity in to account which is information about people activity and location (USEPA report on environment, 2022).

One of harmful metal is Lead. Lead is not supposed to be found in human body because it's not naturally present in human body as a result even if small amount it presences in the body of human will affect the person, this effect will be higher when it comes to infant because as their body didn't finish developing it will be affected more than adults. Some of health problems due to lead are mental retardation, learning disabilities. Lead contamination caused by different Medias these are through water, air, soil/dust and dietary intake. (U.S. Department of Health and Human Services, 1991).

Lead is a naturally occurring element it can be found in different media of the environment like in soil, water and air. Its bluish-white lustrous metal it's malleable, highly ductile, relatively have poor electric conductivity, its resistance to corrosion but deteriorate when expose to air. Lead has been used extensively in a variety of applications primarily owing to its low melting point as excellent corrosion resistance in the environment (ATSDR, 2007). When lead is exposed to air and water, films of lead sulfate, lead oxides, and lead carbonates are formed that, in turn, act as protective barriers, slowing or halting further corrosion of the underlying metal. For these reasons, lead has been intentionally added to a wide range of components in the built environment, examples including cable sheathing, circuit boards, lining for chemical baths and storage vessels, chemical transmission pipes, electrical components, polyvinyl chloride (as a chemical stabilizer), and radiation shielding. Lead continues to be used extensively in rolled and extruded products in the construction industry; the use lead sheeting in the building industry has increased in recent years (IARC, 2006). Currently, the production of batteries, used predominantly in the automotive industry, comprises the single largest global market for refined lead (75%) since the phase-out of lead in household paints, gasoline additive and solder in food cans However, certain lead compounds are still used in the industrial setting as basic paint primers for iron and steel (Panagapko, 2009). figure 1 summarize the sources of lead which contribute to lead presences in the environmental medias and the route of entry in the human body through this environmental medias.



Sources: WHO, 2015

Figure 1: Sources and route of exposure for lead contamination

2.1. Lead in Soil

Soil is one of environmental medium, the final destination materials that are throwing in to the environment from different human activities are in to soil; this pollutants will affect the physo-chemical property of the soil media this makes the soil contaminated with heavy metal like lead, the accumulation of this heavy metals and pollutants become a threat to human and the environment when it exceeds than the standard value. (Soodan et al., 2015). Lead found in soil naturally. Lead in the soil will increase due to lead contained paints, leaded gasoline for vehicles and lead batteries (USEPA, 1998). There are different reason that affects the concentration of lead in soil, these are traffic volume, distances from hypothesized sources, type and condition of housing and lead paint. There is higher soil lead level in area where there is high traffic volume but soil lead level decreases with the distance from the roadway and 40% of lead emitted as vehicular exhaust is sufficiently large particles that it will deposit near the roadway. (Milberg et al., 1980); the distances from hypothesized sources of elevated soil lead Soil lead also differ on the distances from hypothesized sources of elevated soil lead like garages and car washing places, associate with higher lead level.(USEPA, 1998).Type and condition of housing will affect the lead content in soil in area where there are old and deteriorating housing. Lead has been added to paint for decades to provide color and increase durability and for fastest drying time. In time these paint deteriorate from walls and lead particles released to environment media

Lead does not biodegrade, decay therefore lead in soil is the long term sources of lead exposure and the soil or dust acts as pathways to children exposure to lead contamination (CDC, 1992). Children's can be exposed to lead contamination due to playing in bare soil and hand to mouth touch, eating fruit which grows in lead contaminated soil, or due to dust that came from the soil. Soil contamination due to a presence of lead will decrease with depth increment and also the concentration of lead found in soil increase in summer season (Raid and Huda, 2021) which indicate that the amount of dust from soil found more in summer. A research that were conducted in United State indicated that the soil concentration in lead will affect BLL 10 times greater than water lead in drinking water. The sources of dust lead is soil around sample location, there is a statistical connection between dust lead and soil lead (USEPA, 1993).

Different Researchers conducted on urban soil found that the soil which is near to garage, road way, mining sites and industrial area have a higher lead concentration (Krueger and Dungay,1989, Davis et al.,1987,pouyat et al.,1995). The type of heavy mineral in clay soil has an effect on lead concentration, some clays might absorb a lot of heavy metals due to their physical properties (Fadhel and Abdulhussein, 2022).

The movement of lead in the soil gradual because it has strong tendency to be attracted by organic matter this will make it hard to move and biologically inert. The movement of lead in soil affect by different factors among this PH, moisture content, type of soil, water infiltration rate. (Nguyen et al., 2021).

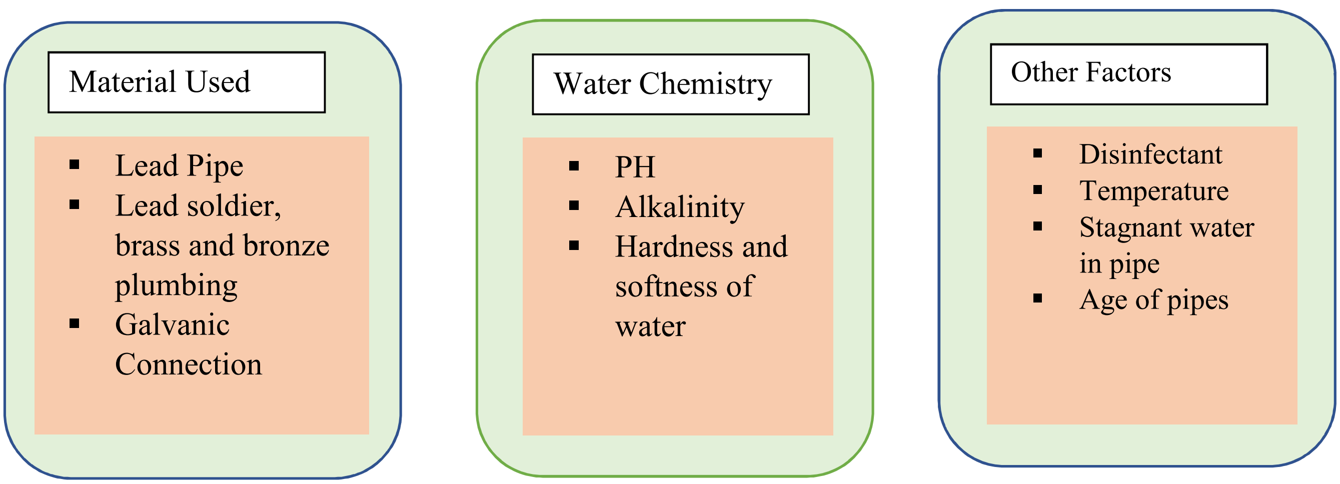
2.2. Lead in Drinking Water

Water supply system consists of the sources (ground or surfaces water), treatment plant and distribution system. Collection and distribution water to the end user consists of different components to transport and deliver the water, these include pipes, fittings, and storage tanks. Materials that used in the distribution system that are from dissolution of lead from lead services lines and plumbing fittings and faucet from lead containing components contribute to the concentration of lead present in the water (health Canada, 2013).

Presences of lead in drinking water can be as a result of the release of lead from lead coated materials. The amount of lead present in the water depend on the supply system on which this lead coated materials installed, the contact time between the water and the material and the water chemical property. This lead containing material includes services connection pipes, fittings, taps, solider joints. Lead can be deposited and accumulate in galvanized cast iron pipes. Chloramine a chemical which is used as a disinfectant in drinking water may elevate the concentration of lead that present in water because it changes the water chemistry. (Edwards et al., 2009).

Factors affecting the extent of lead contamination include; PH, when there is high PH the lead concentration in drinking water decrease this is due to decrement of corrosion of lead coated pipe, whereas when PH of water is low the water become more acidic and therefor lead leaching from lead pipe will increase, when there is low alkalinity in the water the water become acidic and become highly corrosive. Temperature affects lead concentration also hot water can dissolve more lead quickly than cold water that because lead compounds can dissociate rapidly in hot water so as temperature increase there is a probability of in lead concentration increment. The amount of time the water stays in the pipe the longer the water in contact with lead pipe the more reaction takes places to increases the concentration of lead when taking first draw water the lead concentration significantly increases(Dave ,2020) . Research conducted in Slovenian kindergarten indicate that there is lead concentration were beyond WHO guideline, however the lead concentration decreases below 10µg/l (WHO standard) after flushing the water for sometimes prior to sample taking. (Bitene, 2013). The “on-again”, “off-again” water use pattern is going to affect lead concentration in drinking water because the lead remain stagnant in the plumbing (USEPA, 1989). The amount of lead concentration will also be affected by the type of fixture. Age of A pipe will affect the level of lead in drinking water, as pipe age it can easily corrode and react with drinking water in the pipe therefore as a pipe aged the lead concentration increases

In general factors affecting lead contamination in drinking are revised in figure 1:



Sources: Akoumianaki, 2017

Figure 2: Summary of general factors that affect the concentration of lead in drinking water

The probability that lead to occur at the sources of drinking water is unlikely and will be low, however it can affect ground water if there is mining field or smelter near ground water well also it can affect surfaces water surfaces water from waste discharge from industrial or residential area or from rain water and it can be removed easily using treatment plant (USEPA, 1989).

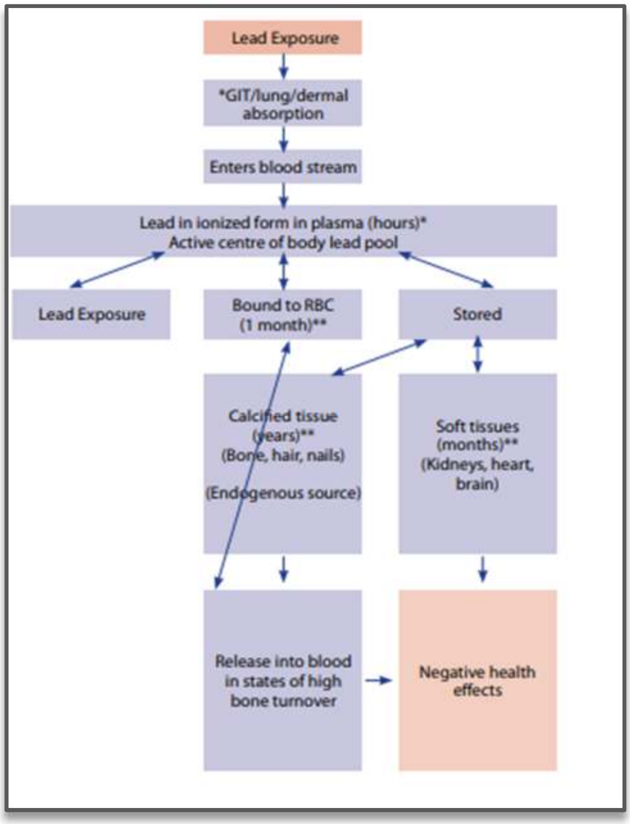
2.3. Blood Lead Levels

Exposure is the contact between an individual and a pollutant for a given time. It can be expressed as intensity, frequency and duration of contact and also the amount of exposure depends in the concentration of lead in the medium and the activity of a person. (WHO, 2006). Risk assessment for lead is different because the references value which is a concentration where there has no advert effect, is not available for lead. In case of lead contamination there is adverse effect event it present in small amount (USEPA, 2022).

The presences of lead affects most of the systems in the body it can damage the nervous system, renal damage and reproductive system, it's also affect blood pressure causing high blood pressure. It affects psychological behavior, intelligences and growth development children's at early age (Afsha et al., 2018). Once it enter the body, 90% lead stored in the bones, while 10% randomly distributed to all body tissues and organ with blood circulation affecting the brain, nerve system and kidney functions (Dengnan, 2023). Figure 3 shows how lead (Pb) enters the blood stream after absorbed through GI tract/lungs and pathway after it enters the blood stream.

There is strong correlation found between blood lead level and lead in soil, BLLs rises when there is an increment in lead in soil or dust (CDC, 2005). Blood lead level (BLLs) decrease when children's wash off their hands before every meal which indicate that dust is a sources of lead contamination.(freeman et al., 1997) Higher BLLs found in younger children between the ages of one to three years old (Cheng ,2022). Exposure to lead in environmental media due to lead presence in air, soil, water is associated with higher blood lead level. A research conducted in India Panta shows that there is a significant increment in BLLs when lead concentration in the environment media increase by 10 %(Brown et al., 2020).

Recent studies shows that BLLs brings behavioral change to children, according to research conducted in Iran BLLs in children with ADHD is significantly higher than normal Group, the research showed that lead is the risk factor for ADHD. (Mohammad et al. 2022). Another study that were conducted in United State shows that lead exposure has adverse effect in early age and adolescence age even if lead concentration is in small amount in this study the mean BLL were 1.04 but its still affect the BMD(Bone mineral density) of children's and adolescents (Aiyong et al., 2022).



Sources: WHO, 2015

Figure 3: Lead metabolism path way

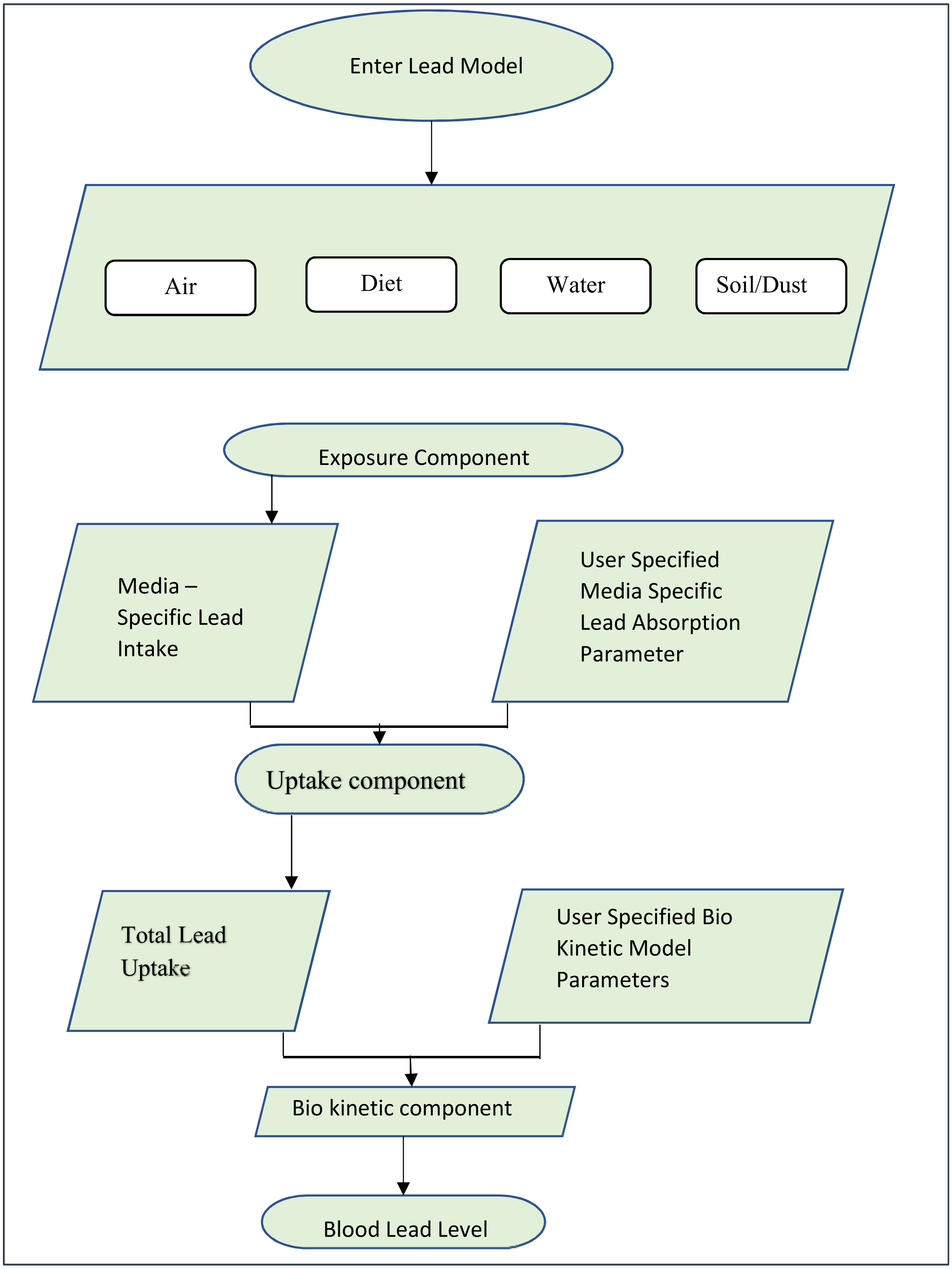
2.4. Integrated Exposure Uptake Biokinetic Model for Children

IEUBK is a simulation model it used to anticipate the likely blood lead level distribution using the exposure to lead at a given location and the probability that children expose to lead contaminated environment will have blood lead level exceeding health-based concerns; these prediction helps for risk assessment. Four step process that link environmental lead exposure blood lead concentration of children from age 0-84 month. It has four step these are exposure, uptake, biokienitics, and variability. Described in the table 1.

Table 1: Components of IEUBK model

No.	Model Components	Description
1	Exposure component	is the calculation of intake rate from lead concentration in the environment media, the input media include in IEUBK model are air, soil dust, and drinking water
2	Uptake Component	Model process the lead absorbed by a child body through ingestion/inhalation to blood stream it is quantity of lead absorption by the child in systemic circulation.
3	Biokenetics	It is Its analytical expression of the evolution of lead absorbed in the body over time by physiologic or biochemical processes.
4	Variability	IEUBK model use log-normal probability distribution to characterize variability. The biokenetic module gives lead concentration as an output, concentration then lead concentration probability distribution module estimate the plausible distribution of lead

The structure of IEUBK Model is presented in the figure 4.



Sources: IEUBK technical support document

Figure 4: IEUBK Technical Support Document

Chapter Three: Methodology

3.1. Study Area

The study was conducted in Addis Ababa, which is the capital city of Ethiopia located in central part of Ethiopia. The city lies at a geographic coordinate of 9°1’48’’N 38° 44’24’’E and has an area of 540 km^2. Its average altitude above sea level is 2355 meters. Addis Ababa has a humid subtropical mild summer climate that is mild with dry winters, mild rainy summer moderate seasonality. The temperature differences is up to 10°C, depending on elevation and prevailing wind pattern. According to Central Statistics Agency of Ethiopia the projected population from 2007 census the population of Addis Ababa city is 3,603,000 million (CSA,2019). It is the biggest city in the country, the city is divided into 11 boroughs called subcities and 112 weredas shown in figure 5.

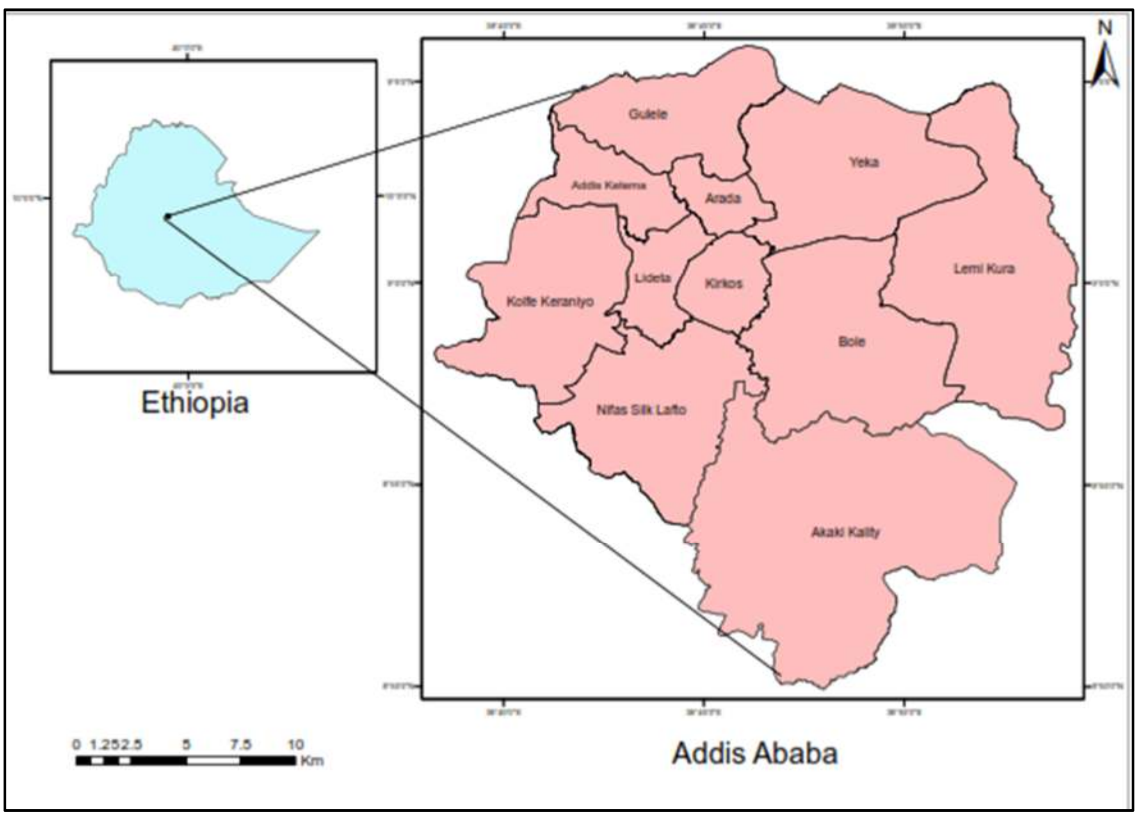


Figure 5: Addis Ababa City Boundary

The entire city of Addis Ababa gets its water supply and waste water services from The Addis Ababa Water and Sewerage Authority (AAWSA) which was established by proclamation in 1970. Water supply sources of Addis Ababa city is both surface and ground water sources. For the case of surface water production, Geffersa and Legedadi Dams have been built at various times with an expansion/ up-grading work being done in each of these dams. For the case of ground water production, both deep and shallow wells were drilled at Akaki, Legedadi, Fenta pocket areas and in the city vicinity. The raw water from the dams is treated at the two treatment plants, namely: Geffersa Treatment and Legedadi Treatment plant. The treated water is conveyed through the Legedadi and Geffersa Transmission lines to the reservoirs at various locations in the city. Moreover, the ground water from Akaki and Fenta well fields are treated with chlorination at some reservoirs prior to transportation to the southern parts of the city through Akaki Transmission system. According to secondary data collected from AAWSA the water supply distribution system of AAWSA covers 489.5 km^2. From this 283.43km^2 covered by ground water from Akaki well fields and legedadi well fields, 167.03km^2 covered from Legedadi treatment plant and 40.03km^2 covered from Gefersssa treatment plant.

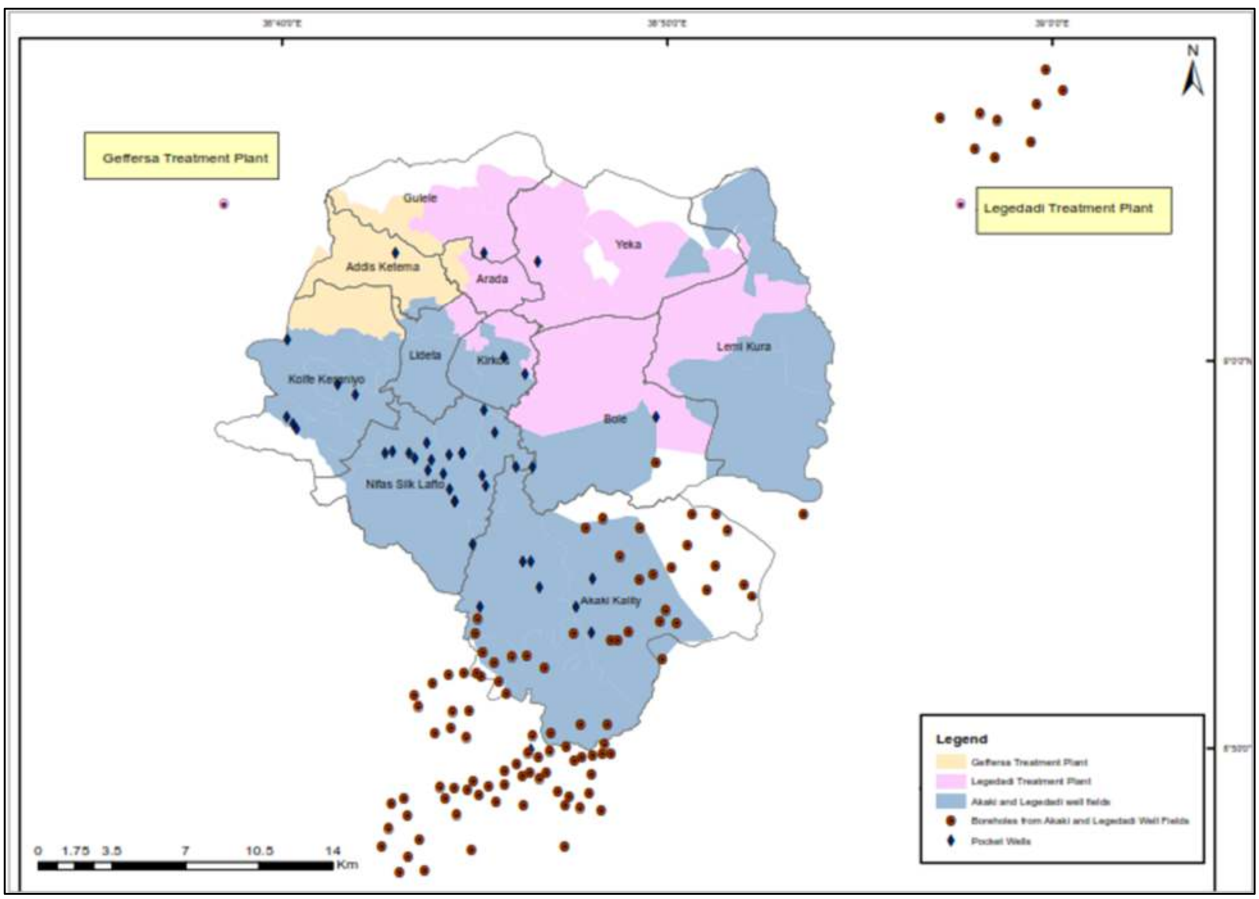


Figure 6: *Water sources location and the area covered by water sources*

3.2. Data Collection

Primary data were collected from Laboratory test results and field surveys. Secondary data were collected from Addis Ababa Water and Sewage Authority necessary maps, distribution system network and the area it covers, location of well fields, pocket wells and also data gathered from Ethiopian Food and Drug Authority office in each sub cities to determine the number of day care in the city. The table below shows the number of day care in each sub city.

Table 2: Number of Day cares in Addis Ababa

No.	Sub City	No. of day Care
1	Addis Ketema	15
2	Akaki Kality	23
3	Arada	5
4	Bole	12
5	Gullele	7
6	Kirkos	42
7	Kolfe Kerango	30
8	Lemi Kura	39
9	Lideta	5
10	Nifas Silk	37
11	Yeka	14
Total		**229**

3.3. Sampling Technique

Sample were collected from child care services to determine the level of lead exposure to the tap water and soil. Stratified random sampling method were adopted to determine the number of sample. The stratification carried based on the number of day care in each sub city. Sample were collected from each strata. 28 soil and water samples were collected from day cares in Addis Ababa city The number of sample in each strata (Sub city) were determine from proportional allocation by the following equation

$N_k=n*W_k$, Where N_k is total number of sample in a stratum

N total number of sample

W_k Number of day care in strata / total number of day care

Based on the above equation the number of sample determined in each sub city presented as follows:

Table 3: The number of sample taken from each sub city

No.	Sub City	No. of day Care
1	Addis Ketema	2
2	Akaki Kality	3
3	Arada	1
4	Bole	2
5	Gullele	1
6	Kirkos	4
7	Kolfe Kerango	3
8	Lemi Kura	5
9	Lideta	1
10	Nifas Silk	4
11	Yeka	2
Total		**28**

All sample locations gets their water supply form AAWSA. Water sample were taken directly from AAWSA service line. Flushed sample were taken from all sample location because access to daycares weren't allowed before its opening time. The daycare centers usually use the tap water to prepare formula milk for children's, and prepare some cereal foods for children's. In all daycare centers the compound area has some parts of the area impervious surfaces and some area with green yards. All samples were collect in summer time (dry season).

Samples were collected from each sources to determine if there is lead level from the sources. Samples were collected from Legedadi, Geffersa before and after treatment. Since here is no treatment for Akaki well fields and pocket wells therefore sample were taken from before and after chlorination. A total of 64 were collected in which 28 soil sample 28 tap water sample and 8 samples from sources. Figure 6 shows the total number of sample location from the sources and day care it also shows the distribution system area coverage of each sources. Location (X and Y coordinates) of each sample location is shown in annex 1.

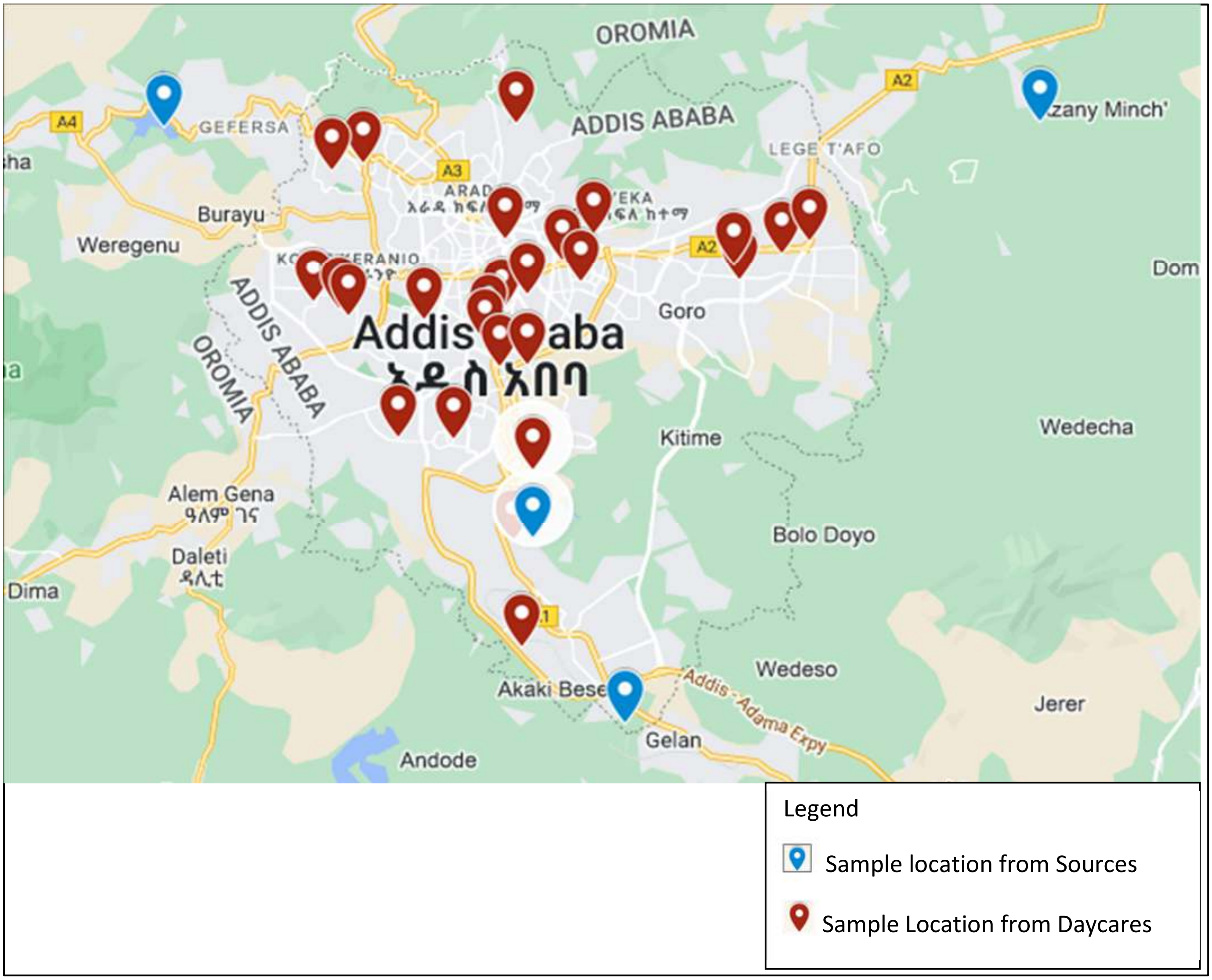


Figure 7: Sample location

3.4. Sampling Procedure

Samples were collected from 8:00 AM to 10:00 PM. Plastic bottle were used to take water sample. Sampling bottles were cleansed with detergent and distilled water prior to sample collection in figure 7. 300ml water samples were collected from each day care and water sources as shown in figure 8. Soil sample were taken from the upper surfaces of soil 2.45cm-5cm and put in clean plastic bag. Then samples were taken to Addis Ababa University, College of Natural and computational sciences, Chemistry laboratory. The water samples were then acidified and refrigerated till the digestion process.

Figure 9: Cleaning sampling bottle

Figure 8: Sample collection from legedadi treatment plant

Laboratory Procedure for Soil Sample: soil sample were digested to extract the lead. The digestion procedure for soil sample is as follow

Digestion of soil Sample

I. 0.5gm soil sample weighed
II. 4ml Nitric acid(HNO_3), 1ml per chloric acid($HCLO_4$) and 0.5ml (H_2O_2)hydrogen peroxide added to the soil sample
III. The sample were heated for 2hr and 30min on Kjeldhal digestion block

IV. After the solution were cooled it filtered into 50ml volumetric flask

V. The sample were diluted with deionized water till it reach the mark

Equipment and Chemical Used

Equipment's: Kjeldahl digestion block, pipet, 50ml volumetric flask, whatman no.42 filter paper

Chemicals: Nitric acid(HNO_3), per chloric acid($HCLO_4$) and (H_2O_2)hydrogen peroxide

Figure 10: Soil samples heated on Kjeldhal Digestion block

Laboratory Procedure for Water Sample: water sample were digested to extract the lead. Digestion takes place using hot plate digestion method. The digestion procedure for soil sample is as follows:

Digestion of water sample

I. 50ml water sample measured and immersed to 250ml conical flask

II. 5ml nitric acid were added to the sample

III. The sample were heated on hot plate at 120^0c till 10ml solution left

IV. After the solution were cooled it filtered into 50ml volumetric flask

V. The sample were diluted with deionized water till it reach the mark

Figure 11: Water sample heated on hot plate

Equipment and Chemical Used for water sample

Equipment's: Hot plate, pipet, 50ml volumetric flask, whatman no.42 filter paper

Chemicals: Nitric acid (HNO_3)

Figure 12: Samples in 50ml volumetric flask after digestion process

To ensure the representativeness of the quantitative result both water and soil samples were analyzed in duplicate. Blank analysis were carried out to assess the performances of instrumental techniques.

3.5. Analysis of Samples

Analysis of soil and water sample were done using graphite furnace atomic absorption spectrometry (model ZEEnit 700P Analytic jena, Germany) it is high performances graphite furnace AAS. Sensitivity of ZEEnit 700P Graphite Furnace Atomic Absorption Spectrometer is 0.94µg/l 1%Abs (Pb 283) it has wave length 180-900nm.

Graphite furnaces atomic absorption spectroscopy (GFAAS) uses graphite-coated furnaces to vaporize the sample. Free atoms will absorb light at wavelength characteristics of the element of interest then the amount of light absorbed can be linearly correlated to the concentration of analyte present. The samples are deposited in small graphite coated graphite tube then the sample be heated to vaporize and atomize the analyte. The atoms absorbs visible light and make transition to higher electronic energy level. The basic components of GFFAS are sources of light (lamps) to emit resonances line radiation, atomization chamber(graphite tube) which makes the sample to vaporized, a monochromator to select the element of interest, detector to detect the amount of light absorption, signal processor computer system to display the result of the analysis.(https://speciation.net/Database/Instruments/Analytik-Jena-AG/ZEEnit-700-;i469)

Calibration

Calibration for graphite furnace atomic absorption spectrometry (model ZEEnit 700P Analytic jena) were conducted using four known standard solution with known concentration, 2,4,8 and 16µg/l know concentration of lead prepared from (Certified Reference Material) of 1000µg/L stock solution to prepare each of the calibration standards and the absorbance's of lead were recorded and present in figure 12:

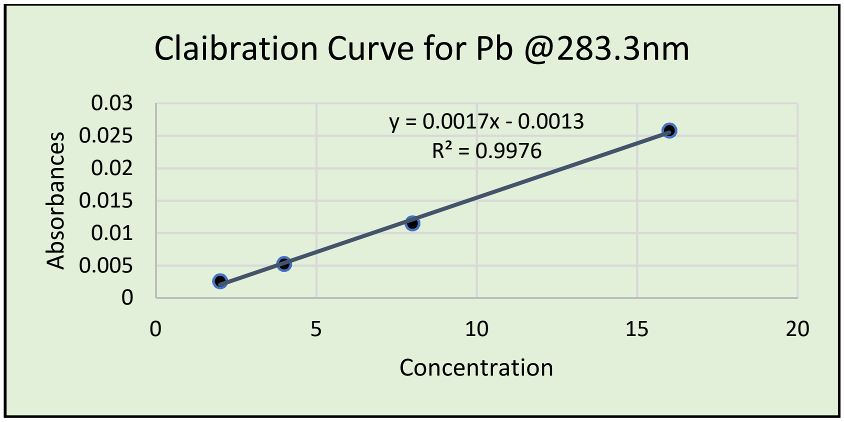


Figure 13: Calibration of GFAAS analytic Jena

3.6. Data Analysis and in IEUBK Model

Once the lead concentration determined from GFAAS the mean value of lead concentration for soil/dust and drinking water were calculated for each sub cities and for the whole city of Addis Ababa in Microsoft Excel. Mean lead concentration for water and soil/dust inserted in IEUBK lead model version 2.0 to determine the BLL in children's.

Seven parameter inputs windows can be modified according to site-specific condition. This parameters are Air, Dietary, Drinking water, soil/dust, and maternal, alternate, GI Values/bioavailability data. Default values of IEUBK model were used for air and dietary input.

Air

Default value of 0.1mg/m3 was used for the outdoor lead concentration and indoor lead concentration taken as 30% of outdoor air lead concentration (IEUBK user guide, 2021).

Dietary Data

Default value used for dietary lead concentration. The default values for daily dietary Pb intake are the estimate values that are derived based upon United State Food and Drug Administration (FDA) food monitoring data (IEUBK model user guide, 2021

Drinking Water Data

Drinking value data has two sections: water consumption rates and water concentration data. Default value were used for water consumption data. Mean lead concentration (µg/l) of water in daycare samples were used for water lead concentration in drinking water.

Soil/Dust Data

Another input parameter is soil lead concentration, mean value of soil lead concentration were used from collected laboratory data. Default value for ingestion rate was used (IEUBK model user manual, 2021) strongly recommend for the users to take the default data for soil/dust ingestion rate because the values are representative data that they represent average daily intake for population. Mass fraction of soil to Dust (Msd) was used, Msd represent the contribution of soil to dust and also Multiple Sources Analysis (MSA) method used to determine household dust lead concentration (IEUBK model user manual, 2021).

Chapter Four: Result and Discussion

4.1. Lead Concentration in soil

The lead concentration in the soil sample were determined in laboratory as stated above. The mean lead concentrations for each sub cities in soil sample from 28 daycares were calculated. From 11 sub cities lead concentration in Kirkos sub city is the highest with 0.00265mg/g and the minimum Lead concentration is in Gulele sub city with 0.00205 mg/g. The mean lead concentration of Addis Ababa city soil from day care is 0.00237±0.08(SD)mg/g. All samples test result are below the permissible value according to WHO standard 0.1mg/g(WHO,2023) .The mean lead concentration in each sub cities are shown below in figure 13.

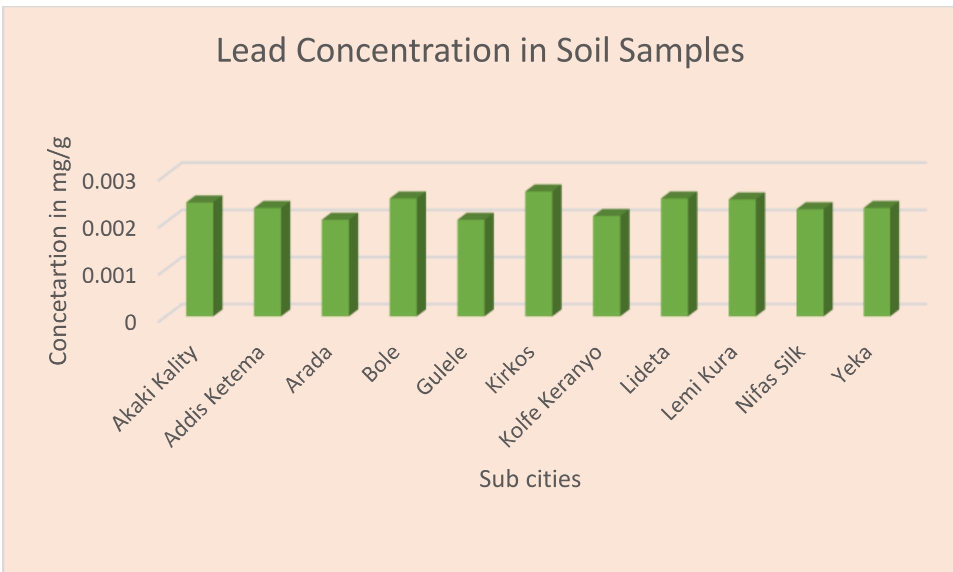


Figure 14: Mean lead concentration in each sub cities

The concentration of lead in soil show lower value in a newly built peripheral roadways compared to old places these areas are exposed to soil contamination for short period of time. Based on Juan et al. (2022), the age of a building also contribute to the concentration lead. In an area where there is newly built homes have low lead concentration than old settlement areas. A study that conduct in Canada demonstrate that geometric mean of lead contamination were significantly different, where buildings that built before 1970s has a geometric mean 187mg/kg were as buildings that built after 1980s has a geometric mean of 28.5mg/kg (Bell et al., 2011).

For the current study, all the sampling points are located in the residential area where the traffic loads are low. Based on the observation made by the researcher, garages, gas stations and bus stations are not found around all the sampling points. This might led to low lead level in all soil samples. This finding is supported by WHO (2015) that reported decrease in blood lead level of children after ban of lead gasoline and Health Canada (2013) which stated soil lead contamination is higher near contaminated point source rather than residential areas and parklands.

Lead contamination increases due to anthropogenic activities, a research conduct in different land use areas in Iraq shows that the mean lead concentration of soil in industry areas where higher than that of residential areas with mean lead value less than one. (Fadhel and Abdulhussine, 2022). Another research that conducted on southern east Ethiopia exhibited high level of lead concentration in area where there is high traffic density (Getaneh et al., 2014).

4.2. Lead Concentration in Water

The laboratory result for water Sample were computed as shown in the methodology. The mean lead concentration in water samples is 8.26 ±1.6 µg/l with minimum and maximum of 6.08 and 11.55 µg/l respectively. From tap water 28 samples 21 water samples are below WHO (2004) standard which is 10 µg/l and 7 samples are above permissible value (10 µg/l). Test result of water samples attached in annex 2. The mean lead concentration in each sub cities are as shown in figure 14:

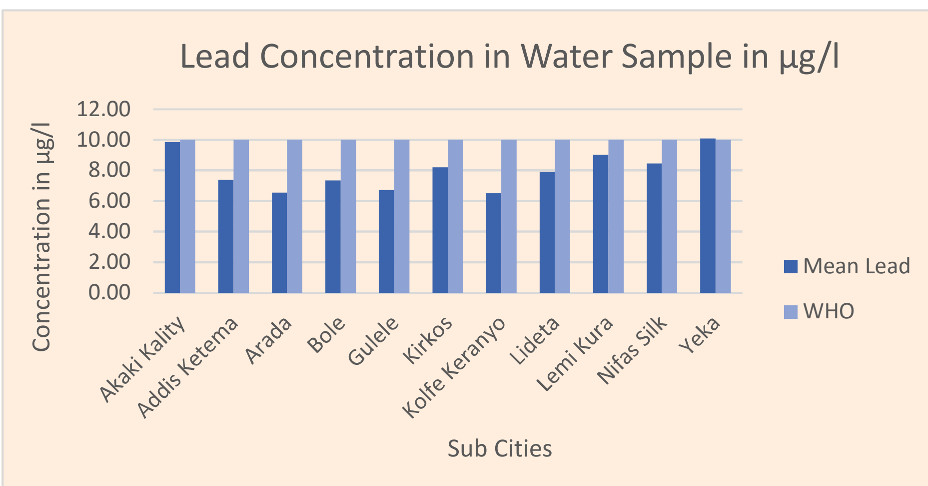


Figure 15: Lead concentration in Addis Ababa Sub cities

There are different materials used as pipe component in piped system.. These materials are brass, lead, galvanized iron, PVC. In pipe system lead components could be pipes, solders and goose neck, brass found in components like fittings, valves, coupling or other fixtures, galvanized steel pipes, PVC pipes. If lead component in the pipe system have contact with other metals result in releasing lead (WHO, Technical report, 2022). (Wang, 2012; St. Clair et al., 2015; Ng, Lin & Lin et al., 2020) As cited in WHO technical report describe it as Lead that form a galvanic couple with other metal release higher lead concentration than components that are not in contact with these materials. Some of Sample location were found in old settlement area were some of the pipe type is galvanized steel according to AAWSA water supply network data. Galvanized steel can be sources of lead because galvanic corrosion can result in released of lead particulate to the drinking water (Akoumianaki, 2017).

Stagnation time for drinking water is another factor for drinking water lead concentration, all samples were flushed samples which could be the reason for low Pb in water samples; when sample taken after flushing the first draw water the lead concentration decreases compared to the first draw water sample (Bitenc, 2013). Flow rate of drinking water affects the concentration of lead when the flow rate is high lead concentration also increases this might be due to velocity increment can enhances the detachment of lead particulate from pipe.(Peng et al. ,2022).

Sample from water sources of Addis Ababa city were analyzed by GFAAS for lead contamination in the laboratory. The result of lead concentration are as Shown in the Table 4.

Table 4: lead level in from water sources for Addis Ababa drinking water

No.	Location	Name	Lead in µg/L in Water
1	Source	Legedadi before treatment	26.25
2	Source	Legedadi after treatment	2.042
3	Source	Geferrsa before treatment	20.51
4	Source	Geferrsa afer treatment	2.43
5	Source	Akaki well field before chlorination (BH-11)	2.05
6	Source	Akaki well field before chlorination (BH-11)	2.04
7	Source	Pocket 1	2.06
8	Source	Pocket 2	2.06

Lead contamination in surfaces water is higher than that of ground water. Legedadi and Gefersa dam before treatment lead concentration results are 26.25 & 20.51 µg/L. lead concentration decreases to 2.04 & 2.4 µg/L after treatment of water. Non organic matter (NOM) in the surfaces water increases as due to pollution and change in land use and lead level decrease with removal (coagulation) of NOM (Javier et al, 2023).The lead level Akaki ground water is 2.05 µg/L. Urban waste, domestic sewage, factory effluent contaminate Akaki river (Yohannes et al, 2017) however the ground water that is used for drinking purpose is protected from industrial effluents and contamination.(Endale et al, 2021). Water samples from water sources has lower value of lead concentration compared to water samples that were taken from daycare centers. Lead concentration from legedadi catchment range from 6-10.2 µg/l, Akaki catchment the lead level ranges from 6-11.55 µg/l. For Geffers catchment all samples were below 7-8 µg/l. Lead concentration greater than 10 µg/l found in Akaki and Legedadi catchment despite the sources water lead level were about 2 µg/l.

Table 5: Lead concentration in soil and drinking water in Ethiopia and international reported data in

References	Lead level in Soil(µg/g)	Lead level in water (µg/l)	Study Area
Current study	2.37(mean)	8.26(Mean)	Addis Ababa
Bitew et al, 2021	ND	4.42 & 5.34(means) respectively	(Akality, & Gulele) Addis Ababa
Endale .et.al, 2021	ND	0.36-146 (range) & 17.8 (mean)	Addis Ababa
Dawit. et al,2018	ND	62.37(Mean)	Addis Ababa
Getaneh. Et al, 2014	200.08(mean)	10.63 (mean)	Jimma
El fadeli et al,2013	113-127 (Range)	3.35, 5.5 &5.3(means) respectively	(Old water pipe, Land irrigated from untreated waste, minning site) Morrocow
Ali et al, 2013	1-73420(Range)	ND	Bagdad, Iraq
Omar B Ahmed, 2023	ND	$2.4*10^{-5}$(mean)	Saudi Arabia

Lead level in drinking water and soil in Ethiopia and international researches presented in above table 5 and compared to the current study. The soil in the current study has lower reported value from Jimma (Getaneh. Et al, 2014), Morrocow (El fadeli et al, 2013), Iraq (Ali et al, 2013). Lead contamination in Baghdad indicate that lead contamination in site other than industrial area are within permissible value but in industrial area exceed permissible value (100mg/kg) (WHO ,2023). According to Bitewe et,al, 2022 BGI Brewery factory in Addis Ababa city has higher value of lead concentration in effluent that discharged from the factor. Higher value of soil where there is higher traffic volume (Getaneh. Et al, 2014).

Mean Drinking water lead level in current study, Kality and Gulele (Bitew et al, 2021), Morrocow, (El fadeli et al, 2013), Saudi Arabia (Omar B Ahmed, 2023) are within permissible value of WHO standard (10 µg /L) (WHO 2006) Study from Jimma (Getaneh. Et al, 2014), Morrocow (El fadeli et al, 2013), Iraq (Ali et al, 2013), Addis Ababa (Endale .et.al, 2021; Dawit. et al, 2018) mean lead concentration from tap water exceeds the permissible value. In the current study the tap water lead level is greater than that of sources water after treatment there could be cross contamination while the water transport in the distribution system. . Lead concentration has direct relationship with distance from water sources as water sources distance increase the lead level also increase (Getaneh. Et al, 2014).

4.3. Blood Lead Level in Children's

The blood lead level in children's less than four years old were computed using IEBUK lead model version 2.0. The BLL in children were computed for 11 sub cities. The BLL for each sub city presented as follows:

1. **Akaki Kality:** The Mean lead concentration for the water and soil/dust were taken as 9.84 µg/l and 0.0024 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in the table 6:

Table 6: Akaki Kality Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.03	1.28	1.295	0.137	3.347	1.8
12m-24m	0.057	2.416	2.032	0.149	4.655	1.9
24m-36m	0.075	2.51	2.417	0.107	5.109	1.9

36m-48m	0.093	2.602	2.57	0.101	5.365	1.9

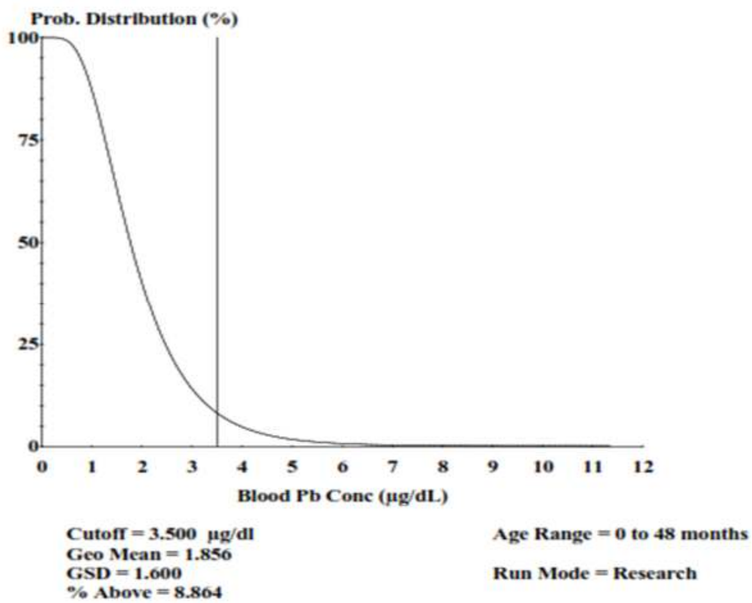


Figure 16: The probability Distribution curve for Akaki KAlity Sub city

The probability distribution curve of BLL for Akaki Kality shown in the figure 15, The geometric mean BLL for children less than four years is 1.856 and 8.86 % children's in Akaki Sub city exceed 3.5µg/l.

2. **Addis Ketema**: The Mean lead concentration for the water and soil/dust were taken as 7.38 µg/l and 0.0023 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 7:

Table 6: Addis Ketema Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.28	1.429	0.137	2.888	1.6
12m-24m	0.057	2.415	1.531	0.15	4.164	1.7
24m-36m	0.075	2.51	1.821	0.107	4.524	1.7
36m-48m	0.093	2.602	1.935	0.101	4.741	1.6

The probability distribution curve of BLL for Addis Ketema shown in figure 16 , indicates the geometric mean BLL for children less than four years is 1.64 and 5.34 % children's in Addis Ketema Sub city exceed 3.5µg/l.

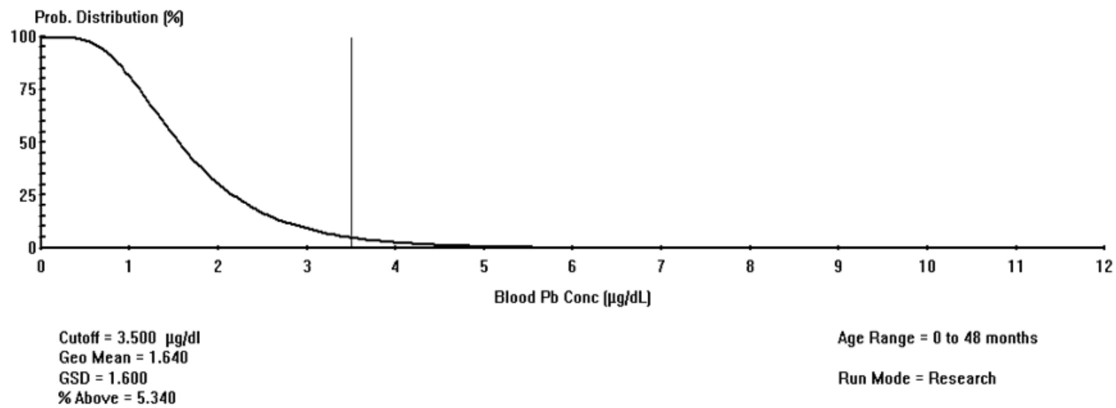


Figure 17: The Probability Distribution curve for Addis Ketema

3. **Arada**: The Mean lead concentration for the water and soil/dust were taken as 6.53 µg/l and 0.002 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 9:

Table 7: Adrada Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.28	1.267	0.138	2.728	1.5
12m-24m	0.057	2.415	1.357	0.145	3.994	1.6
24m-36m	0.075	2.51	1.614	0.107	4.321	1.6
36m-48m	0.093	2.602	1.714	0.101	4.524	1.6

The probability distribution curve of BLL for Arada Sub city shown in figure 17, indicates the geometric mean BLL for children less than four years is 1.56 and 4.33 % children's in Arada Sub city exceed 3.5µg/l.

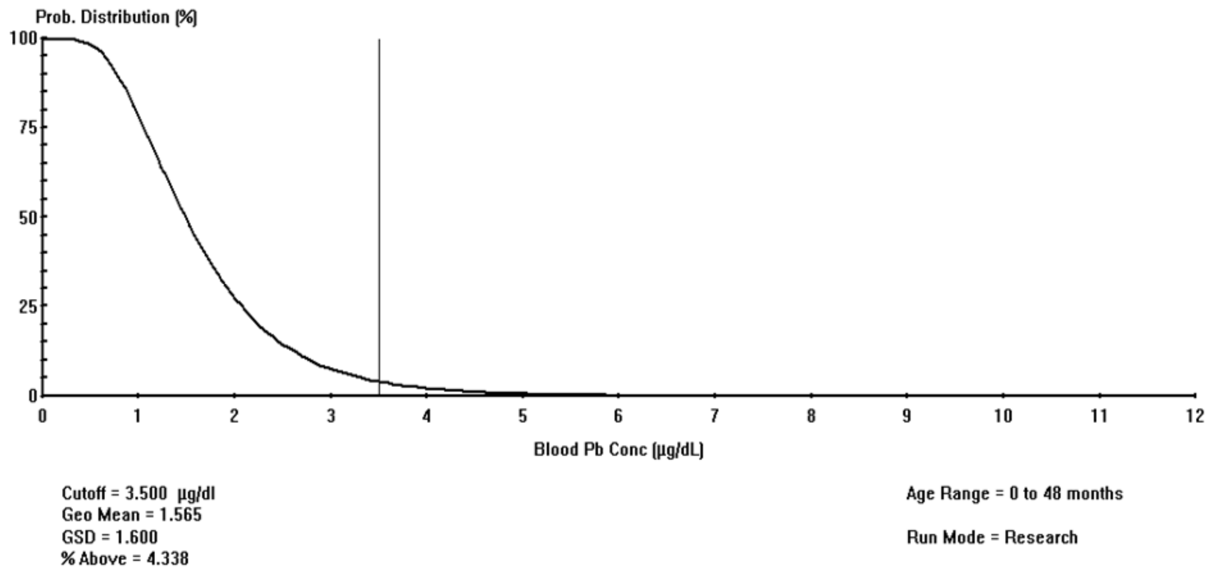


Figure 18: The probability Distrbution Curve of Arada Sub city

4. **Bole**: The Mean lead concentration for the water and soil/dust were taken as 7.33 µg/l and 0.0025 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 9:

Table 8: Bole Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.28	1.42	0.137	2.879	1.6
12m-24m	0.057	2.415	1.521	0.15	4.154	1.7
24m-36m	0.075	2.51	1.809	0.107	4.522	1.7
36m-48m	0.093	2.602	1.922	0.101	4.728	1.6

The probability distribution curve of BLL for Bole Sub city shown in figure 18, indicates the geometric mean BLL for children less than four years is 1.63 and 5.27% children's in Bole Sub city exceed 3.5µg/l.

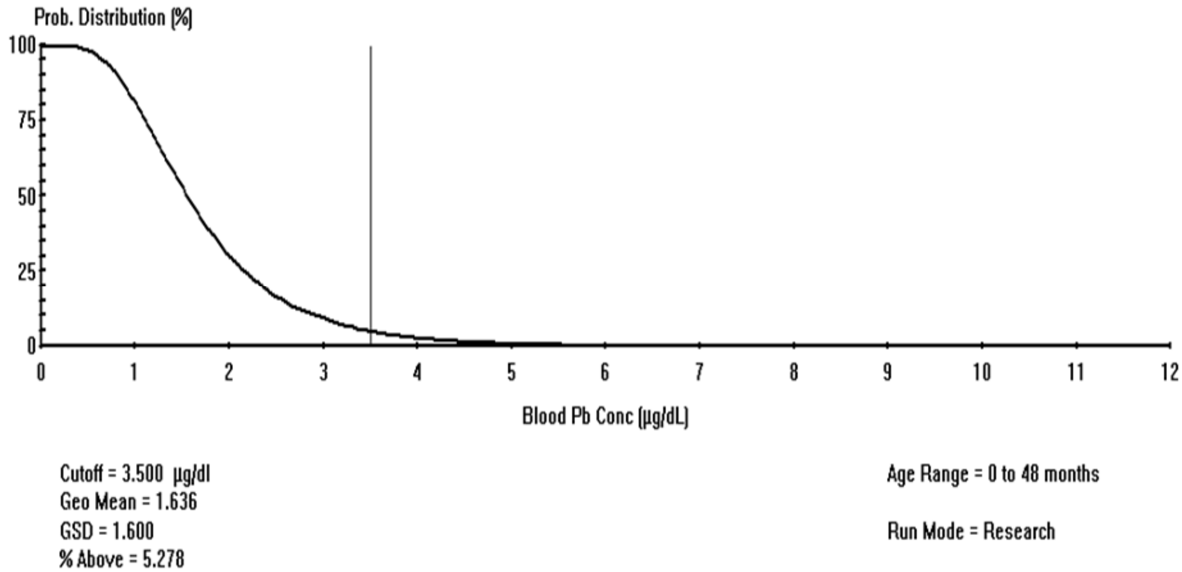


Figure 19: The probability Distribution curve of Bole sub city

5. **Gulele**: The Mean lead concentration for the water and soil/dust were taken as 6.71 µg/l and 0.0020 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 10:

Table 9: Gulele Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.03	1.28	1.301	0.137	2.762	1.5
12m-24m	0.057	2.416	1.394	0.15	4.03	1.7
24m-36m	0.075	2.51	1.658	0.107	4.364	1.6
36m-48m	0.093	2.602	1.761	0.101	4.57	1.6

The probability distribution curve of BLL for Gulele Sub city shown in figure 19, indicates the geometric mean BLL for children less than four years is 1.58 and 4.54% children's in Gulele Sub city exceed 3.5µg/l.

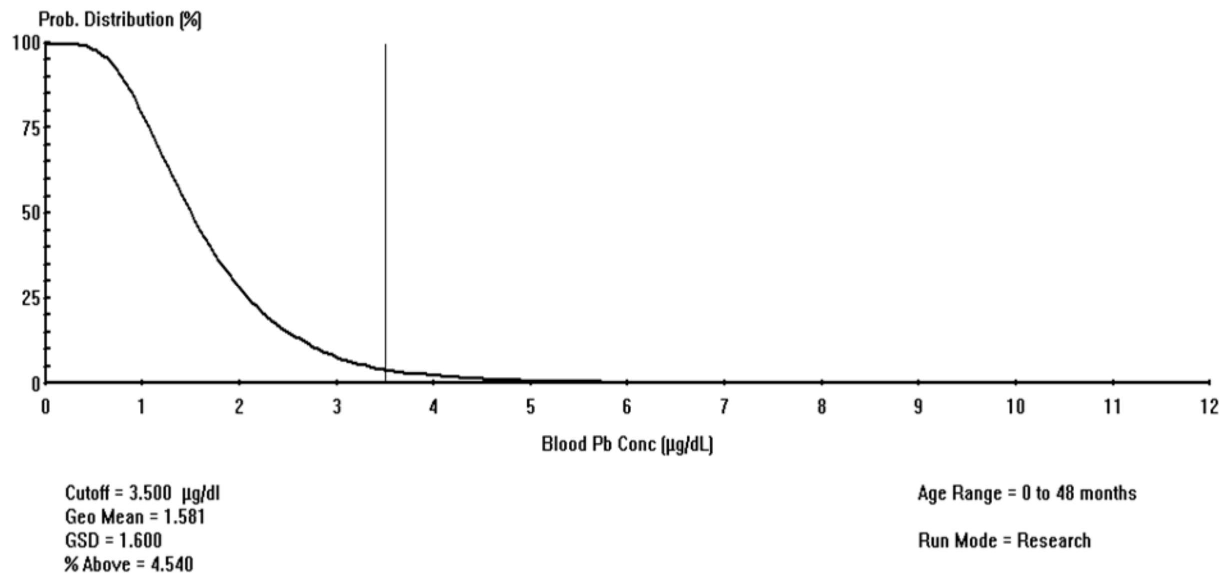


Figure 20: The probability Distribution Curve of Gulele sub city

6. **Kirkos**: The Mean lead concentration for the water and soil/dust were taken as 8.19 µg/l and 0.0026 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 11:

Table 10: Kirkos Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.28	1.583	0.138	3.04	1.6
12m-24m	0.057	2.415	1.679	0.149	4.326	1.8
24m-36m	0.075	2.51	2.018	0.107	4.717	1.7
36m-48m	0.093	2.602	2.144	0.101	4.947	1.7

The probability distribution curve of BLL for Kirkos Sub city shown in figure 20, indicates the geometric mean BLL for children less than four years is 1.71 and 6.4% children's in Kirkos Sub city exceed 3.5µg/l.

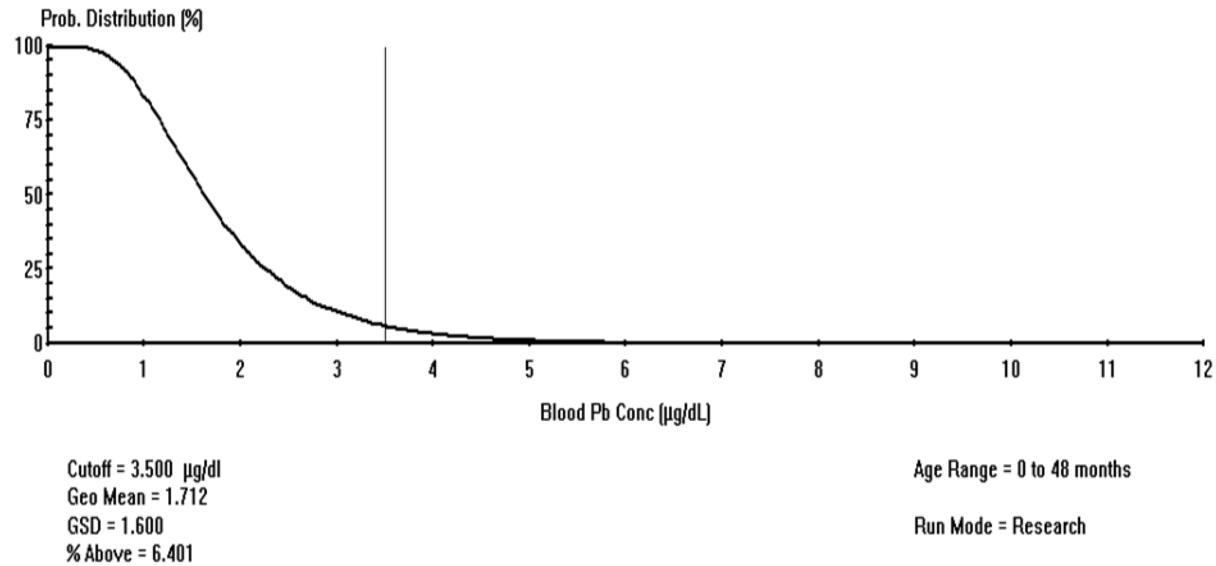


Figure 21: The probability Distribution curve for Kirkos Sub city

7. **Kolefe Keranyo**: The Mean lead concentration for the water and soil/dust were taken as 6.49 µg/l and 0.0021 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 12:

Table 11: Kolfe Keranyo Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.28	1.259	0.138	2.721	1.5
12m-24m	0.057	2.415	1.348	0.15	3.986	1.6
24m-36m	0.075	2.51	1.604	0.107	4.311	1.6
36m-48m	0.093	2.602	1.704	0.101	4.514	1.6

The probability distribution curve of BLL for Kolfe Keranyo Sub city shown in figure 21, indicates the geometric mean BLL for children less than four years is 1.56 and 4.23% children's in Kolfe Keranyo Sub city exceed 3.5µg/l.

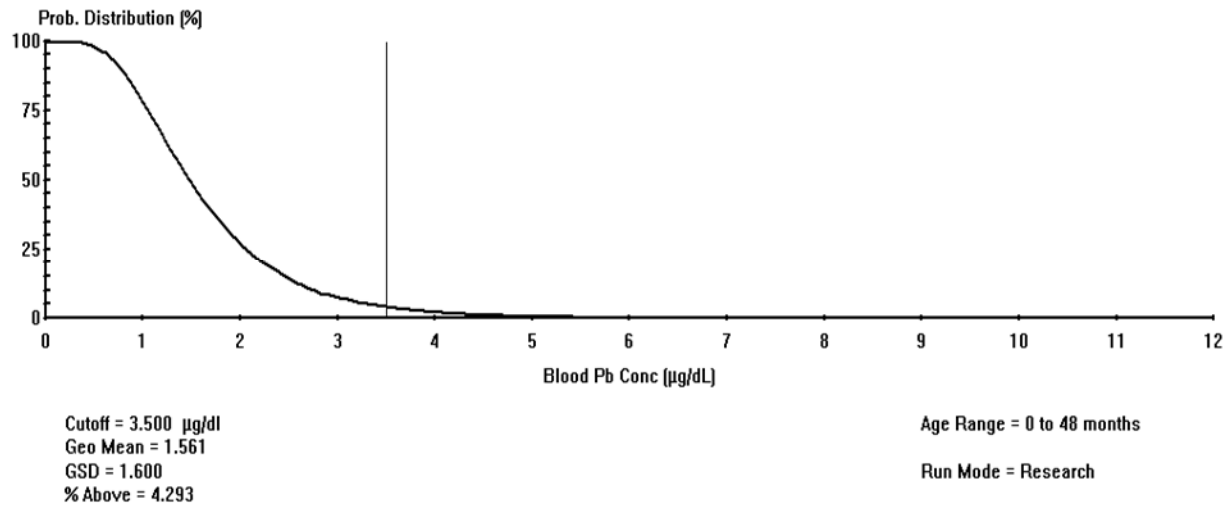


Figure 22: The probability Distribution Curve for Kolfe Karanyo

8. **Lideta**: The Mean lead concentration for the water and soil/dust were taken as 7.91 µg/l and 0.0025 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 13:

Table 12: Lideta Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.28	1.53	0.138	2.987	1.6
12m-24m	0.057	2.415	1.639	0.149	4.326	1.8
24m-36m	0.075	2.51	1.95	0.107	4.717	1.7
36m-48m	0.093	2.602	2.072	0.101	4.947	1.7

The probability distribution curve of BLL for Lideta Sub city shown in figure 22 , indicates the geometric mean BLL for children less than four years is 1.68 and 6.0% children's in Lideta Sub city exceed 3.5µg/l.

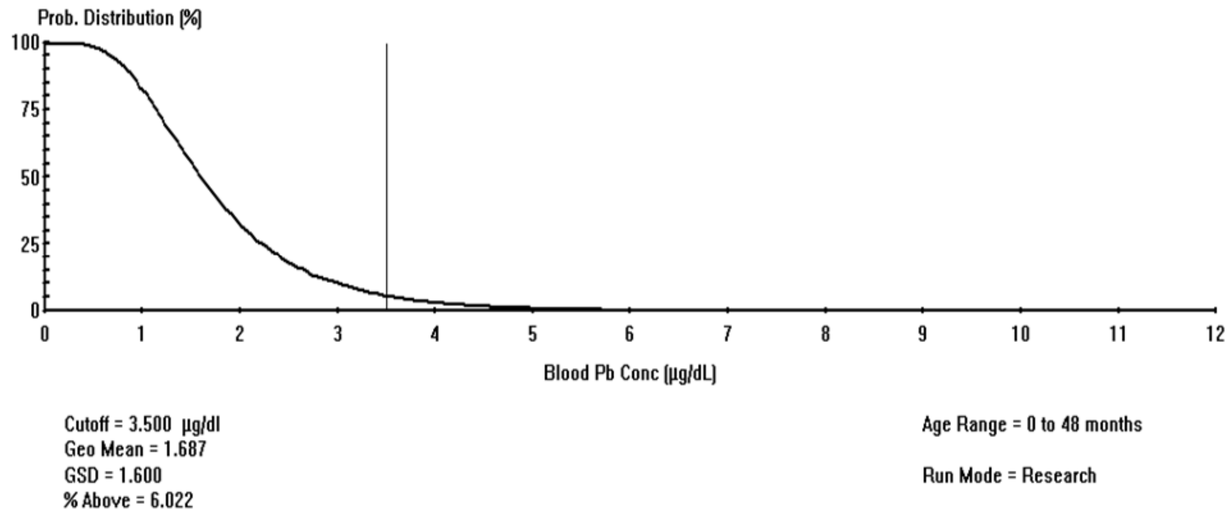


Figure 23: The probability distribution curve of Lideta Sub city

9. **Lemi Kura**: The Mean lead concentration for the water and soil/dust were taken as 9.01 µg/l and 0.0024 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 14:

Table 13: Lemi Kura Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.28	1.739	0.137	3.193	1.7
12m-24m	0.057	2.415	1.864	0.15	4.49	1.9
24m-36m	0.075	2.51	2.217	0.107	4.912	1.8
36m-48m	0.093	2.602	2.356	0.101	5.155	1.8

The probability distribution curve of BLL for Lemi Kura Sub city shown in figure 23, indicates the geometric mean BLL for children less than four years is 1.78 and 7.57% children's in Lemi Kura Sub city exceed 3.5µg/l.

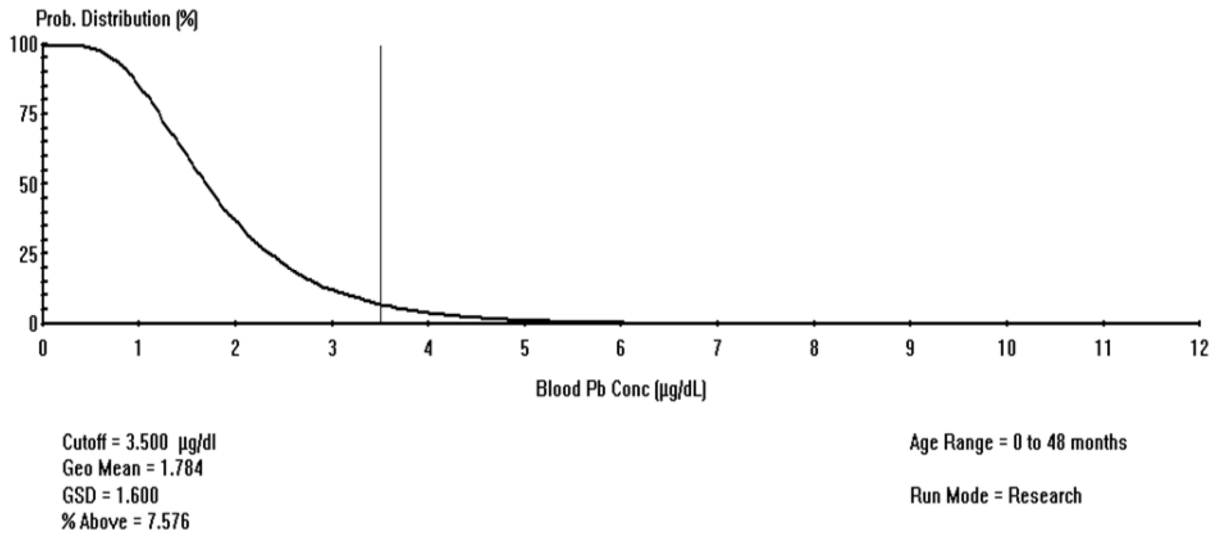


Figure 24: Probability Distribution Curve for Lemi Kura Sub city

10. **Nifas Silk**: The Mean lead concentration for the water and soil/dust were taken as 8.44 µg/l and 0.0022 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table 15:

Table 14: Nifas Silk Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.03	1.28	1.63	0.137	3.086	1.7
12m-24m	0.057	2.416	1.748	0.15	4.376	1.8
24m-36m	0.075	2.51	2.079	0.107	4.771	1.8
36m-48m	0.093	2.602	2.209	0.101	5.01	1.7

The probability distribution curve of BLL for Nifas Silk Sub city shown in figure 24, indicates the geometric mean BLL for children less than four years is 1.73 and 6.74% children's in Nifas Silk Sub city exceed 3.5µg/l.

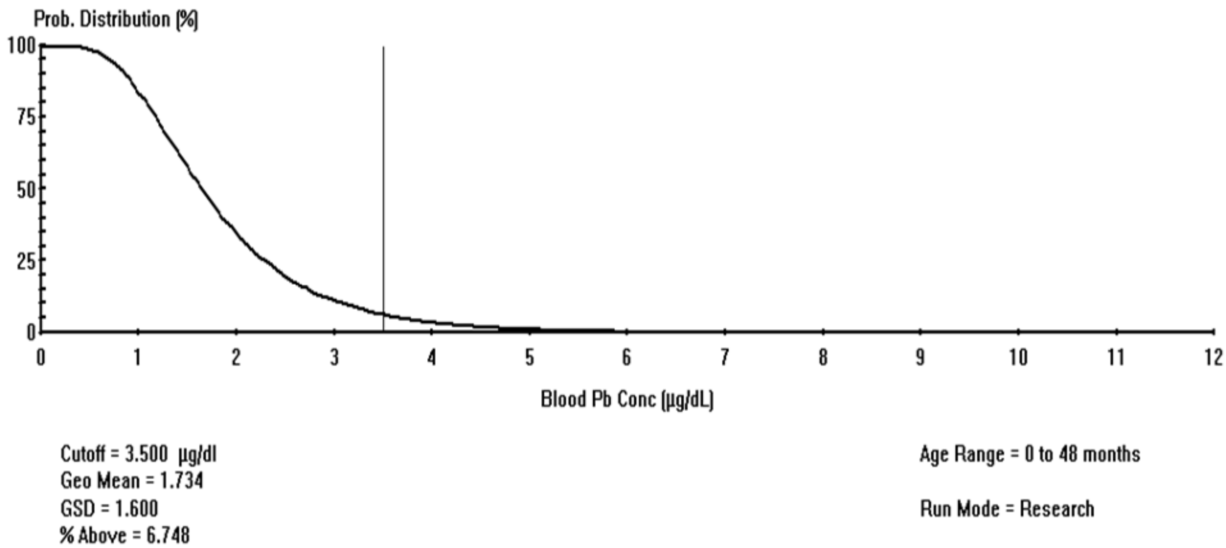


Figure 25: Probability Distribution Curve for Nifas Silk

11. **Yeka:** The Mean lead concentration for the water and soil/dust were taken as 10.07 µg/l and 0.0023 µg /g respectively all other input data were default data of IEUBK model. Calculated lead up take and BLL shown in table16

Table 15: Yeka Sub city calculated Uptake and BLL value

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.28	1.939	0.137	3.39	1.8
12m-24m	0.057	2.415	2.079	0.149	4.7	1.9
24m-36m	0.075	2.51	2.473	0.107	5.163	1.9
36m-48m	0.093	2.602	2.629	0.101	5.423	1.9

The probability distribution curve of BLL for Yeka Sub city shown in figure 25, indicates the geometric mean BLL for children less than four years is 1.87 and 9.23% children's in Yeka Sub city exceed 3.5µg/l.

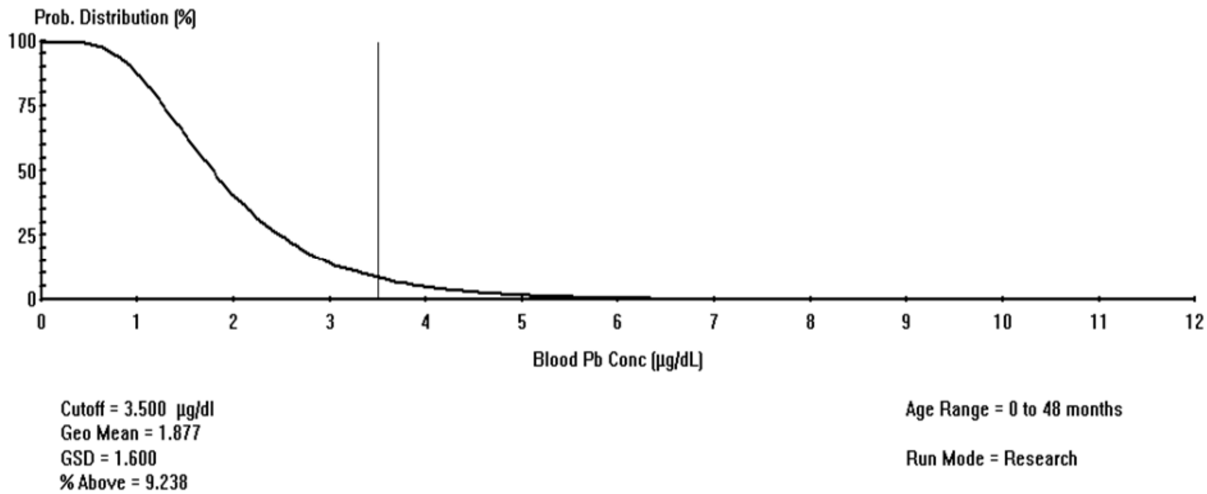


Figure 26: Probability Distribution Curve for Yeka Sub city

Blood lead Level in Addis Ababa City

The Mean lead concentration for the water and soil/dust were taken as 8.26µg/l and 0.00237 µg /g respectively all other input data were default data of IEUBK model. There is no safe blood lead level in children's even small amount have adverse effect in children overall nerve system, ability to pay attention and academic achievement and the Blood references value is 3.5µg/dl (CDC, 2021). Calculated lead uptake and BLL for Addis Ababa city presented in Table 17:

Table 16: Lead Uptake and Blood lead level in Addis Ababa City

Month	Air (µg/day)	Diet (µg/day)	Water (µg/day)	Soil/Dust (µg/day)	Total (µg/day)	Blood (µg/day)
6m-12m	0.034	1.285	1.596	0.137	3.053	1.6
12m-24m	0.057	2.423	1.711	1.49	4.34	1.8
24m-36m	0.075	2.517	2.035	0.107	4.734	1.7
36m-48m	0.093	2.608	2.163	0.101	4.965	1.7

The geometric mean of Blood Lead Level in children from day care sample is 1.718µg/dl. The percentage of exceeding 3.5µg/l is 6.497% for children's range from 0-48 months Shown in figure 26:

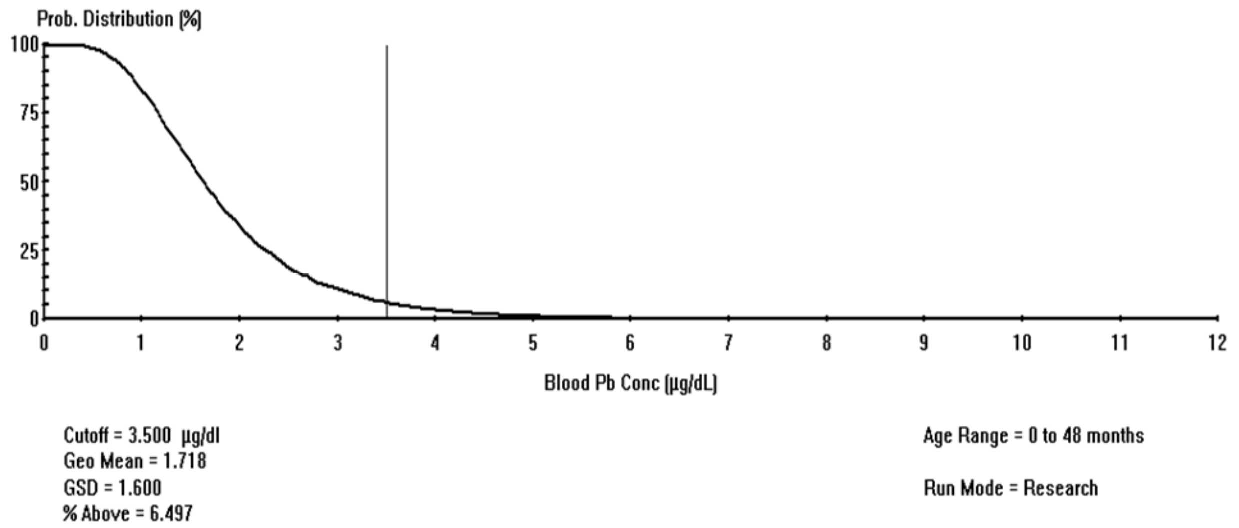


Figure 27: The Probability Distribution Curve for Addis Ababa City

A systematic review that analyze the BLL in LMICs (Low and Middle Income Countries) found that the pooled mean BBL in Ethiopia was 0-1.6µg/dl with SD 3.31. The review conducted on 34 countries which have adequate data on BBL in children's and adults. The BBL in LMICs is greater than HICs taking in to account the general populations in LMICs. The sources of exposure for HICs and LMICs is different; for higher income countries (HIC) ban of lead petrol and lead paint contributed to decrement of BBL in children however in LMICs despite the absences of lead paint ban there is low exposure of lead due to lead paint. According to the systematic review the major cause of exposure to lead is e-waste, informal lead acid battery recycling and metal mining and processing; foods and spices also contributed to BLL exposure (Bret et al., 2021).

Even though the BLL in each sub city below the BLRV 3.5µg/dl low blood lead level has harmful effects for children's and infants. Children are more vulnerable to lead contamination because they absorb nutrients more effectively than adults (SCHER, 2011). These effects are decrease IQ level, decrease hearing, decreased growth, and neurological effect (Sravya, 2015). Needllman et al found that children's who have lead level in dentine of deciduous tooth had higher risk of to complete high school and had less performance in school administrated IQ test.

4.4. Limitations of the study

This study conducted to assess the exposure of lead in tap water and soil in Addis Ababa City Day cares. Exposure to lead will affect childrens because childrens ingest soil while playing and absorbtion of lead for childrens is higher than adults, this study helps to explore lead blood level and lead level in soil and water in day care facilities.the study sought to estimate the blood lead level from IEUBK model.

Lead can be found in air, water, and soil this study include only water and soil further work can be conducted for interseted local areas using lead in the air. Also default value for dietary intake were used in IEUBK model. It would be favourable if lead level data were avialable on dietary intake. Only flushed samples were taken for this study sragnant water wasn't consider.

Further, it would be benefical is sample were taken from different land use types to have better understanding spatial variation of lead level.

Chapter Five: Conclusion and Reccomendation

5.1. Conclusion

In this study blood lead level in childrens less than four years old blood lead level were estimated using IEUBK model based on soil and water laboratory test result while taking default value for parameters (air and diterry intake). From this study the following conclustion are deduced:

- Lead level in soil from 28 daycare samples that were taken from each sub cities were below WHO recommendation (10µg/g)
- 75% of daycare samples had lead level below permisbile value of 10µg/l, while 25% of samples from 11 subcites had lead value above permixble value of 10µg/l(WHO, 2004).
- Water sample from surface sources had lead concentartion above WHO recommendation before treatment however samples that took after treatment were below WHO recommendation. All ground water samples which were taken before and after chlorination were below WHO recommendation.
- The computed average Blood lead level in childrens less than four years old in Addis Ababa city were 1.718µg/dl and percentage of exceedences the blood lead level reference value of 3.5 µg/dl were 6.49%.

This study will provide a better understanding of how drinking water and soil lead contamiantion affect childrens blood lead level.In the current study the lead level in daycares tapwater is greater than from lead level from sources of water (after treatment) this could indicate that there might be a sources of lead that affect the lead concentration in between sources of water and tap water. Knowning the sources of lead conatmination will help to provide better mitigation plan to reduce the lead level that present in the enviroment

5.2. Reccomendation

Based on the study conducted some of l daycares tap water lead concentartion are above the permisible value. Surface water sources lead level also above the recommended value. Therefore further research to find the possible sources of lead in drinking water in Addis Ababa. Some mitigation measures are present below:

- AWWSA Monitoring and reporting perodic water quality program; testing the water for lead in drinking water in regural interval basis.
- Minstry of Health should test enviromental medias soil, air and water that expouse to point sources of lead contamination, this could be industry area, mining site
- AAWSA need to consider providing Corrosion control Using corrosion inhibtators chemicals to that can reduce lead concentration in drinking water pipes.
- Addis Ababa Water and Sewage Ahtority needs to repalce old service pipe lines in the distrbution system that could contrbuite to leeching of lead from surfaces of pipes
- Minstiry of health and Addis Ababa sewage authority providing Public eduction and customer awwerness about health effects lead contamination from exposure of lead in the enviroment media

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Annex

No.	Subcity	Name	X(m)	Y(m)
1	Akaki Kality	Alem	474294.95	985040.6
2	Akaki Kality	Agunta	474674.34	980624.3
3	Akaki Kality	Blen	475254.3	987778.8
4	Addis Ketema	Golden	468206.52	1000723.99
5	Addis Ketema	Fema	466860.52	1000474.11
6	Arada	Eshetu	474453.89	998835.35
7	Bole	Little Steps	474970.09	992408.7
8	Bole	Little Scholars	477069.51	995828.56
9	Gulele	Pommy	470615.57	1002441.43
10	Kirkos	Kidi	473302.52	993919.76
11	Kirkos	Good Begnings	473888.31	994599.75
12	Kirkos	Maranata	473166.4	993341.48
13	Kirkos	Unique 700	474899.75	995303.12
14	Kolfe Keranyo	Leyu	466148.9	994980.02
15	Kolfe Keranyo	Meryem	466393.91	995074.46
16	Kolfe Keranyo	Rich	468199.13	994409.58
17	Lideta	Sololand	470569.67	994258.93
18	Lemi Kura	Alef	483557.94	995856.69
19	Lemi Kura	Atliya	485283.03	997023.26
20	Lemi Kura	Wonder Land	483479.15	996107.36
21	Lemi Kura	Ende Enat	482301.27	996514.86
22	Lemi Kura	Keyab	486382.71	997592.34
23	Nifas Silk	Naomi	471855.3	989252.04
24	Nifas Silk	Sunrise	473400.22	991808.02
25	Nifas Silk	Kinder	469595.47	989305.22
26	Nifas Silk	Alem one	473773.08	992201.03
27	Yeka	Hummpty Dummty	477599.99	997821.21

28	Yeka	Little explorer	476338.31	996694.1

Annex 1: Name of Samples, and Location

Annex 2. Sources Water sample location

No.	Sub city	Name	X(m)	Y(m)
1	Source	Legedadi before treatment	495629.26	1002256.13
2	Source	Legedadi after treatment	495629.26	1002256.13
3	Source	Geferrsa before treatment	459632.05	1002348.11
4	Source	Geferrsa afer treatment	459632.05	1002348.11
5	Source	Akaki well field before chlorination (BH-11)	478875	977517.04
6	Source	Akaki well field before chlorination (BH-11)	478875	977517.04
7	Source	Pocket 1	476474.23	983610.47
8	Source	Pocket 2	475424.06	985180.3

Annex 3. Time and Date of collected samples

No.	Subcity	Name	Date	Time
1	Akaki Kality	Alem	February,24	8:00AM
2	Akaki Kality	Agunta	February,24	9:30AM
3	Akaki Kality	Blen	February,24	7:00AM
4	Addis Ketema	Golden	February,22	3:30PM
5	Addis Ketema	Fema	February,22	4:45 PM
6	Arada	Eshetu	February,23	4:30PM
7	Bole	Little Steps	February,21	8:25AM
8	Bole	Little Scholars	February,21	9:37AM
9	Gulele	Pommy	February,23	1:18PM
10	Kirkos	Kidi	February,20	2:22PM
11	Kirkos	Good Begnings	February,20	3:06PM
12	Kirkos	Maranata	February,20	4:15PM
13	Kirkos	Unique 700	February,27	9:53AM
14	Kolfe Keranyo	Leyu	February,22	10:13AM
15	Kolfe Keranyo	Meryem	February,22	10:48AM
16	Kolfe Keranyo	Rich	February,22	11:32AM
17	Lideta	Sololand	February,20	2:38PM
18	Lemi Kura	Alef	February,21	1:55PM
19	Lemi Kura	Atliya	February,21	4:27PM
20	Lemi Kura	Wonder Land	February,21	5:22PM
21	Lemi Kura	Ende Enat	February,21	2:27PM
22	Lemi Kura	Keyab	February,21	3:42PM
23	Nifas Silk	Naomi	February,23	10:24AM
24	Nifas Silk	Sunrise	February,23	1:16PM
25	Nifas Silk	Kinder	February,27	11:10AM
26	Nifas Silk	Alem	February,20	5:13PM
27	Yeka	Hummpty Dummty	February,23	5:35PM
28	Yeka	Little explorer	February,21	11:05AM

Annex 4: Time and Date of Collected Sources Sample

No.	Sub city	Name	Date	Time
29	Source	Legedadi before treatment	March, 2	4:10PM
30	Source	Legedadi after treatment	March, 2	4:13PM
31	Source	Geferrsa before treatment	March, 2	11:22AM
32	Source	Geferrsa afer treatment	March, 2	11:32AM
33	Source	Akaki well field before chlorination (BH-11)	March,3	12:39AM
34	Source	Akaki well field before chlorination (BH-11)	March,3	1:16PM
35	Source	Pocket 1	March,3	1:51PM
36	Source	Pocket 2	March,3	2:22PM

Annex 5. Lead Concentration in soil/dust and drinking water media and also BLLs in children's

No.	Subcity	Name	Lead in µg/L in Water	Lead in mg/g in Soil	Blood Lead Level (BBL) in µg/dl	% Exceeding 3.5µg/l
1	Akaki Kality	Alem	11.284	0.003	1.982	11.322
2	Akaki Kality	Agunta	10.844	0.00205	1.944	10.55
3	Akaki Kality	Blen	7.401	0.0022	1.655	5.34
4	Addis Ketema	Golden	7.151	0.0025	1.632	5.06
5	Addis Ketema	Fema	7.612	0.0021	1.672	5.633
6	Arada	Eshetu	6.5315	0.00205	1.579	4.33
7	Bole	Little Steps	7.2305	0.0023	1.6	5.155
8	Bole	Little Scholars	7.424	0.0027	1.64	5.4
9	Gulele	Pommy	6.7075	0.00205	1.6	4.53
10	Kirkos	Kidi	7.3855	0.0029	1.61	5.34
11	Kirkos	Good Begnings	8.1305	0.0025	1.7	6.32
12	Kirkos	Maranata	9.1465	0.0024	1.79	7.7
13	Kirkos	Unique 700	8.107	0.0028	1.71	6.373
14	Kolfe Keranyo	Leyu	6.0775	0.0022	1.58	4.54
15	Kolfe Keranyo	Meryem	6.2835	0.00204	1.543	4.02
16	Kolfe Keranyo	Rich	7.1185	0.00215	1.682	5.943
17	Lideta	Sololand	7.9095	0.0025	1.686	6.01
18	Lemi Kura	Alef	6.359	0.0027	1.545	4.13
19	Lemi Kura	Atliya	10.1855	0.00225	1.88	9.43
20	Lemi Kura	Wonder Land	9.099	0.0031	1.784	7.575
21	Lemi Kura	Ende Enat	10.205	0.00231	1.88	9.452
22	Lemi Kura	Keyab	9.207	0.00205	1.785	7.591
23	Nifas Silk	Naomi	8.8285	0.00235	1.72	6.523
24	Nifas Silk	Sunrise	7.086	0.00215	1.614	4.973
25	Nifas Silk	Kinder	6.2955	0.0025	1.544	4.087
26	Nifas Silk	Alem	11.554	0.0021	2	11.84

27	Yeka	Hummpty Dummty	10.031	0.0024	1.87	9.13
28	Yeka	Little explorer	10.115	0.0022	1.88	9.34

Annex 6. Lead Concentration from sources Sample

No.	Location	Name	Lead in µg/L in Water
1	Source	Legedadi before treatment	20.625
2	Source	Legedadi after treatment	2.0425
3	Source	Geferrsa before treatment	20.51
4	Source	Geferrsa afer treatment	2.0435
5	Source	Akaki well field before chlorination (BH-11)	2.0575
6	Source	Akaki well field before chlorination (BH-11)	2.0405
7	Source	Pocket 1	2.065
8	Source	Pocket 2	2.0595


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