UNIVERSITY OF NAIROBI

Assessment of Maternal and Umbilical Cord Blood Lead Levels from Selected Informal Settlements in Nairobi County, Kenya.

By

Lumumba Edith Aida Dorsilla
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Declaration

I declare that this thesis is my original work and has not been submitted elsewhere for research. Where other people's work or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.

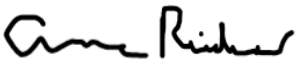
Lumumba Edith Aida Dorsilla
I56/11301/2018
Department of Chemistry
Faculty of Science and Technology
University of Nairobi

Signature  Date: 13th November 2022

This thesis is submitted for examination with my approval as the research supervisor:

Dr. Faridah Hussein Were Signature:  Date: 18th November 2022
Department of Chemistry,
Faculty of Science & Technology
University of Nairobi
P.O Box 30197-00100
Nairobi Kenya
fwere@uonbi.ac.ke

Dr. John Onam Onyatta Signature:  Date: 21st November 2022
Department of Chemistry,
Faculty of Science and Technology
University of Nairobi
P.O Box 30197-00100
Nairobi Kenya
john.onyatta@uonbi.ac.ke

Dr. Anne Riederer Signature:  Date: 22nd November 2022
Department of Environmental and Occupational Health Sciences
University of Washington
P.O Box 351618
Seattle WA, USA
anneried@uw.edu

Dedication

This thesis is dedicated to my late parents, Mr. and Mrs. Patrick Lumumba Ouko, to my son John Seth Mboke and to all the children that the Lord will bless me with.

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Abstract

Lead (Pb) is used in many manufacturing processes due to its useful properties. It is an important component in the manufacturing and recycling of lead batteries, manufacturing of paints and production of glazed pottery among others. However, Pb has no biological function; it is toxic, accumulates in biological systems and persists in the environment. The World Health Organization acknowledged that Pb is among the ten most toxic elements to human health. Pregnant women are vulnerable to the toxic effects of Pb as lead passes via the placenta to the developing fetus. As a result, it negatively affects the intelligence quotient (IQ) of the fetus since there is no brain barrier. Previous studies have indicated high levels of Pb in soil, water, and house dust in informal settlements. There is nonetheless scarce data on Pb exposure levels of mother-child pairs in Kenya despite the concerted efforts of phasing out leaded fuel and recently Pb in paint. The study was aimed at assessing the levels of lead in mothers and their newborns and potential sources of Pb exposure in selected informal settlements in Kenya. Blood from a total of 100 newborns (umbilical cord blood) and their mothers living in informal settlements was collected at the Pumwani Maternity Hospital and analyzed for levels of Pb using Inductively coupled plasma mass spectrometry (ICP-MS). The method of analysis was validated using ClinChek® Whole Blood Control, lyophilized, for Trace Elements, at different concentrations of Level I, II, III, procured from RECIPE Chemicals +instruments GmbH. A questionnaire was used to capture the likely sources of Pb exposure in the mother's environment. The median blood lead levels (BLLs) in newborns and their mothers were 2.1 and 26.7 µg/dL respectively. A high proportion of mothers (97%) had BLLs that exceeded the center for disease control (CDC) reference value of 5 µg/dL whereas, 25% of their newborns had BLLs above the 3.5 µg/dL reference value in children. A positive correlation (r_s=0.65, p=0.000) between maternal BLL and newborn BLL, was observed which deduces that maternal BLL may be an important indicator for prenatal lead exposure. Proximity to dumpsite and residence in painted houses were significantly associated (p=0.004 and p=0.000 respectively) with elevated BLLs. The study has highlighted BLLs in mothers and their newborns and the key contributing factors that urgently call for interventions and strategies to reduce these exposures in informal settlements.

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List of Abbreviations and Acronyms

AAS	Atomic Absorption Spectroscopy
ACGIH	American Conference of Governmental Industrial Hygienists
ATSDR	Agency for Toxic Substances and Disease Registry
BLLs	Blood Lead Levels
CBD	Central Business District
CBRN	Chemical Biological Radiological and Nuclear
CDC	Centre for Disease Control and Prevention
COE	Centre of Excellence
CRM	Certified Reference Material
CWC	Chemical Weapons Convention
dL	Decilitre
EDTA	Ethylediaminetetraacetic acid
FAO	Food and Agriculture Organization
GCD	Government Chemist Department
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
IPEN	International Pollutants Elimination Network
KEBS	Kenya Bureau of Standards
KIRDI	Kenya Industrial Research and Development Institute
KNBS	Kenya National Bureau of Statistics
NACOSTI	National Commission for Science, Technology and Innovation
NCC	Nairobi City County
ppm	Parts Per Million
ppb	Parts Per Billion
ULAB	Used Lead Acid Batteries
UNEP	United Nations Environment Programme
US EPA	United States Environmental Protection Agency

CHAPTER ONE
INTRODUCTION

1.1 Background information

Lead (Pb) remains widely used for manufacturing processes due its useful properties. It is used in manufacturing and recycling of lead acid batteries, paint, fuel, plumbing systems, glazed pottery, and electronic equipment among others (Baird and Cann, 2012; WHO, 2011; Ladelle *et al*., 2019). However, lead does not have any biological function. It is highly toxic, accumulates in biological systems and is persistent in the environment.

High blood lead levels (BLLs) have been reported in many countries across Africa especially in children. In NGagne Diaw, Senegal for example, there was unexplained death of children, investigations by environmental health experts concluded that the area was contaminated with Pb from informal recycling of lead batteries (Haefliger *et al*., 2009). Furthermore, siblings and mothers of the deceased children had BLLs above 100 μg/dL (WHO, 2008; Haefliger *et al*., 2009). Another study in Zamfara, Nigeria revealed BLLs exceeding 10 μg/dL amongst 204 children tested, the elevated lead was as a result of illegal extraction of its ores therefore contaminating water and homes in the village (Greig *et al*., 2014; Dooyema *et al*., 2012; CDC, 2010). Different proportions of 18%, 25% and 57% of children in Chowa, Mukulu and Kasanda of Zambia respectively, had BLLs that exceeded 65 μg/dL. It was reported that the elevated Pb levels was as a result of contaminated soil and water from smelter fumes during lead mining (Yabe *et al*., 2015; Abe *et al*,2015).

Over the years studies have revealed that manufacture and recycling of lead acid batteries is a chief source of Pb exposure (ATSDR, 2007). Similar studies carried out in Kenya have revealed significant amounts of Pb in the environment, especially in informal settlements. A study on air and BLLs in Used Lead Acid Batteries (ULAB) manufacturing sites in Kenya had mean BLLs for production and office workers that exceeded 30 μg/dL (Were *et al*., 2012). The state of affairs is worse in the informal sector where over 50% of ULAB is recycled by the informal recyclers in the developing world (Blacksmith Institute, 2011). Furthermore, the sector lacks resources and infrastructure to carry out this hazardous process in an environmentally sound manner.

A research conducted in the localities of informal ULAB recycling activities in Kenyan slums reported significantly high Pb levels in household dust which exceeded the US EPA guidance levels (Ondayo *et al*., 2016; US EPA, 2016). There was also an incident of Pb poisoning between workers and children and serious environmental contamination around poorly managed used lead acid battery recycling factory within Owino Uhuru slums in Mombasa (Okeyo *et al*., 2012), blood lead levels in 130 children aged between 12-59 months sampled from the area ,ranged from 1 to 31 μg/dL (Etiang' *et al*.,2018) .In addition, a study conducted in Nairobi and Olkalau in Kenya on 308 subjects reported that 25% of the subjects had elevated BLLs (Kimani, 2005).

Individuals can be exposed to Pb when they inhale contaminated air or consume substances containing lead (UNEP/FAO, 2003). Pica which refers to the persistent, compulsive craving for and the ingestion of substances usually considered inedible is said to be associated with severe Pb poisoning (Shannon, 2002). The U.S. Centers for Disease Control and prevention (CDC) had recommended a BLL of ≤5 μg/dL for expectant women and children (CDC, 2015), but the level was recently reviewed to lower than 3.5 μg/dL in children (CDC, 2021). Health authorities have concluded that there is no safe level for Pb exposure that impacts on pregnancy and neurological development of newborns (WHO, 2011).

A pregnant woman may accumulate and store in her bones and release it to the fetus. Lead poisoning has serious health consequences during pregnancy including increased rates of miscarriage and stillbirths (WHO, 2011). In addition, Pb from the mother's blood passes to the placenta and impacts on fetal development. Lactating mothers also transfer Pb to newborn children through breast-feeding. Exposure to Pb in utero and early in life is associated with gestational hypertension, low birth weight, and neurological deficits. Lead has irreversible impacts on the brain development (Heng *et al.*, 2022).

1.2 Statement of the problem

There is scarce information on the exposure levels of Pb in Kenya especially among vulnerable groups despite efforts in eradication of lead in fuel and currently in paints, and plumbing systems including drafting policies on management of e-waste.

Blood lead levels of 223 pregnant women in Nairobi had 70.4 % of samples with BLL >10 μg/dL which exceeded the CDC reference value (Owago *et al*., 2009). Another study in Lagos, Nigeria reported that the median BLL for 440 newborns and their mothers was 39.2 μg/dL and 64.3 μg/dL respectively (Ladele *et al*., 2019). To the best of our knowledge in Kenya there is no study that has been carried out to link the mother's environmental exposure to the child. Although there are quite a number studies on prenatal Pb exposure worldwide, there is very little recent data on prenatal Pb exposure in Kenya. In view of this, a study was therefore conducted to assess maternal and umbilical cord BLLs together with potential contributors of Pb exposure in informal settlements of Nairobi.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the study was to assess the levels of lead in mothers and their newborns and potential sources of Pb exposure in selected informal settlements in Kenya.

1.3.2 Specific objectives.

The specific objectives of this study were:

i. To assess the level of Pb in maternal and umbilical cord blood from mothers and their newborns living in informal settlements in Nairobi.
ii. To evaluate the data on the Pb levels in comparison with international health-based reference values.
iii. To determine likely contributors of Pb exposure in the environment of mothers from informal settlements in Nairobi.

1.4 Justification and significance of the study

There is considerable health concern, especially in developing countries, about Pb exposure to vulnerable population particularly women of reproductive age, children and through them future generations. Expectant women, unborn babies and children are most prone to the severe effects of Pb exposure. Even though a significant number of studies on BLLs in vulnerable people have been carried out in developed countries, there are very scarce data on the same in developing countries. Factors such as lack of effective policies, malnutrition, densely populated areas,

informal industries just to mention but a few make it impossible to compare data from developed countries with those in developing countries. This study has assessed the maternal and newborn BLLs and thus provided the anticipated periodic screening data on maternal and newborn BLLs from informal settlements in Nairobi in order to eliminate or prevent this exposure. The study has also recommended interventions that will assist in structuring of policy to prevent Pb exposure among the vulnerable groups.

1.5 Scope and Limitations of the study

The study assessed pregnant women who were residents of Dandora and Kariobangi informal settlements within Nairobi County. Questionaries were used to determine likely contributors of lead exposure in the mother's environment. The study was limited to the responses that was given through the questionaries.

CHAPTER TWO
LITERATURE REVIEW

2.1 Physical and chemical properties of lead

Lead metal exists as grey-white in color, glossy, soft, quite heavy and is corrosion resistant. Its atomic weight is 207.2 g/mol and vapor pressure is 1.77 mm Hg at 1000 °C (Abadin *et al*., 2007). Lead in the earth's crust mostly occurs as lead ore. Compounds such as lead nitrate, lead acetate, lead chloride and lead oxide are brightly colored and hence they are used to manufacture of paint. Solubility of compounds of Pb varies from insoluble to water soluble although pure Pb does not dissolve in water (Greenwood and Earnshaw, 1998).The stable forms of Pb are divalent (Pb^{2+}) and tetravalent (Pb^{4+}) oxidation states (Abadin *et al*., 2007).

2.2 Uses of lead

Lead does not have any known biological function (CDC, 2021). Pure Pb and amalgams are used in the production of lead acid batteries due to its high conductivity. These batteries have lower and significantly cheaper prices when compared to other types of batteries (Gulbinska, 2014). When alloyed with other metals and hardeners Pb can be used to manufacture bullets. This is possible because of its low melting point, ease in casting pellets and better retention velocity due to low density (Ramage, 1980). It is also used for piping in domestic water supplies and chemical plants because of its resistance to corrosion. The corrosion resistance of Pb is particularly useful in acid manufacturing plants (Abadin *et al*., 2007). Compounds of Pb are used for coating items such as ceramics, tableware, floor tiles, porcelain and some sanitary ware. Brightly colored lead compounds are also widely used in paint manufacturing (Abadin *et al*., 2007). The use of lead is however being phased out as a result of its toxic effects (Baird and Cann, 2012).

2.3 Potential exposures and sources of lead in informal settlements

Humans are exposed to Pb when they breathe in contaminated air and ingest contaminated food. The health implications of Pb are the same regardless of the route of exposure (UNEP/FAO, 2003). Metal industries such as lead smelters are currently the highest contributors to lead emissions in the air (US EPA, 2013).

Lead based paints are also a source of Pb exposure. The paint is applied on buildings, toys, furniture, playground equipment which children come into contact with. House dust arising from this paint is a major source of lead contamination (Lanphear *et al*., 1998). Old leaded pipes may also contribute to the contamination of drinking water with Pb (US EPA, 2016). Other sources of Pb may include the use of Pb containing traditional remedies, contamination of food and Pb earthenware coatings used in food containers (WHO, 2022).

Pollution from contaminated industrial fumes, mining, disposal of electronic waste and use of ammunition have also contributed to environmental exposure of Pb (WHO, 2022). Pregnant women who have deficiencies in calcium which is prevalent in Kenya are also likely to be exposed to Pb as a result of ingestion of non-food items contaminated with Pb (Shannon, 2002; Braithwaite, 2004).

Manufacture and recycling of ULAB has also been associated with exposure of Pb in women in informal settlements (Were *et al*., 2012). Research has also established that soil and water sampled at Dandora dumpsites in Nairobi contained high levels of lead (Mulamu, 2014). Waste pickers a majority of whom are women and children from informal settlements are involved in collecting valuables from the dumpsites. Most of these materials are scrap metals which during processing emit Pb fumes in the environment (Mulamu, 2014).

Fetuses are at even bigger risk as Pb can freely cross the placenta exposing them to Pb from the mothers previous and current Pb exposures (Abadin *et al*., 2007). Exposure to toxicants in utero may lead to downstream events such as neurodevelopment delays, behavioral issues and learning disabilities (Davis *et al*., 2019).

2.4 Transfer of lead from mother to child during pregnancy

Lead in the body is circulated through the blood and gets to the other systems like the brain, kidney and liver. It is then stored in the tissues such as bones where it bioaccumulates over time. For exposed mothers the bones serve as the chief organ from which lead can be released during pregnancy and lactation (WHO,2011). The lead is transferred from the mother’s blood to the fetal blood through the placenta and umbilical cord by simple diffusion mechanism, and

eventually infiltrates the brain since there is no blood brain barrier (Rísová,2019). The diffusion mechanism is presented in Figure 2.1.

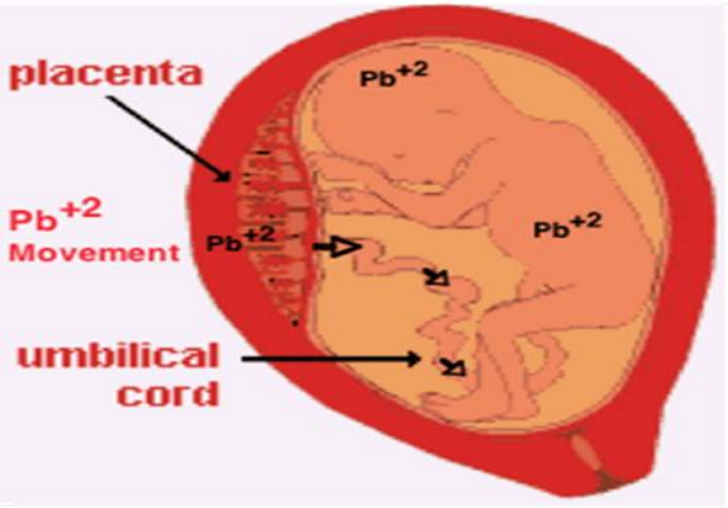

Figure 2.1: Transfer of lead from mother to child during pregnancy
Source: Mohammad, 2018

2.5 Health effects of lead

Studies have revealed that lead negatively affects multiple organs systems of humans. Consumption of enormous amounts of lead can result into a wide variety of gastrointestinal symptoms (US EPA, 2006). Exposures resulting in BLL between 70 and 100 µg/dL in children and between 100 and 120 µg/dL in adults may result to severe kidney and brain damage (ATSDR, 2007).

It has been reported that Pb has detrimental effects on the neurodevelopment of children. Low levels of Pb exposure early in life have been associated with a delay in cognitive development. During pregnancy exposure to lead can result in a higher likelihood of early labor, low birth weight among many other negative effects (ATDSR, 2007).

Pb has been shown to have influence on hemoglobin synthesis leading to anemia. Lead inhibits the enzyme ferrocheletase, which is involved in iron transport in the bone marrow and catalyzes the introduction of ferrous iron into the porphyrin ring haem, this is the last stage of haemoglobin synthesis (Sakai, 2000).

On average the lead in blood of individuals with only normal background exposure is 10-20 µg/dL. Blood levels of 40 µg/dL or more are considered excessive and indicate undue absorption of Pb, even if no symptoms are detected. The WHO proposed 5 µg/dL in women of child bearing age as maximum tolerable lead in blood concentrations (WHO, 2022).

2.6 Factors affecting the degree of toxicity of lead exposure

There are several factors that affect the degree of toxicity to an individual exposed to lead. This includes; dose of lead exposure, duration and frequency of exposure, nutritional status and personal characteristics of individuals.

2.6.1 Dose of lead exposure

The higher the amount of lead one is exposed to the higher its toxic effects towards the individual. The dose may be dependent on the occupational activity, proximity to the source and whether the individual resides in a rural or urban setting (Tchounwou, 2012)

2.6.2 Duration and frequency of exposure

Recurrent exposure to lead even in slight amounts results to accumulation of lead in the body. High single or multiple exposures occurring over a period of 1-2 days are categorized as acute exposures. Exposures occurring over extended period of time are on the other hand characterized as chronic exposures. Both chronic and acute exposure to lead is toxic to one's health (Tchounwou, 2012).

2.6.3 Personal characteristics of individuals

Children are more susceptible to the toxic effects of lead as compared to adults. There is also high deposition of lead in elderly individuals compared to the middle aged. The body lead burden is also higher in cigarette smokers and alcoholics (Tchounwou, 2012).

2.6.4 Nutritional status

Fasting, ingestion on an empty stomach, low calcium intake, iron deficiency, high zinc levels and vitamin D enhances the absorption of lead in the digestive system (Tchounwou, 2012).

2.7 Biomarkers of human lead exposure.

Studies have been carried out on environmental Pb exposure that involves soil, water and crops but these did not give the actual exposure levels. Biological samples such as breast milk, saliva, urine, bones and blood tend to provide a more likely representative of Pb exposure (WHO, 2011).

Whole blood however is considered as a good pointer of Pb exposure due to its ease of sampling, homogeneity of sample especially because BLLs appear to differ in a linear manner with exposure (Owago *et al*., 2009).

2.8 Analytical methods to determine blood lead levels

There are several analytical techniques that are used to determine BLLs that include; Inductively coupled plasma mass spectrometry (ICP-MS), Anodic stripping voltammetry (ASV), Atomic absorption spectrometry (AAS).

2.8.1 Anodic stripping voltammetry

It is an electrochemical technique that can be used for measurement of BLLs. The sample is first treated to convert Pb into its ionic form. A reference electrode and a thin film mercury graphite electrode are then dipped into the treated sample. A negative potential is then applied onto the mercury graphite electrode for some time which allows lead and other cations to concentrate onto the negatively charged electrode. The direction of potential is then reversed for some minutes thus generating an increasingly large potential. When the voltage reaches a specific and characteristic voltage for lead, all lead ions are released (stripped) from the electrode producing a current that can be measured. The current generated is proportional to the amount of lead present (World Health Organization, 2011). Currently portable ASV devices are used for near patient testing in cases where rapid diagnosis or screening of lead exposure is required.

Some of the advantages of portable ASV instruments are; Small sample size is required, can be done at non laboratory sites, low purchase and running costs. Some of the disadvantages of portable ASV instruments are; Limited analytical working range, high risk of sample cross contamination, levels above 5 µg/dL need to be confirmed by highly complex laboratory equipment (Skoog, 2007).

2.8.2 Atomic absorption spectrometry

AAS is a commonly used method for elemental analysis. It is based on the measurement of radiation absorbed by the analyte. When an atom absorbs UV-Visible radiation it makes transitions to higher energy levels and the amount of radiation absorbed is measured by use of a detector (Báez and García , 2012).

Each chemical element tends to have unique ionization energy as a result of the unique configuration of electrons in the outer shell. Calculation of concentration is based on Beer-Lambert law which states that absorbance is directly proportional to concentration for a given set of conditions. Standards of known concentration are used to create a calibration curve from which concentration of samples can be calculated (Skoog, 2007).

2.8.2.1 Flame atomic absorption spectrometry

Flame atomic absorption spectrometry (FAAS) normally uses an air-acetylene flame to atomize Pb at temperatures in the range of 2100 to 2400 °C (Skoog,2007). Some of the advantages of FAAS are; Short analysis time (seconds), relatively easy to use, reasonably few interferences, and low capital and running costs. Some of the disadvantages of FAAS are; large sample size is required, high detection limit (~10 µg/dL), cannot be left unattended (flammable gas) (Skoog, 2007)

2.8.2.2 Graphite Furnace Atomic Absorption Spectrometry

Most graphite furnace atomic absorption spectrometry (GFAAS) instruments use an electrically heated graphite tube to pylorise blood matrix and atomize lead (Skoog,2007). Some of the advantages of GFAAS are; Low detection limit (~1 µg/dL), can analyze small samples (50–100 µL), may be left unattended, no need for sample preparation. Some of the disadvantages of

GFAAS are; for volatile compounds analytes may at times be lost in the process of ashing, samples may not be fully atomized and may produce memory effect within the furnace, possibility of background absorption (Skoog, 2007)

2.8.3 Inductively coupled plasma mass spectrometry

ICP-MS is a multi-elemental technique that uses inductively coupled plasma source to dissociate the sample into its constituent atoms or ions. The ions are extracted from the plasma and passed into a mass spectrometer where they are separated and measured based on their mass to charge ratio (Skoog, 2007). A schematic diagram of the functional components of ICP-MS is presented in Figure 2.2. Some of the advantages of ICP-MS are; Very low detection limit (0.02 µg/dL) Fast analysis time (< 1 minute), low sample use. Some of the disadvantages of ICP-MS are; High purchase and running cost, requires skilled staff to operate (Skoog,2007).

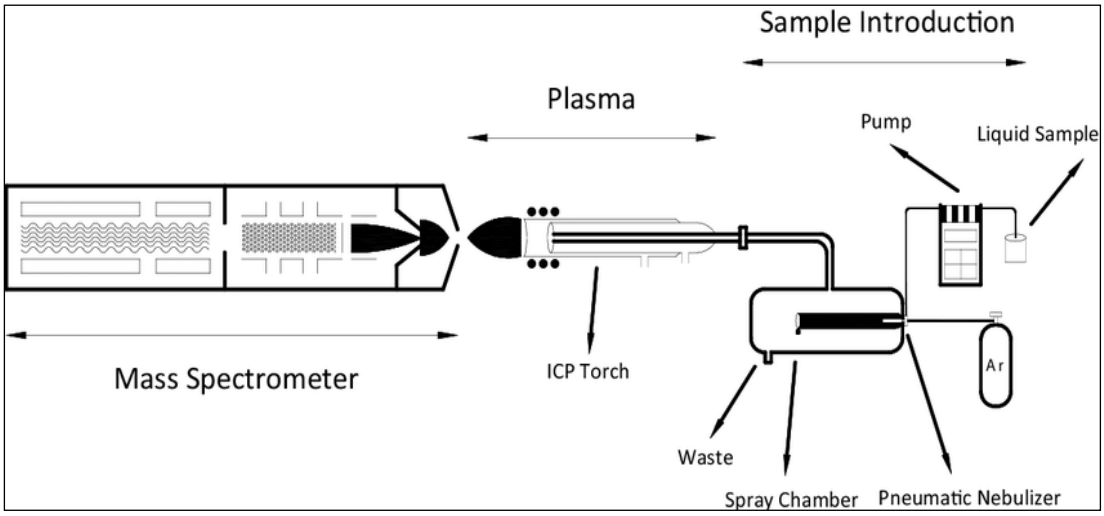

Figure 2.2: Schematic diagram of the functional components of ICP-MS
Source: Kashani and Mostaghimi, 2010

2.9 Summary of gaps in knowledge

A study of BLLs of 223 pregnant women in Nairobi showed that 70.4 % of the samples had BLLs >10 µg/dL which exceeded the CDC reference level (Owago *et al*., 2009). Another study in Lagos, Nigeria reported that the median BLLs for newborns and their mothers was 39.2 and 64.3 µg/dL, respectively (Ladele *et al*., 2019). However, in Kenya there is no study that has been carried out to link the mother's environmental exposure to the child. Although there are a number

studies on prenatal lead exposure worldwide, there is very little recent data on prenatal lead exposure in Kenya.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Research protocol

The study was carried out after approvals of the research protocol from Kenyatta National Hospital–University of Nairobi-Ethics and Research Committee (KNH-UoN-ERC)-Permit No: P835/10/2019 (Appendix 18). The protocol outlined the rationale for the study, its objective, the methodology and the management of data. It also highlighted ethical issues in consideration.

Permission and approvals were then sought from the management of Pumwani Maternity Hospital to conduct the study survey and collect maternal and umbilical cord blood (Appendix 19). Having been granted these permits and approvals, blood sampling at the hospital then began in December 2020 and ended in June 2021 at Pumwani Maternity Hospital.

The study is cross-sectional and descriptive in nature that used questionnaires in both English (Appendix 14) and Kiswahili (Appendix 15) to gather the targeted information from mothers drawn from densely populated informal settlements of Dandora and Kariobangi in Nairobi County. The laboratory analysis of blood lead levels (BLLs) was performed using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) (Appendix 20) at the Government Chemist Department Laboratory in Nairobi County under the Ministry of Interior and Coordination of National Government.

3.2 Description of study area

The study focused on densely populated informal settlements of Kariobangi and Dandora in Nairobi County targeting women who delivered at Pumwani public maternity hospital as shown in Figure 3.1. The hospital had subsidized medical care by the government. It is frequented by the poor and disadvantaged women of the society. Women delivering at this hospital are mostly low-income earners from informal settlements with a likelihood of high risk of Pb exposure. The hospital conducted quite a number of deliveries on a daily basis, between 50 and 100 normal deliveries and from 10 to 15 caesarian sections. (NCC, 2019).

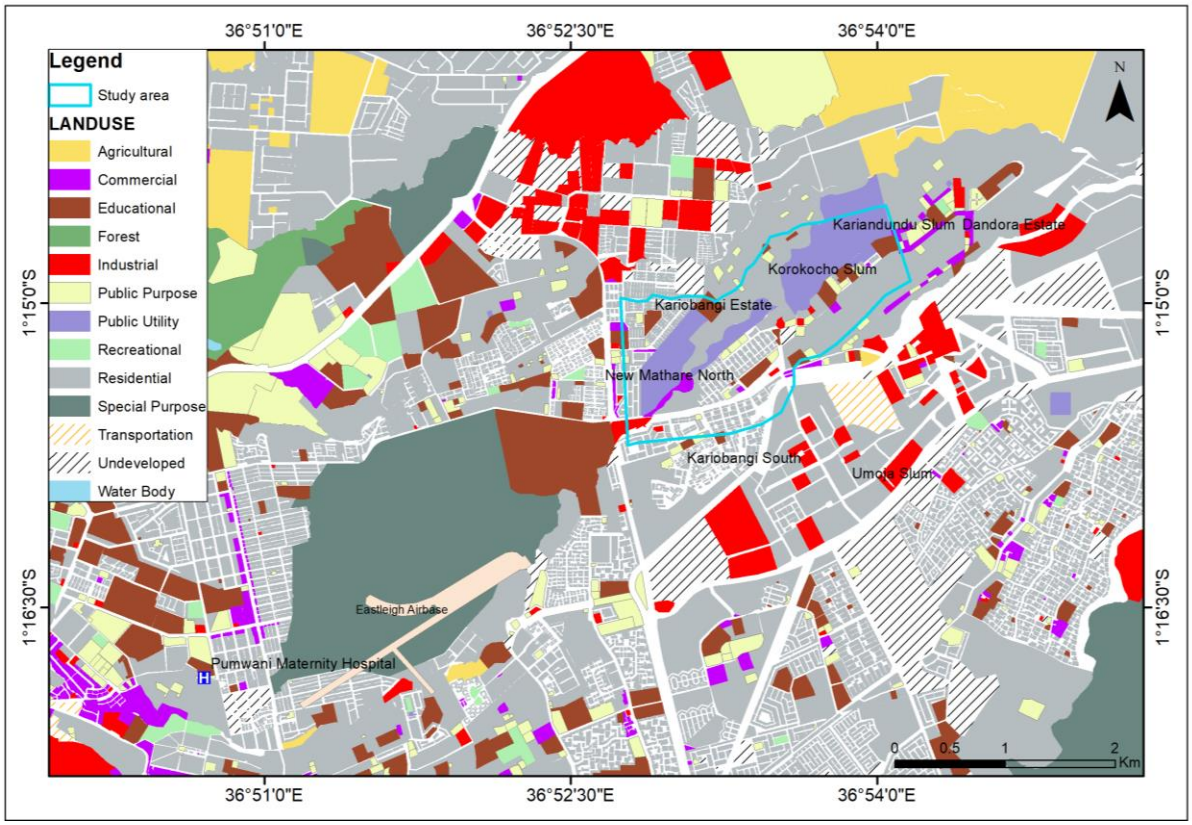

Figure 3.1: A map of the study area

Dandora whose GPS coordinates are, Latitude: -1° 14' 60.00"S Longitude: 36° 53' 59.99" E is located in Embakasi division about 8 km from Nairobi Central Business District (CBD). It is divided into five phases with a general population of 295,670. It is home to Nairobi's principal dumpsite (KNBS, 2019). Majority of women and their children pick valuables from these wastes (Appendix 22). Previous studies on soil, water and house dust have shown that the area is heavily polluted with heavy metals especially lead (Kimani, 2021; Ondanyo *et al*., 2016; Hokuto *et al*., 2015; Kimani, 2007). A study on leachates from ten sampling trenches at Dandora dumpsite recorded significantly high levels of lead ranging from 4,650 to 9,580 µg/kg (Tsuma *et al., 2016*).

Kariobangi whose GPS coordinates are, Latitude: -1° 14' 60.00" S Longitude: 36° 52' 59.99" E on the other hand is a residential area located 15 km from Nairobi CBD and covers about 20 square km^2 (KNBS, 2019). It has an agglomeration of industries known as Kariobangi light industries. The light industries are an industrial cluster characterized by poor infrastructure and high population densities (Wagura, 2019). To a larger extent the zoning of residential and

industrial area is ineffective in separating the hazardous areas from the communities. A number of studies have revealed high levels of Pb in soil, paint and water from the area (Mwai *et al*, 2022; Njoroge *et al.*, 2008; Kimani, 2005). Ondayo *et al* (2016) reported high levels of Pb in 70.7% household floor dust (n=322) sampled in Kariobangi. The study further predicted that 99.9% of children below the age of seven years living in the area would likely have BLLs above the CDC reference value (Ondayo *et al*., 2016).

Bordering Dandora and Kariobangi informal settlement is Nairobi River (Appendix 22). Some waste from Dandora dumpsite ends up into the river thus spreading health and environmental risks to the people living within the area as well as those living downstream who could be using the water for various purposes including drinking and agriculture. Indeed, studies have reported high levels of lead in water, soil, fish and plants sampled from the river (Gaiti, 2020; Njuguna *et al.*, 2017; Masese, 2010)

3.3 Study participants

The study considered mothers who were above 18 years old with informed consent and residing in densely populated Dandora and Kariobangi informal settlements in Nairobi for more than one year where long-term exposure was assumed. The participants included mothers and their newborns delivered at Pumwani Maternity Hospital.

3.3.1 Exclusion criteria

Mothers who were not living in Dandora or Kariobangi informal settlement or were resident for less than one year were excluded from the study. Those who were not willing to consent to the study were also excluded from the study. Women who presented with emergent or complicated conditions such as uterine rapture, ecclampsia, ante-partum hemorrhage and those with sickle cell anemia were excluded from the study.

3.4 Participant recruitment and enrollment

A total of one hundred and fifty (n =150) mothers with informed consent in English (Appendix 16) or Kiswahili (Appendix 17) residing in Dandora or Kariobangi informal settlements for more than one year with their newborns (n=150) in Pumwani Maternity Hospital were recruited to participate in the study. Out of the 150 mothers recruited, 50 of them did not participate in the

study as 22 of them withdrew their consent in the course of the study, 10 lost their newborns during delivery,10 developed complications during delivery and 8 sample vials were inappropriately labeled. A total of one hundred mothers (n=100), consisting of 48 from Kariobangi and 52 from Dandora and their newborn (n=100) gave their blood samples and also filled the questionaries. Giving the response rate of 66.7% which was rated adequate.

3.5 Sample collection and pre-treatment

About 2 mL and I mL of blood samples from mothers and their newborns (umbilical cord), respectively were collected into trace element-free BD Vacutainer® royal blue top, venous blood collection tubes coated with K_2EDTA (BD, Franklin Lakes, New Jersey) by an authorized medical officer in the labour and delivery rooms. To prevent coagulation each tube was swirled severally in order to mix the blood with EDTA (Ladelle *et al*., 2019; Owago *et al.*, 2009). A vacutainer® tube was filled with distilled-deionized water after every twenty blood samples collected and was treated in the same way as the collected blood samples. These were recorded as field blanks for the study. A total of eight field bank samples were collected for this study.

The blood samples from the mothers who participated in the study were coded as M01, M02…. up to M100, and the corresponding blood samples from newborns coded as B01, B02…. up to B100. Thereafter, K to represent mothers from Kariobangi and a D to represent mothers from Dandora was added to the corresponding maternal codes. The field blank samples were also coded as F01, F02……. up to F08. The samples were then stored in a cooler box with appropriate precautions to avoid contamination of the samples. Thereafter, the samples were frozen at 4^oC according to Owago *et al* (2009), and stored at the Toxicology Department (biohazard laboratory) of the Government Chemist Laboratories prior to Pb analysis.

3.6 Questionnaire administration

After delivery and recovery, a trained authorized medical officer gathered information from mothers using the questionnaires in English (Appendix 14). The questionnaire was also administered in Kiswahili for those mothers who did not understand English (Appendix 15) The information gathered included their bio data, socio-demographic history, environmental exposure and area of residence of the participants. The questionnaire was adopted from Were *et al.* (2008) study of lead and other heavy metals levels in the fingernails of 200 children in Kenya.

3.7 Sample digestion

400 µL of thawed whole blood was transferred into a well labeled beaker and 4ml of nitric acid trace metal grade (Thermo Fisher Scientific, Waltham, Massachusetts) added to it. The sample was then slowly digested on a hot plate in the fume hood for about 3 hrs at 100 ^{0}C. After digestion distilled-deionized water was added to the sample to make 10 ml of the sample solution (Zota *et al*., 2016; Shimadzu Cooperation, 2017). A laboratory blank (coded L01, L02……. up to L10) was digested in a similar manner to the samples for every day blood samples were being digested. The laboratory blank contained all the reagents used for digestion apart from the analyte of interest (blood sample). A total of ten laboratory blanks were digested. The eight field blanks collected during sampling were also digested in similar manner to samples.

Certified reference material, ClinChek® Whole Blood Control, lyophilized, for Trace Elements in different concentrations, Level I, II, III (RECIPE Chemicals +instruments GmbH , München, Bayern) were digested in a similar manner to the samples.

200 µL of mother's blood samples labeled M95K and M26K from the youngest mothers were each spiked with 200 µL of 20 ppb standard. The samples were thereafter labeled as recovery samples 16 (R16) and 10 (R10). The spiked samples were then digested in a similar manner as those of un-spiked samples.

3.8 Preparation of standards

A series of working standards for lead in parts per billion (ppb) were prepared as 10 ppb, 20 ppb, 30 ppb, 40 ppb, 50 ppb in 100 mL volumetric flasks from the standard stock solution of 100 mg/L ICP Multi-elemental standard (Reagecon, Clare, Ireland). The serial dilutions are presented in Appendix 4 and the certificate of analysis for the multi-elemental standard in Appendix 5.

3.9 Lead analysis using Inductively Coupled Plasma-Mass Spectrometry

The calibration standard solutions, sample solutions, field and laboratory blank samples were assayed in triplicate using ICP-MS (Thermo Scientific ICAP RC model, Waltham, Massachusetts) with an auto-sampler (Teledyne Cetac Technologies ASX-560 model, Omaha, Nebraska). Certified reference materials were run to give five replicate measurements using ICP-

MS. Samples whose bloods lead levels were above the linear range of calibration (above 50 ppb), were diluted, re-analyzed and the value of the reanalyzed sample reported. All samples were randomly loaded on the auto-sampler. The key instrument parameters for ICP-MS were optimized as per the instrument's manual (Table 3.1).

Table 3.1: ICP-MS optimal analytical conditions for analysis of lead

ICP-MS Optimal Parameters	
Instrument warm up	20 minutes
Uptake time	120 seconds
Cool gas	13.98 L/min
Auxilary gas	0.8 L/min
Nebulizer gas	1.06 L/min

The instruments limit of detection (LoD) for lead was 0.0016 ppb

3.10 Quality control and assurance

All the glassware used in this study were decontaminated by soaking them overnight in 5% nitric acid trace metal grade (Thermo Fisher Scientific, Waltham, Massachusetts) and rinsed thoroughly using distilled-deionized water. They were subsequently dried in the oven at 105^0C and stored in clean dry racks. Plastic tubes were cleaned using non-ionic liquid soap and rinsed using distilled-deionized water. They were then soaked overnight in 1:1 nitric acid, rinsed with distilled-deionized water and stored in an open rack.

Water used for sample and standard preparations was distilled-deionized from Government Chemist analytical laboratory. Standard solutions for calibration were prepared from a commercial stock standard with a certificate of analysis traceable to ISO 17025 (Reagecon, Clare, Ireland), the certificate of analysis is presented in Appendix 5. They were checked for constancy of absorption before taking the readings. Trace metal grade nitric acid was used for sample preparations; the certificate of analysis is presented in Appendix 13.

Optimization of ICP-MS conditions was done prior to analysis of samples and standards according to table 3.1. The instruments sample probe and tubing were rinsed for one minute using dilute trace metal grade nitric acid (2%) after every sample run to minimize sample to sample memory effects.

During analysis ten laboratory and eight field blank samples were run through the ICP-MS to ensure that the system was free from contaminants and interferences. The mean ±SD Pb concentration in the blanks (Appendix 10) was found to be 0.13 ± 0.047 µg/dL. Control charts for the field and laboratory blanks were also prepared in Appendix 11.

The limit of detection of the method was 10 ppb which was the concentration of the lowest calibration standard. For statistical calculations machine values were used for observations that were below the method detection limit.

Two blood samples from participant young mothers were spiked with a 20 ppb calibration standard, digested and analyzed for blood lead levels. The recovery of the method was found to be 102.3% and 101.8% (Appendix 12) which was deemed accurate and reliable.

The method of analysis was validated using ClinChek® Whole Blood Control Lyophilized samples for trace elements analysis, certified reference material (CRM) in 3 levels (CRM I, CRM II and CRM III) (RECIPE Chemicals +instruments GmbH, München, Bayern). One sample for each level was analyzed to give five replicate readings (Appendix 8) in the ICP-MS. The results were within the expected range and hence accurate (Table 3.2), Appendix 7 (certificate of analysis for CRM) and Appendix 9 (calculations on BLLs of the CRMs).

Table 3.2: Certified reference material recoveries

Sample name	Observed BLLs Mean ±SD in ppb (n=5)	Observed BLLs range in ppb (n=5)	Mean % Recoveries for Pb	Expected BLL (Mean) in ppb	Expected BLL (range) in ppb
CRM I	39.9 ±0.03	39.9-40.0	106.1%	37.6	30.1-45.2
CRM II	97.3 ±0.19	97.1-97.5	101.8%	95.6	76.5-115
CRM III	262.5 ±0.56	261.8-262.8	100.9%	260	208-312

±SD = Standard Deviation from the Mean BLLs=Blood Lead Levels

The questionnaire used in the study was pretested on five pregnant women from Kariobangi and Dandora attending antenatal checkup at Pumwani Maternity Hospital and improvements made on it based on the outcome of the pretest.

3.11 Data analysis

Statistical analysis was conducted using Microsoft excel (Microsoft Corporation, Redmond, Washington). The mean levels in µg/dL and the standard deviation of lead were determined. Socio-demographic factors comparisons with varying concentration of lead levels in the maternal blood was done using chi-square test. Spearman's correlation (r_s) coefficient was used to demonstrate the correlation between maternal BLLs and umbilical cord BLLs. Student t test was used to compare BLLs of mothers from Kariobangi and Dandora informal settlement. The level of statistical significance was set at $p < 0.05$.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Maternal blood lead levels

The raw data of blood lead levels (BLLs) drawn from the 100 mothers are presented in Appendix 1 and the corresponding cumulative distribution of the BLLs are given in Table 4.1. They ranged from 4.0 to 91.2 µg/dL with a mean of 27.3 µg/dL and standard deviation (±SD) of 15.54 µg/dL. The median maternal BLLs was 26.7 µg/dL. This median was 5 times higher than that of CDC reference level of 5 µg/dL in women of childbearing age. The elevated BLLs could be due to high levels of Pb contamination in Nairobi informal settlements that has also been reported by various researchers (Kimani, 2021, Ondanyo *et al*., 2016, Hokuto *et al*., 2015, Kimani, 2005). These BLLs are comparable to the findings of Owago *et al* (2009) that revealed substantial BLLs which ranged from non-detectable to 295.0 µg/dL with a mean of 29.5 µg/dL in 223 pregnant women in Kenya. Furthermore, the recent research reviews across Africa have reported alarmingly high BLLs (Nakata *et al.,* 2021, Ladelle *et al*., 2019, Bede *et al.,* 2018).

Table 4.1: The distribution of maternal blood lead levels

Range of BLLs (µg/dL)	Frequency	%Cumulative frequency
0-5	3	3
5-10	6	9
10-20	25	34
20-30	28	62
30-40	20	82
40-50	14	96
50-60	0	96
60-70	2	98
70-80	0	98
80-90	1	99
90-100	1	100

From Table 4.1, using the CDC 5 µg/dL blood lead reference level in women of child bearing age, it was found that 97% (n=97) of the mothers had BLL >5 µg/dL. It is observed that elevated BLL remains a public health problem in developing countries and explicitly Kenya. Moreover, there is no known biological function of Pb irrespective of the route of exposure. Lead is highly toxic with specific physiological effects to virtually all the biological systems (Bellinger and Bellinger, 2006). These effects are clearly explained by Figure 4.1. For instance, the highest number of women fell into the category of BLLS between 20 and 30 µg/dL, this levels of Pb have been implicated in decreased level of vitamin D metabolism and increased risk of hypertension. The two women in this study whose BLLS were between 80 and 100 µg/dL could be at a high risk of frank anemia and nephropathy (Bellinger and Bellinger, 2006).

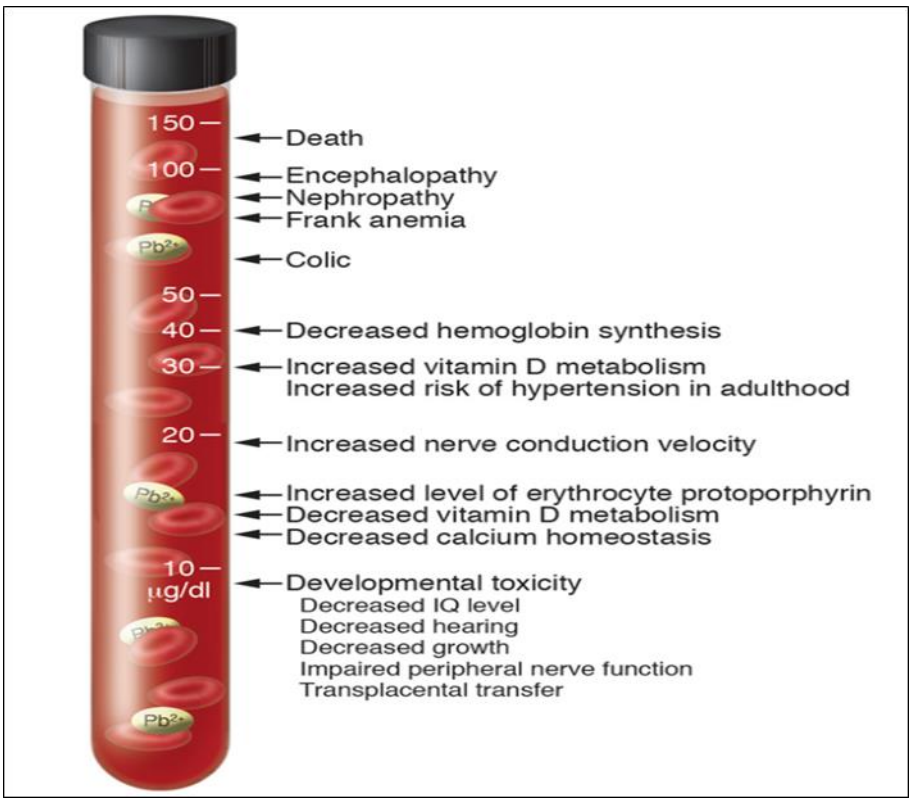

Figure 4.1: Effects of blood lead at different concentrations.
Source: Bellinger and Bellinger, 2006

4.2 Umbilical cord blood lead levels

On the other hand, the umbilical cord BLLs from the 100 newborns sampled are given in Appendix 2 and the distribution is summarized in Table 4.2. The BLLs of the newborns ranged from 0.7 to 9.9 µg/dL with a mean of 2.7 µg/dL and a standard deviation (±SD) of 1.92 µg/dL. The median BLL was 2.1 µg/dL. The BLLs observed in newborns are a strong indicator that Pb

freely crosses the placenta hence exposing the fetus to the mother's BLLs. Even though 75% of the newborns had BLLs below the CDC level of concern, scientific evidence suggests that there is no safe BLLs as even small amounts of Pb could cause devastating health effects, especially to the child's developing brain (CDC, 2021). It is also a serious concern as lactating mothers transfer Pb to their newborn children through breastfeeding (Heng *et al.*, 2022).

Table 4.2: The distribution of umbilical cord blood lead levels

Range of BLL (µg/dL)	Frequency	% Cumulative frequency
0-1	6	6%
1-2	41	47%
2-3	24	71%
3-4	13	84%
4-5	6	90%
5-6	4	94%
6-7	0	94%
7-8	2	96%
8-9	1	97%
9-10	3	100%

Using the previous CDC reference BLLs of 5 µg/dL in children (CDC, 2021), 10% (n=10) of newborns (Table 4.2) had BLLs above the CDC level of concern. BLLs above 5 µg/dL have been associated with decreased IQ, decreased hearing, decreased growth, and impaired nerve function in children which persists into adulthood (Bellinger and Bellinger, 2006). Health authorities have also concluded that there is no safe BLLs. It is for this reason that the current CDC reference level was revised to 3.5 µg/dL. Nonetheless, when the current CDC level of concern of 3.5 µg/dL (CDC, 2021) is applied, 25% (n=25) of the newborns in this study had BLLs that were above the level of concern. These levels have irreversible impacts on the brain development of children (Heng *et al.*, 2022).

4.3 Correlation between maternal and newborn blood lead levels

Spearman's correlation (r_s) coefficient was used to assess the correlation between maternal and umbilical cord BLLs. The level of statistical significance was set at p <0.05. From the study and as shown in Figure 4.2, there was a positive correlation (r_s=0.65, p=0.00) between maternal and newborn BLLs, which infers that maternal BLLs may be a significant marker for prenatal Pb exposure. This result agrees with reports from other researchers which showed that there was a direct relationship between maternal and umbilical cord BLLs. (Nakata *et al.*, 2021,Ladele *et al.*, 2019 and Kirel *et al.* ,2005).

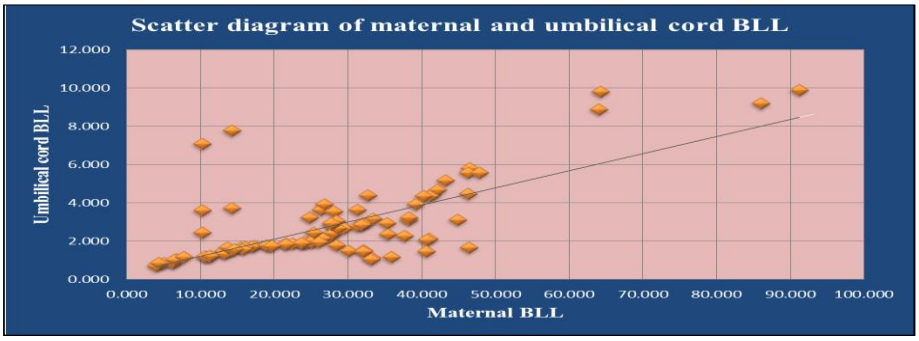

Figure 4.2: Scatter diagram for the correlation between maternal and umbilical cord BLL.

Studies have indicated that maternal lead can pass via the placenta to the fetus (Onuzulu, 2019) thereby exposing the fetus to lead. Once the Pb enters the childs blood stream, it has potential of damaging biological sytems.The primary target organ being the central nervous system. Low levels of Pb have been implicated to affect the immune and cadiovascular systems. Aditionally, Pb toxity has been acociated with the ability to replace calcium which affects neurotransmitter structure that impairs neuroligical functions and other severe health impacts (CDC, 2021). The BLLs in mothers should therefore be a point of concern as this will continue affecting the children even during lactating periods (Heng *et al*., 2022). Several studies have revealed that mothers exposed to Pb in their enviroment had high levels of lead in breast milk (Bassil *et al*., 2018;Gundacker, 2002). The risk of continued exposure in the newborns can not be ignored as the newborns will grow in the mothers environment. The exposure to Pb in children tends to be different from that of adults in a variety of ways. The amount of fluids, food and air taken by children per kilogram of body weight tends to be more when compared to that of adults. What a child eats also differs from adults as in most cases they eat more of a particular type of food than

adults. A child's behavior and lifestyle also influence exposure. Children are nearer to the ground and with more mouth hand to mouth activities (Tarragó, 2012).

4.4 Comparison of blood lead levels of mothers from Kariobangi versus Dandora

The BLLs of mothers from Kariobangi was compared to that of mothers from Dandora as shown in Table 4.3.

Table 4.3: Comparison of blood lead levels of mothers from Kariobangi versus Dandora

Area of residence	Mean ± SD (µg/dL)	Range (µg/dL)	t-value at p=0.05
Kariobangi (n=48)	27.45 ± 16.51	4.00 - 86.03	-0.09
Dandora (n=52)	27.15 ± 14.75	4.46 - 91.22	

From Table 4.3 the mean BLLs of mothers from Kariobangi of 27.45 ± 16.51 µg/dL was higher than those of mothers from Dandora that was 27.15 ± 14.75 µg/dL. The t calculated value of -0.09 is lower than the t-critical value of 1.98 at p=0.05, df 98 thus indicating that there is no significance difference between the BLLs of women from the two areas. This would suggest that the levels of contaminations between the two informal settlements would likely be the same.

4.5 Demographic characteristics of mothers

From the questionnaires, the ages of the mothers sampled ranged from 21 to 40 years. 60% (n=60) reported secondary school as their highest level of education, while 30% (n=30) had primary school education as their highest level. Only 5% (n=5) of these women had tertiary education, and 5% (n=5) did not any form of formal education. It is also important to note that all mothers including those with highest level of education (tertiary) were not aware of the toxic effects of lead. A lot of effort, therefore, needed towards creating awareness on Pb and its toxic effects at the community level.

4.6 Possible contributors of lead exposure

Factors that were most likely to affect mothers Pb exposure such as age, residing near or working at a dumpsite, drinking water from old leaded pipes, pica, living in lead painted houses were considered using the questionnaires (Appendices 14 and 15).

4.6.1 Relationship between blood lead levels and age of mothers.

The ages of mothers that were sampled ranged from 21years to 40 years with a mean age of 30.4±4.9 years. Grouping the participants into four categories of age <25, 25-29, 30-34 and >35 years and application of chi-square at significance level of 0.05, the BLL were as summarized in Table 4.4.

Table 4.4: Relationship between BLLS and age of mothers

Age group	N	Number of mothers with BLL > 5 ug/dL	Number of women with BLL < 5 ug/dL
<25	3	1	2
25-29	40	39	1
30-34	29	29	0
>35	28	28	0
$\chi 2$	43.59		
p value	0.00		

$\chi 2$- Chi square
p<0.05 level of significance between the age-group and BLL
n= number mothers in a particular age group

From the study there is a statistical significance (*p*<0.05) between the mothers age and their BLL (*p*=0.00). This is not surprising as Pb bio accumulates, implying that women who have lived in that environment are likely to accumulate more Pb. This is contrary to the study conducted on BLL from pregnant women in Nairobi which reported that there was a weak correlation between age and BLLs (Owago *et al*., 2009).

4.6.2 Contribution of painted houses on maternal BLL

From the mothers sampled, 87 % (n=87) reported that they were living in painted houses with 58 % (n=58) reporting that some sections of their houses had peeling paint. The BLLs in relation to painted houses are as summarized in Table 4.5.

Table 4.5: Contribution of painted houses on maternal BLL

Residence in a painted house	Number of mothers with BLL > 5 ug/dL	Number of mothers with BLL < 5 ug/dL
Yes	87	0
No	10	3
$\chi 2$	20.7	
p value	0.00	

$\chi 2$- Chi square $p<0.05$ level of significance between painted houses and BLL

Results in Table 4.5, showed that residence in a painted house was significantly associated with elevated BLL (p=0.00). The findings are however not surprising since a number of studies in Kenya have indicated that lead levels in paint sold in the Kenyan market was above the recommended limit (CEJAD, 2017; Mwai *et al*., 2021; Were *et al.*, 2008).

4.6.3 Contribution of proximity to dumpsites to maternal BLLs

56% (n=56) of the women whose blood samples were analyzed lived next to a dumpsite (approximately ≤10meters). The BLL in relation to proximity to dumpsite is summarized in Table 4.6.

Table 4.6: Contribution of proximity to a dumpsite to maternal BLLs

Residence near a dumpsite	Number of mothers with BLL > 5 ug/dL	Number of mothers with BLL < 5 ug/dL
Yes	56	0
No	41	3
$\chi 2$	3.9	
p value	0.04	

$\chi 2$- Chi square $p<0.05$ level of significance between proximity to dumpsite and BLL

Living next to dumpsite was significantly associated (p=0.04) with elevated BLLs. Indeed, researchers have also reported that dumpsites are a major contributor to high levels of lead in the environment. The lead is basically deposited in soil and eventually leaches into water systems

and reaches the food chain (Ondanyo *et al*., 2016; Tsuma *et al*., 2016) therefore exposing the population to its negative effects.

4.6.4 Contribution of battery recycling activities to maternal BLL

48% (n=48) of mothers reported to be living close to a battery recycling plant or activities (approximately 10 meters and below). The BLLs of the women in relation to proximity to battery recycling plant or activities is summarized in Table 4.7.

Table 4.7: Contribution of battery recycling activities to maternal BLL

Residence close to battery recycling plant	Number of mothers with BLL > 5 ug/dL	Number of mothers with BLL < 5 ug/dL
Yes	48	1
No	49	2
$\chi 2$	0.3	
p value	0.6	

$\chi 2$- Chi square

$p<0.05$ level of significance between proximity to battery recycling activities or plant and BLL

The p value (0.6) suggests that the relationship between living in vicinity of battery recycling activities and elevated BLL is not statistically significant. Lead recycling activities however are an important source of environmental pollution and human exposure in many developing countries (WHO, 2022) and further studies in this area is encouraged as the results depended on the mother's response. A study conducted by Were *et al,* 2012 reported elevated BLL in workers from a battery recycling plant and high lead levels in the air around the vicinity.

4.6.5: Influence of consumption of non-food items on maternal BLL

40% (n=40) of the mothers were found to consume non-food items such as stones and soil during their pregnancy. The relationship between consumption of non- food items and BLL is summarized in Table 4.8.

Table 4.8: Contribution of consumption of non-food items to maternal BLL

Consumption of non-food items	Number of mothers with BLL > 5 ug/dL	Number of mothers with BLL < 5 ug/dL
Yes	40	2
No	57	1
$\chi 2$	0.8	
p value	0.4	

$\chi 2$- Chi square
$p<0.05$ level of significance between PICA and BLL

The consumption of non-food items was associated with elevated BLLs but this did not achieve the level of statistical significance ($p<0.05$). It may be probable that the non-food items that the mothers consumed did not contain lead and their BLLs were as a result of other sources. This also calls for further study to explore the responses that were given by the mothers.This was consistent with research conducted on pregnant women in Mexico where it was reported that although prevalence of pica was high it was not indicative to elevated BLL (Bhakhireva *et al.*, 2013).

4.6.6 Influence of drinking water from old pipes on maternal BLL

53% (n=53) of the mothers were reported to be drinking water that pass through old pipes. The relationship between drinking water from old pipes and BLL is summarized in Table 4.9

Table 4.9: Contribution of drinking water from leaded pipes to maternal BLL

Drinking water from old pipes	Number of mothers with BLL > 5 ug/dL	Number of mothers with BLL < 5 ug/dL
Yes	53	2
No	44	1
$\chi 2$	0.2	
p value	0.6	

$\chi 2$- Chi square $p<0.05$ level of significance between drinking water from old pipes and BLL

There was no statistically significant association between drinking water from old pipes and elevated BLLs. Probably the piping system used for channeling drinking water was not leaded. It

should be noted however that leaded pipes may also contribute to the contamination of drinking water with lead (EPA, 2016).

4.6.7 Influence of use of glazed pottery on maternal BLL

The study showed that 57% (n=57) of the mothers used glazed pottery to serve food. The relationship between the use of glazed pottery and BLL is summarized in Table 4.9

Table 4.10: Relation between the of use of glazed pottery to maternal BLL

Use of glazed pottery	Number of mothers with BLL > 5 ug/dl	Number of mothers with BLL < 5 ug/dl
Yes	57	1
No	40	2
$\chi 2$	0.8	
p value	0.4	

$\chi 2$- Chi square $p<0.05$ level of significance between use of glazed pottery and BLL

The study showed that there was no statistically significant relationship between the use of glazed pottery and elevated BLL. There may be a probability that the paint used to glaze the pottery did not contain lead. This was in contradiction to a study conducted by Owago *et al*., (2009) in which it was reported that use of glazed pottery was the main contributor to elevated BLL.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has given an overview of BLLs in the newborns and their mothers from Kariobangi and Dandora the informal settlements and has also pointed out some of the important sources of lead exposure in informal settlements in Nairobi, Kenya. It has showed that 97% (n=97) of the mothers had BLLs above 5 µg/dL, of the CDC level of reference indicating that the elevated BLL in informal settlements is of public health concern. On the other hand , 25% (n=25) of the newborns had BLLs that exceeded the current CDC cut off level of 3.5 µg/dL (CDC, 2021). There was a positive correlation (r_s=0.65, p=0.00) between maternal and newborn BLLs, which implies that maternal BLL could be a significant marker for prenatal lead exposure.

From the mothers' responses, factors that were significantly associated with elevated BLLs were: living in painted houses, living or working adjacent to the dumpsite and maternal age. However, there was no statistical relationship between battery manufacturing proximity, non-food item consumption and use of old pipes for water distribution, and elevated blood lead levels in maternal blood or in the newborns.

5.2 Recommendations

The recommendations arising from this study are:

i. Sharing of the findings with policy makers, industry, health care and community is necessary to implement actions that reduce environmental lead exposure.
ii. Dissemination and creating awareness about the toxic effects of lead and conducting frequent studies to monitor the levels of lead in the general population.
iii. Further studies should be conducted to evaluate the impact of breastfeeding on blood lead levels in infants and on neurodevelopment
iv. Health policies should also be included screening of pregnant women and children for lead poisoning and include more interventions of reducing blood lead levels such as through chelation therapy, more intake of calcium and vitamin D.

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APPENDICES

Appendix 1: Maternal bloods lead levels analyzed in triplicates using ICP-MS

Maternal blood lead levels from Dandora				
Sample code	Blood lead levels (BLL) (µg/dL)			
	BLL 1	BLL 2	BLL 3	Mean ± SD
M09D	28.695	28.468	28.633	28.598 ± 0.118
M24D	6.930	6.830	6.683	6.814 ± 0.125
M63D	64.363	63.165	65.258	64.262 ± 1.050
M52D	22.773	22.285	22.733	22.597 ± 0.271
M89D	17.678	17.070	17.535	17.428 ± 0.318
M55D	17.075	17.323	16.623	17.007 ± 0.355
M64D	13.015	13.658	13.433	13.368 ± 0.326
M49D	24.025	23.715	23.715	23.818 ± 0.179
M76D	13.073	13.298	13.093	13.154 ± 0.125
M53D	28.313	27.863	27.650	27.942 ± 0.338
M22D	86.298	86.233	85.558	86.029 ± 0.410
M41D	10.925	10.610	11.085	10.873 ± 0.242
M47D	26.510	26.288	26.868	26.555 ± 0.293
M67D	27.468	27.268	27.293	27.343 ± 0.109
M01D	25.223	25.213	25.215	25.217 ± 0.005
M88D	25.000	25.000	25.855	25.285 ± 0.494
M82D	24.720	23.085	23.585	23.797 ± 0.838
M90D	14.188	14.003	14.103	14.098± 0.093
M60D	11.388	11.305	11.320	11.338 ± 0.044
M15D	26.738	26.528	26.548	26.604 ± 0.116
M54D	33.640	33.355	33.350	33.448 ± 0.166
M45D	42.468	42.113	42.085	42.222 ± 0.213
M39D	46.388	46.273	46.273	46.311 ± 0.066
M70D	41.140	41.088	41.063	41.097 ± 0.040
M12D	31.133	31.283	31.533	31.316 ± 0.202
M81D	19.748	19.673	19.725	19.715± 0.038
M17D	7.815	7.803	7.800	7.806 ± 0.008
M13D	16.023	16.048	16.028	16.033 ± 0.013
M94D	44.928	44.853	44.828	44.869 ± 0.052
M20D	41.208	41.058	40.808	41.024 ± 0.202
M48D	26.635	26.310	26.06	26.335 ± 0.288
M77D	27.748	27.835	27.735	27.773 ± 0.054
M30D	32.275	32.228	31.803	32.102 ± 0.260
M14D	14.270	14.265	14.278	14.271 ± 0.006
M06D	38.240	38.240	38.243	38.241 ± 0.001

Sample code	Blood lead levels (BLL) (µg/dL)			
	BLL 1	BLL 2	BLL 3	Mean ± SD
M14D	28.118	28.113	28.103	28.111 ± 0.008
M92D	35.403	35.400	35.405	35.403 ± 0.003
M18D	26.823	26.825	26.828	26.825 ± 0.002
M28D	40.813	40.81	40.805	40.809 ± 0.004
M34D	25.403	25.378	25.398	25.393 ± 0.013
M21D	31.298	31.283	31.278	31.286 ± 0.010
M37D	35.925	35.948	35.928	35.933 ± 0.012
M38D	10.288	10.295	10.290	10.291 ± 0.004
M78D	40.690	40.685	40.688	40.688 ± 0.002
M32D	28.440	28.435	28.425	28.433 ± 0.008
M83D	28.440	28.435	28.425	28.433 ± 0.008
M31D	32.275	32.228	31.803	32.102 ± 0.260
M23D	14.270	14.265	14.278	14.271 ± 0.006
M40D	38.240	38.24	38.243	38.24 ± 0.001
M35D	33.213	33.213	33.2	33.208 ± 0.007
M12D	14.728	14.728	14.498	14.651 ± 0.133
Overall mean ±SD	27.45 ± 16.51			
M.D= Maternal code for mothers in Dandora				
Maternal blood lead levels from Kariobangi				
Sample code	Blood lead levels (BLL) (µg/dL)			
	BLL 1	BLL 2	BLL 3	MEAN ± SD
M71K	5.065	5.265	5.095	5.142 ± 0.108
M25K	4.328	4.455	4.608	4.463 ± 0.140
M42K	21.830	21.683	21.19	21.568 ± 0.335
M27K	90.525	92.045	91.075	91.215 ± 0.770
M19K	25.478	25.180	25.350	25.336 ± 0.149
M87K	47.008	45.583	47.225	46.605 ± 0.892
M33K	31.350	31.695	32.65	31.898 ± 0.673
M26K	13.663	13.795	13.790	13.749± 0.075
M46K	3.998	3.978	4.020	3.998 ± 0.021
M10K	6.228	6.513	6.473	6.404 ± 0.154
M29K	4.270	4.415	4.325	4.337 ± 0.073
M07K	15.713	15.33	15.498	15.513 ± 0.192
M99K	24.248	24.62	24.525	24.464 ± 0.194
M98K	63.675	63.345	64.940	63.987 ± 0.842
M74K	28.903	30.178	29.478	29.519 ± 0.639
M56K	10.288	10.803	10.775	10.622 ± 0.290

M95K	43.190	43.980	42.483	43.218 ± 0.749
M57K	39.165	39.165	39.24	39.190 ± 0.043
Sample code	Blood lead levels (BLL) (μg/dL)			
	BLL 1	BLL 2	BLL 3	MEAN ± SD
M08K	24.138	24.138	24.125	24.133 ± 0.007
M36K	46.335	46.335	46.333	46.334 ± 0.001
M65K	32.778	32.528	32.548	32.618 ± 0.139
M91K	42.138	41.125	41.135	41.466 ± 0.582
M16K	14.138	12.638	13.138	13.304 ± 0.764
M73K	19.748	19.228	19.22	19.398 ± 0.302
M61K	19.140	19.000	19.058	19.066 ± 0.070
M44K	21.745	21.545	21.52	21.603 ± 0.123
M79K	28.055	28.035	28.048	28.046 ± 0.010
M84K	29.085	27.835	28.835	28.585 ± 0.661
M50K	11.055	11.180	11.680	11.305 ± 0.331
M11K	6.688	6.488	6.48	6.552 ± 0.118
M69K	32.078	32.003	32.055	32.045 ± 0.038
M58K	26.195	26.170	26.150	26.172 ± 0.023
M43K	31.930	31.885	31.875	31.897 ± 0.029
M72K	15.830	15.863	15.858	15.850 ± 0.018
M51K	40.303	40.335	40.323	40.320 ± 0.016
M75K	30.228	30.108	30.208	30.181 ± 0.064
M68K	14.263	14.278	14.253	14.264 ± 0.013
M100K	47.773	47.775	47.975	47.841 ± 0.116
M62K	32.758	32.778	32.750	32.762 ± 0.014
M97K	37.663	37.745	37.520	37.643 ± 0.114
M35K	33.213	33.213	33.200	33.208 ± 0.007
M86K	10.248	10.245	10.245	10.246 ± 0.001
M66K	24.760	24.758	24.768	24.762 ± 0.005
M59K	35.270	35.273	35.275	35.273 ± 0.003
M80K	27.748	27.835	27.735	27.773 ± 0.054
M93K	10.270	10.193	10.365	10.276 ± 0.086
M96K	45.940	45.895	47.438	46.424 ± 0.878
M23K	13.663	13.795	13.790	13.749 ± 0.075
Overall mean ±SD	27.15 ± 14.75			

M = Maternal Sample (1-100 coding)
±SD = standard deviation from the mean
K = Kariobangi
D = Dandora
Method detection limit=10 ppb
Samples whose bloods lead levels were above the linear range of calibration (above 50ppb), were diluted and re-analyzed and the value of the reanalyzed sample reported.

Appendix 2: Umbilical cord blood lead levels by ICP-MS in triplicates

Sample code	Blood lead levels (BLL) (μg/dL)			
	BLL 1	BLL 2	BLL 3	MEAN ± SD
B71	0.899	0.846	0.800	0.848 ± 0.050
B85	0.876	0.876	0.816	0.856 ± 0.035
B25	0.809	0.806	0.800	0.805 ± 0.005
B09	2.645	2.648	2.646	2.646 ± 0.002
B24	1.001	1.211	0.959	1.057 ± 0.135
B42	1.928	1.808	1.839	1.858 ± 0.062
B27	9.806	9.805	9.801	9.804 ± 0.003
B19	2.096	2.047	2.047	2.063 ± 0.028
B63	9.896	9.895	9.871	9.887 ± 0.014
B52	1.853	1.846	1.891	1.863 ± 0.024
B89	1.743	1.748	1.718	1.736 ± 0.016
B87	5.853	5.716	5.791	5.787 ± 0.069
B55	1.710	1.711	1.707	1.709 ± 0.002
B33	2.856	2.856	2.853	2.855 ± 0.002
B26	1.472	1.497	1.465	1.478 ± 0.017
B46	0.718	0.718	0.718	0.718 ± 0.000
B10	0.918	0.878	0.944	0.913 ± 0.033
B29	0.845	0.839	0.825	0.836 ± 0.010
B64	1.445	1.409	1.425	1.426 ± 0.018
B07	1.661	1.661	1.619	1.647 ± 0.024
B99	1.906	1.909	1.909	1.908 ± 0.002
B98	8.836	8.902	8.861	8.866 ± 0.033
B49	1.897	1.887	1.877	1.887 ± 0.010
B76	1.409	1.480	1.467	1.452 ± 0.038
B53	2.345	2.348	2.346	2.346 ± 0.002
B74	2.676	2.655	2.671	2.667 ± 0.011
B22	9.199	9.203	9.193	9.198 ± 0.005
B41	1.186	1.164	1.193	1.181 ± 0.015
B56	1.178	1.183	1.186	1.182 ± 0.004
B95	5.173	5.173	5.173	5.173 ± 0.000
B47	2.199	2.116	2.187	2.167 ± 0.045
B67	2.209	2.168	2.167	2.181 ± 0.024
B57	3.970	3.886	3.889	3.915 ± 0.048
B08	1.903	1.948	1.918	1.923 ± 0.023
B36	5.595	5.508	5.568	5.557 ± 0.045

Sample code	Blood lead levels (BLL) (µg/dL)			
	BLL 1	BLL 2	BLL 3	MEAN ± SD
B65	2.928	2.944	2.924	2.932 ± 0.011
B01	1.926	1.909	1.939	1.925 ± 0.015
B91	4.453	4.423	4.459	4.445 ± 0.019
B16	1.356	1.342	1.361	1.353 ± 0.010
B73	1.728	1.734	1.799	1.754 ± 0.039
B88	2.018	2.078	2.044	2.047 ± 0.030
B61	1.798	1.746	1.754	1.766 ± 0.028
B82	1.896	1.895	1.871	1.887 ± 0.014
B44	1.828	1.824	1.821	1.824 ± 0.004
B90	1.542	1.591	1.595	1.576 ± 0.030
B60	1.195	1.185	1.192	1.191 ± 0.005
B15	2.103	2.197	2.184	2.161 ± 0.051
B79	2.547	2.132	2.547	2.409 ± 0.240
B54	3.195	3.140	3.167	3.167 ± 0.028
B45	4.499	4.975	4.503	4.659 ± 0.274
B39	4.499	4.499	4.499	4.499 ± 0.000
B70	4.349	4.316	4.387	4.351 ± 0.036
B84	2.840	2.578	2.642	2.687 ± 0.137
B12	2.798	2.794	2.792	2.795 ± 0.003
B50	1.201	1.211	1.259	1.224 ± 0.031
B11	1.028	1.008	1.039	1.025 ± 0.016
B81	1.773	1.711	1.796	1.760 ±0.044
B17	1.172	1.197	1.165	1.178 ± 0.017
B13	1.695	1.671	1.667	1.678 ± 0.015
B69	2.943	2.945	2.948	2.945 ± 0.003
B58	1.910	1.980	1.922	1.937 ± 0.037
B43	2.899	2.875	2.803	2.859 ± 0.050
B72	1.581	1.588	1.584	1.584 ± 0.004
B51	4.314	4.378	4.342	4.345 ± 0.032
B75	1.378	1.503	1.560	1.480 ± 0.093
B68	7.810	7.800	7.722	7.777 ± 0.048
B100	5.640	5.378	5.661	5.560 ± 0.158
B94	3.095	3.090	3.095	3.093 ± 0.003
B62	4.476	4.276	4.416	4.389 ± 0.103
B20	2.128	2.128	2.127	2.128 ± 0.001
B48	3.362	3.922	3.567	3.617 ± 0.283

Sample code	Blood lead levels (BLL) (µg/dL)			
	BLL 1	BLL 2	BLL 2	MEAN ± SD
B97	2.284	2.282	2.274	2.280 ± 0.005
B77	2.814	2.878	2.842	2.845 ±0.032
B30	1.598	1.446	1.540	1.528 ± 0.077
B14	3.737	3.805	3.609	3.717 ± 0.100
B06	3.137	3.105	3.109	3.117 ± 0.017
B35	1.105	1.194	1.107	1.135 ± 0.051
B86	2.403	2.397	2.484	2.428 ± 0.049
B14	3.547	3.527	3.540	3.538 ± 0.010
B92	2.349	2.340	2.342	2.344 ± 0.005
B18	3.970	3.886	3.889	3.915 ± 0.048
B28	2.096	2.047	2.047	2.063 ± 0.028
B34	2.473	2.327	2.484	2.428 ± 0.088
B21	3.362	3.922	3.567	3.617 ± 0.283
B37	1.186	1.164	1.193	1.181 ± 0.015
B38	3.695	3.208	3.868	3.590 ± 0.342
B78	1.793	1.277	1.333	1.468 ± 0.283
B66	3.242	3.191	3.195	3.209 ± 0.028
B59	2.950	2.901	2.967	2.939 ± 0.034
B32	3.095	3.008	3.068	3.057 ± 0.045
B83	1.853	1.906	1.591	1.783 ± 0.169
B80	2.950	2.901	2.967	2.939 ± 0.034
B31	1.456	1.456	1.453	1.455 ± 0.002
B23	1.570	1.586	1.589	1.582 ± 0.010
B40	3.237	3.238	3.233	3.236 ± 0.003
B35	1.001	1.211	0.959	1.057 ± 0.135
B93	7.547	6.132	7.547	7.075 ± 0.817
B96	1.640	1.678	1.661	1.660 ± 0.019
B23	1.640	1.678	1.661	1.660 ± 0.019
B12	1.645	1.509	1.525	1.560 ± 0.074
Overall mean				2.748 ± 1.92

B= Umbilical cord blood Sample (1-100 coding)

±SD = standard deviation from the mean

For statistical calculations machine values were used for the observations that were below the method detection limit (10ppb)

Appendix 3: Calibration curve for Lead

Calibration
10/19/2021 3:56:58 PM

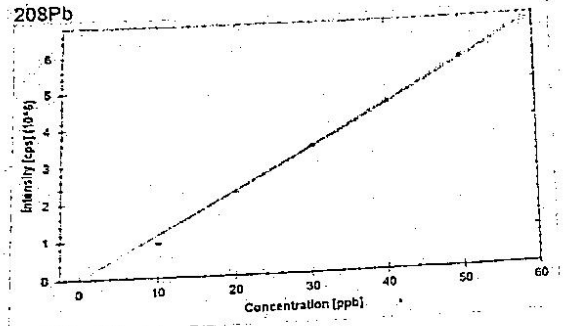
QTEGRA

Calibration Curves:

InstrumentName	SerialNumber
iCAP RQ	Undefined

LabBook	LabBookPath
20211019.imexp	Application Data\Workspace\LabBooks

208Pb



f(x) = 112607.0159*x + 230.0027
R^2 = 0.9975
BEC = 0.002 ppb
LoD = 0.0016 ppb

Appendix 4: Preparation of standards

The Commercial standard solution had a concentration of 100 mg/L (Appendix 5) which was equivalent to 100,000 ppb.

A 1000 ppb (C2) stock solution was prepared in a 100ml (V2) volumetric flask from the commercial standard stock for ICP-MS of 100,000ppb (C1) using the dilution formulae; C1V1=C2V2

Where C1-concentration 1, C2-concentration 2, V1-volume 1, V2-volume 2

100,000ppb*V1=1000ppb*100ml

V1=10000/100,000=1ml

1ml of the commercial standard solution was diluted to 100ml using deionized-distilled water to make 1000ppb stock solution.

The series of working standards (10, 20,30,40,50 ppb) were then prepared using the 1000ppb stock solution.

For example, to prepare 10 ppb:

C1V1 = C2V2

1000 ppb*V1 = 10 ppb*100 mL

V1=1000/1000 = 1 ml

1ml of the stock solution was diluted to 100ml using deionized distilled water to prepare 10ppb of serial working standard.

Appendix 5: Certificate of analysis of ICP-MS multi-elemental standard

Reagecon

Shannon Free Zone, Shannon, Co. Clare, Ireland
Tel: +353 61 472622 Fax: +353 61 472642
Email:sales@reagecon.ie
www.reagecon.com

CERTIFICATE OF GRAVIMETRIC PREPARATION

PRODUCT: ICP Multi-Element Standard (21 elements)

PRODUCT No.: REICPCAL21K

MATRIX: 2-5% HNO_3

LOT NO.: CAL21K21B1

DATE OF PREPARATION: 25th February 2021

EXPIRY DATE: 28th February 2023

DENSITY VALUE: 1.024 g/ml @ 20°C

PREPARATION OF STANDARD:

All standard components have been pre-qualified/verified before use. All analytical measuring devices and instrumentation have been pre-calibrated. The actual concentrations reported below are based on this preparation methodology and compound impurities.

Elements	Nominal mg/kg	Actual mg/kg	Actual mg/l @ 20°C
Ag	97.6	97.8	100.1
As	97.6	98.0	100.3
B	97.6	97.8	100.1
Ba	97.6	97.7	100.0
Be	97.6	97.9	100.2
Ca	97.6	97.8	100.2
Cd	97.6	97.8	100.2
Ce	97.6	98.0	100.4
Co	97.6	97.7	100.1
Cr	97.6	97.9	100.3
Cu	97.6	98.0	100.3
Hg	97.6	97.7	100.1
Mg	97.6	97.7	100.1
Mn	97.6	97.9	100.3
Ni	97.6	97.9	100.3
P	97.6	97.8	100.2
Pb	97.6	98.0	100.3
Se	97.6	98.0	100.4
Sr	97.6	97.9	100.2
Tl	97.6	97.9	100.3
V	97.6	97.9	100.3

The expanded uncertainty (k=2) due to weighing, volumetric preparation and homogeneity is calculated in compliance with EURACHEM/CITAC Guide: Quantifying Uncertainty in Analytical Measurements as ± 0.2 %. All values are verified by ICP-MS analysis using externally sourced ISO 17034 accredited Certified Reference Materials as calibrants/quality controls where possible.

Appendix 6: Calculation of blood lead levels

The concentration of lead (ppb) was found by; dilution factor*ICP-MS reading

Where;

Dilution factor =Final volume/volume of sample taken

Example

The concentration of lead for sample M46K in triplicate

BLL I: ICP-MS reading-1.599, final volume-10 ml, volume taken 0.4 ml (400 µl)

Concentration= 1.599*(10/0.4) =39.975 8 ppb

Since 1 µg/dL=10 ppb, 39.975 ppb=3.998 µg/dL

BLL II: ICP-MS reading-1.591, final volume-10 ml, volume taken 0.4ml (400µl)

Concentration= 1.591*(10/0.4) =39.775 ppb

Since 1µg/dL=10 ppb, 39.775ppb=3.978 µg/dL

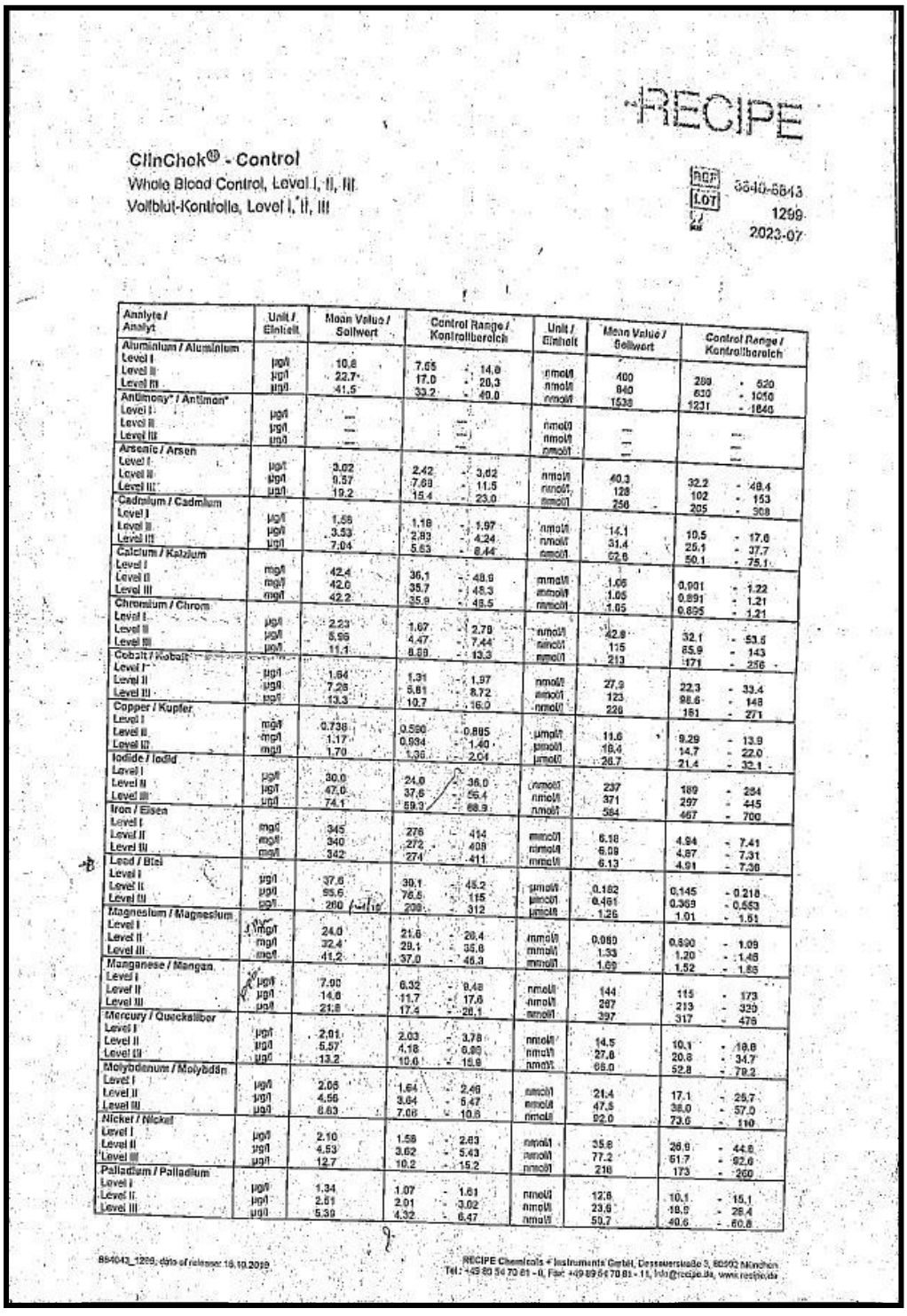
BLL III: ICP-MS reading-1.608, final volume-10ml, volume taken 0.4ml (400µl)

Concentration= 1.608*(10/0.4) =40.20 ppb

Since 1 µg/dL =10 ppb, 40.2 ppb=4.020 µg/dL

The Pb concentration of sample is therefore M46K= (3.998+3.978+4.020)/3= 3.998 µg/dL

Appendix 7: Certificate of analysis for Certified Reference Material



RECIPE

ClinChek® - Control
Whole Blood Control, Level I, II, III
Vollblut-Kontrolle, Level I, II, III

REF 8840-6843
LOT 1299
2023-07

Analyte / Analyt	Unit / Einheit	Mean Value / Sollwert	Control Range / Kontrollbereich	Unit / Einheit	Mean Value / Sollwert	Control Range / Kontrollbereich
Aluminium / Aluminium						
Level I	µg/l	10.8	7.55 - 14.0	nmol/l	400	280 - 520
Level II	µg/l	22.7	17.0 - 20.3	nmol/l	840	630 - 1010
Level III	µg/l	41.5	33.2 - 40.0	nmol/l	1538	1231 - 1846
Antimony* / Antimon*						
Level I	µg/l	---	---	nmol/l	---	---
Level II	µg/l	---	---	nmol/l	---	---
Level III	µg/l	---	---	nmol/l	---	---
Arsenic / Arsen						
Level I	µg/l	3.02	2.42 - 3.62	nmol/l	40.3	32.2 - 48.4
Level II	µg/l	9.57	7.68 - 11.5	nmol/l	128	102 - 153
Level III	µg/l	19.2	15.4 - 23.0	nmol/l	256	205 - 308
Cadmium / Cadmium						
Level I	µg/l	1.56	1.18 - 1.97	nmol/l	14.1	10.5 - 17.6
Level II	µg/l	3.53	2.83 - 4.24	nmol/l	31.4	25.1 - 37.7
Level III	µg/l	7.04	5.63 - 8.44	nmol/l	62.6	50.1 - 75.1
Calcium / Kalzium						
Level I	mg/l	42.4	36.1 - 48.8	mmol/l	1.06	0.901 - 1.22
Level II	mg/l	42.0	35.7 - 48.3	mmol/l	1.05	0.891 - 1.21
Level III	mg/l	42.2	35.9 - 48.5	mmol/l	1.05	0.895 - 1.21
Chromium / Chrom						
Level I	µg/l	2.23	1.67 - 2.79	nmol/l	42.9	32.1 - 53.6
Level II	µg/l	5.96	4.47 - 7.44	nmol/l	115	85.9 - 143
Level III	µg/l	11.1	8.89 - 13.3	nmol/l	213	171 - 256
Cobalt / Kobalt						
Level I	µg/l	1.64	1.31 - 1.97	nmol/l	27.9	22.3 - 33.4
Level II	µg/l	7.28	5.81 - 8.72	nmol/l	123	98.6 - 148
Level III	µg/l	13.3	10.7 - 16.0	nmol/l	226	181 - 271
Copper / Kupfer						
Level I	mg/l	0.736	0.590 - 0.885	µmol/l	11.6	9.29 - 13.9
Level II	mg/l	1.17	0.934 - 1.40	µmol/l	18.4	14.7 - 22.0
Level III	mg/l	1.70	1.36 - 2.04	µmol/l	26.7	21.4 - 32.1
Iodide / Iodid						
Level I	µg/l	30.0	24.0 - 36.0	nmol/l	237	189 - 284
Level II	µg/l	47.0	37.6 - 56.4	nmol/l	371	297 - 445
Level III	µg/l	74.1	59.3 - 88.9	nmol/l	584	467 - 700
Iron / Eisen						
Level I	mg/l	345	276 - 414	mmol/l	6.18	4.94 - 7.41
Level II	mg/l	340	272 - 408	mmol/l	6.09	4.87 - 7.31
Level III	mg/l	342	274 - 411	mmol/l	6.13	4.91 - 7.36
Lead / Blei						
Level I	µg/l	37.6	30.1 - 45.2	µmol/l	0.182	0.145 - 0.218
Level II	µg/l	95.6	76.5 - 115	µmol/l	0.461	0.369 - 0.553
Level III	µg/l	260	208 - 312	µmol/l	1.26	1.01 - 1.51
Magnesium / Magnesium						
Level I	mg/l	24.0	21.6 - 26.4	mmol/l	0.989	0.890 - 1.09
Level II	mg/l	32.4	29.1 - 35.8	mmol/l	1.33	1.20 - 1.46
Level III	mg/l	41.2	37.0 - 45.3	mmol/l	1.69	1.52 - 1.85
Manganese / Mangan						
Level I	µg/l	7.90	6.32 - 9.48	nmol/l	144	115 - 173
Level II	µg/l	14.6	11.7 - 17.6	nmol/l	267	213 - 320
Level III	µg/l	21.8	17.4 - 26.1	nmol/l	397	317 - 476
Mercury / Quecksilber						
Level I	µg/l	2.01	2.03 - 3.78	nmol/l	14.5	10.1 - 18.8
Level II	µg/l	5.57	4.18 - 6.96	nmol/l	27.8	20.8 - 34.7
Level III	µg/l	13.2	10.6 - 15.8	nmol/l	66.0	52.8 - 79.2
Molybdenum / Molybdän						
Level I	µg/l	2.05	1.64 - 2.46	nmol/l	21.4	17.1 - 25.7
Level II	µg/l	4.56	3.64 - 5.47	nmol/l	47.5	38.0 - 57.0
Level III	µg/l	8.63	7.06 - 10.6	nmol/l	92.0	73.6 - 110
Nickel / Nickel						
Level I	µg/l	2.10	1.58 - 2.63	nmol/l	35.8	26.9 - 44.8
Level II	µg/l	4.53	3.62 - 5.43	nmol/l	77.2	61.7 - 92.6
Level III	µg/l	12.7	10.2 - 15.2	nmol/l	216	173 - 260
Palladium / Palladium						
Level I	µg/l	1.34	1.07 - 1.61	nmol/l	12.6	10.1 - 15.1
Level II	µg/l	2.61	2.01 - 3.02	nmol/l	23.6	18.9 - 28.4
Level III	µg/l	5.39	4.32 - 6.47	nmol/l	50.7	40.6 - 60.8

884043_1299, date of release: 18.10.2019

RECIPE Chemicals + Instruments GmbH, Dessauerstraße 3, 80992 München
Tel.: +49 89 54 70 81 - 0, Fax: +49 89 54 70 81 - 11, info@recipe.de, www.recipe.de

Appendix 8: Results of CRMs for five replicate readings by ICP-MS

Sample	Observed BLL in ppb		Expected BLL (range) in ppb
CRM I	BLL 1	39.950	30.1-45.2
	BLL 2	39.925	
	BLL 3	39.950	
	BLL 4	39.900	
	BLL 5	39.875	
Overall mean ±SD		39.9 ±0.03	
% Recovery		106.1%	
CRM II	BLL 1	97.100	76.5-115
	BLL 2	97.500	
	BLL 3	97.400	
	BLL 4	97.100	
	BLL 5	97.150	
Overall mean ±SD		97.3±0.19	
% Recovery		101.8%	
CRM III	BLL 1	262.750	208-312
	BLL 2	262.500	
	BLL 3	262.250	
	BLL 4	261.750	
	BLL 5	263.250	
Overall mean ±SD		262.5±0.56	
%Recovery		100.9%	

Appendix 9: Calculation of blood lead levels for certified reference material

The concentration of lead (ppb) was found by; dilution factor*ICP-MS reading

Where

Dilution factor=Final volume/volume of sample taken

CRM I

For the concentration of lead for CRM I

ICP-MS reading 1 -1.598 ppb, final volume-10 ml, volume taken 0.4 ml (400µl)

Concentration= 1.598*(10/0.4) =39.95 ppb

The expected concentration reported on the certificate of analysis was a mean of 37.6 ppb and a range of 30.1-45.2 ppb (Appendix 7). Hence the observed concentration was within the expected range.

The % recovery was calculated as; (observed concentration/expected concentration) *100

%recovery=39.95/ 37.6*100=106.3%

CRM II

For the concentration of lead for CRM II

ICP-MS reading 1-1.942 ppb, final volume-10ml, volume taken 0.4ml (400 µl), after digestion the sample was diluted again in order to fit within the range of calibration (10 ppb-50 ppb); second volume taken-5ml final volume-10ml

Concentration= 1.942*(10/0.4) *(10/5) =97.10 ppb

The expected concentration reported on the certificate of analysis was a mean of 95.6 ppb and a range of 76.5-115 ppb (Appendix 7). Hence the observed concentration was within the expected range.

The % recovery was calculated as; (observed concentration/expected concentration) *100

%recovery=97.1/ 95.6*100=101.6%

CRM III

For the concentration of lead for CRM III

ICP-MS reading 1-1.051 ppb, final volume-10 ml, volume taken 0.4 ml (400 µl) after digestion the sample was diluted again in order to fit within the range of calibration (10 ppb-50 ppb); second volume taken-1ml final volume-10 ml

Concentration= 1.051*(10/0.4) *(10/1) = 262.75 ppb

The expected concentration reported on the certificate of analysis was a mean of 260 ppb and a range of 208-312 ppb (Appendix 7). Hence the observed concentration was within the expected range.

The % recovery was calculated as; (observed concentration/expected concentration) *100

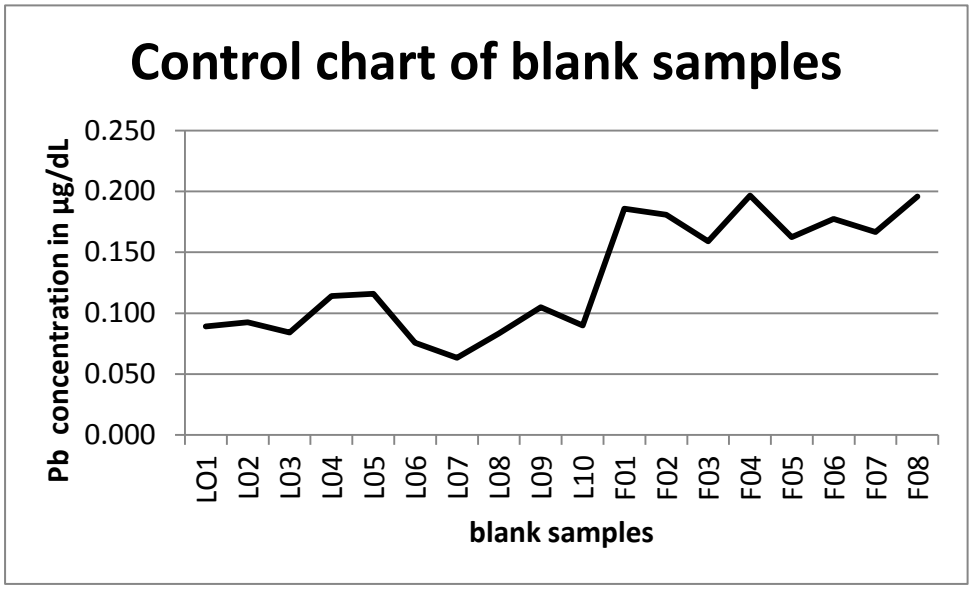
%recovery=262.75/ 260*100=101.1%

Appendix 10: Lead levels of laboratory and field blanks and the mean and standard deviation

Sample code	Lead levels in µg/dL			
	Pb 1	Pb 2	Pb 3	Mean ±SD
L01	0.090	0.088	0.090	0.089 ±0.001
L02	0.098	0.088	0.093	0.093 ±0.004
L03	0.078	0.083	0.093	0.084 ±0.006
L04	0.120	0.113	0.110	0.114 ±0.004
L05	0.105	0.120	0.123	0.116 ±0.008
L06	0.080	0.073	0.075	0.076 ±0.003
L07	0.053	0.075	0.063	0.063 ±0.009
L08	0.078	0.083	0.090	0.083 ±0.005
L09	0.113	0.100	0.103	0.105 ±0.005
L10	0.098	0.083	0.090	0.090 ± 0.006
F01	0.178	0.193	0.188	0.186 ±0.006
F02	0.180	0.183	0.180	0.181 ±0.001
F03	0.163	0.165	0.150	0.159 ±0.007
F04	0.200	0.198	0.193	0.197 ± 0.003
F05	0.165	0.163	0.160	0.163 ±0.002
F06	0.183	0.178	0.173	0.178 ±0.004
F07	0.165	0.165	0.170	0.167 ±0.002
F08	0.190	0.198	0.200	0.196 ±0.004
Overall Mean ±SD				0.130 ±0.047

F=Sample code for field blank ; L=Sample code for laboratory blank

Appendix 11: Control chart for blank samples



Appendix 12: Calculation of % recovery of matrix spike samples

The %recovery was expressed as:

%recovery = ([concentration of spiked sample-concentration of unspiked sample]/concentration of standard) *100

Matrix spike 1

For the %recovery of sample R16 (sample M95K spiked with 20 ppb standard)

Concentration of spiked-63.683 ppb concentration of unspiked-43.218 ppb concentration of standard-20 ppb

%recovery = ([63.683-43.218]/20) *100= 102.326%

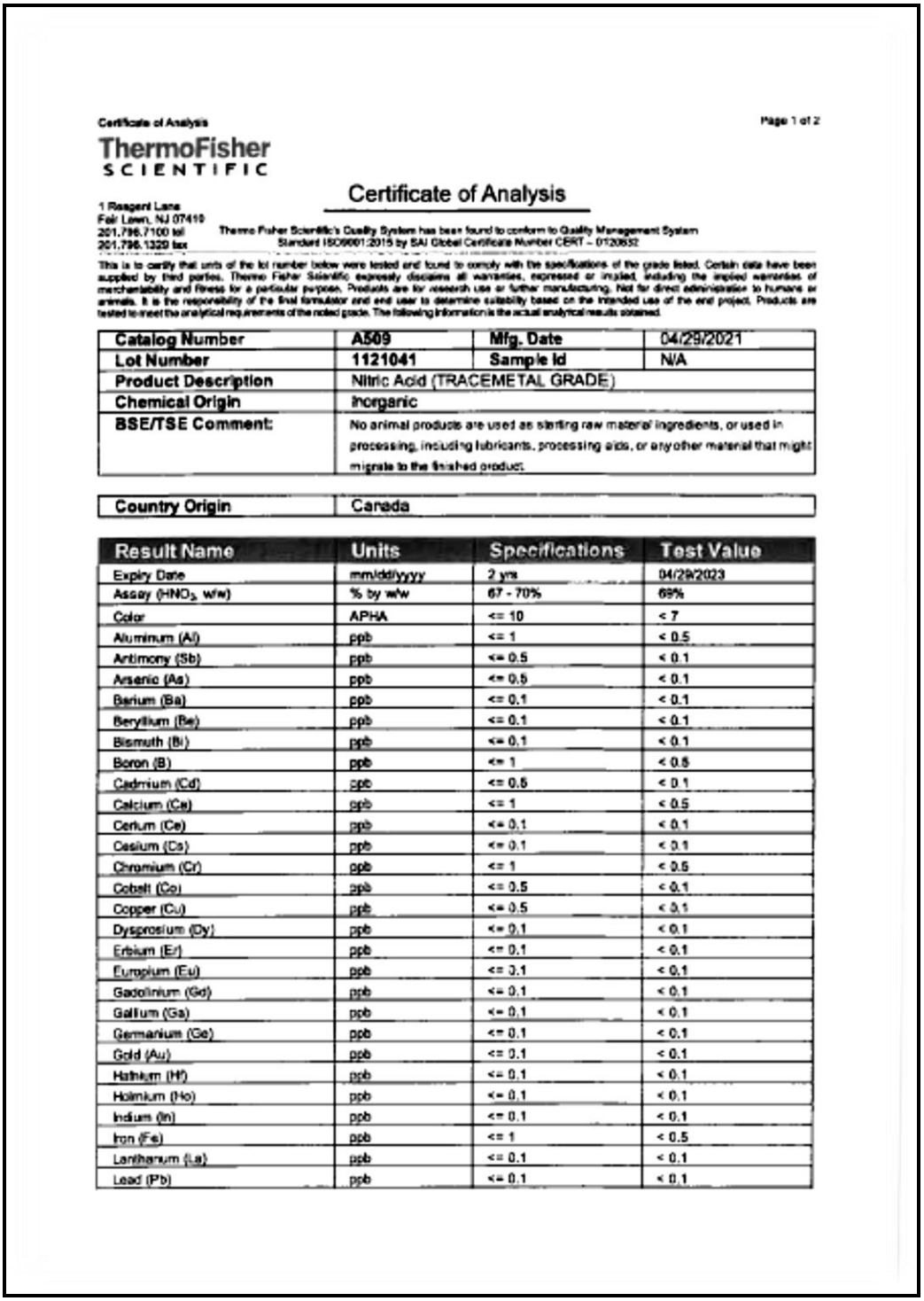
Matrix spike 2

For the %recovery of sample R10 (sample M26K spiked with 20 ppb standard)

Concentration of spiked-37.373ppb, concentration of unspiked-13.749 ppb, concentration of standard-20 ppb

%recovery = ([37.373-17.007]/20) *100= 101.83%

Appendix 13: Certificate of analysis for trace metal grade nitric acid



Certificate of Analysis

ThermoFisher SCIENTIFIC

Certificate of Analysis

1 Reagent Lane
Fair Lawn, NJ 07410
201.796.7100 tel
201.796.1329 fax

Thermo Fisher Scientific's Quality System has been found to conform to Quality Management System Standard ISO9001:2015 by SAI Global Certificate Number CERT – 0120652

This is to certify that units of the lot number below were tested and found to comply with the specifications of the grade listed. Certain data have been supplied by third parties. Thermo Fisher Scientific expressly disclaims all warranties, expressed or implied, including the implied warranties of merchantability and fitness for a particular purpose. Products are for research use or further manufacturing. Not for direct administration to humans or animals. It is the responsibility of the final formulator and end user to determine suitability based on the intended use of the end product. Products are tested to meet the analytical requirements of the noted grade. The following information is the actual analytical results obtained.

Catalog Number	**A509**	**Mfg. Date**	04/29/2021
Lot Number	**1121041**	**Sample Id**	N/A
Product Description	Nitric Acid (TRACEMETAL GRADE)		
Chemical Origin	Inorganic		
BSE/TSE Comment:	No animal products are used as starting raw material ingredients, or used in processing, including lubricants, processing aids, or any other material that might migrate to the finished product.		

Country Origin	Canada

Result Name	Units	Specifications	Test Value
Expiry Date	mm/dd/yyyy	2 yrs	04/29/2023
Assay (HNO_3, w/w)	% by w/w	67 - 70%	69%
Color	APHA	<= 10	< 7
Aluminum (Al)	ppb	<= 1	< 0.5
Antimony (Sb)	ppb	<= 0.5	< 0.1
Arsenic (As)	ppb	<= 0.5	< 0.1
Barium (Ba)	ppb	<= 0.1	< 0.1
Beryllium (Be)	ppb	<= 0.1	< 0.1
Bismuth (Bi)	ppb	<= 0.1	< 0.1
Boron (B)	ppb	<= 1	< 0.5
Cadmium (Cd)	ppb	<= 0.5	< 0.1
Calcium (Ca)	ppb	<= 1	< 0.5
Cerium (Ce)	ppb	<= 0.1	< 0.1
Cesium (Cs)	ppb	<= 0.1	< 0.1
Chromium (Cr)	ppb	<= 1	< 0.5
Cobalt (Co)	ppb	<= 0.5	< 0.1
Copper (Cu)	ppb	<= 0.5	< 0.1
Dysprosium (Dy)	ppb	<= 0.1	< 0.1
Erbium (Er)	ppb	<= 0.1	< 0.1
Europium (Eu)	ppb	<= 0.1	< 0.1
Gadolinium (Gd)	ppb	<= 0.1	< 0.1
Gallium (Ga)	ppb	<= 0.1	< 0.1
Germanium (Ge)	ppb	<= 0.1	< 0.1
Gold (Au)	ppb	<= 0.1	< 0.1
Hafnium (Hf)	ppb	<= 0.1	< 0.1
Holmium (Ho)	ppb	<= 0.1	< 0.1
Indium (In)	ppb	<= 0.1	< 0.1
Iron (Fe)	ppb	<= 1	< 0.5
Lanthanum (La)	ppb	<= 0.1	< 0.1
Lead (Pb)	ppb	<= 0.1	< 0.1

Appendix 14: Questionnaire in English

I am Edith Aida Lumumba, a student pursuing a master's program in Analytical Chemistry in the Department of chemistry, Faculty of Science and Technology of the University of Nairobi. My research involves determination of lead levels in maternal and newborn blood for purposes of informing policy and creation of awareness of lead as a neurotoxicant. This questionnaire is aimed at assessing a mother's environment to establish potential exposure sources. Thank you for agreeing to take part in the research. Please be assured that the data and information generated will only be used for research

Personal data

Code of participant (Mother): ……

Age (years)…….

Date of interview: ……

Area of residence: ……

Socio-economic data

Tick as appropriate

1. What is the highest level of education ever achieved?
   - ❖ Primary
   - ❖ Secondary
   - ❖ Tertiary
   - ❖ Other……
2. What is your current occupation?
   - ❖ House painting
   - ❖ Welding
   - ❖ Construction
   - ❖ Mining
   - ❖ Lead battery recycling/smelting
   - ❖ Electronic repair
   - ❖ Garbage collection/ burning
   - ❖ Other (specify) ……..
3. How long have you been involved in the occupation?
   - ❖ 1-5yrs
   - ❖ 5-10yrs
   - ❖ >10yrs
4. Are you aware of lead as a toxicant or lead poisoning?
   - ❖ Yes
   - ❖ No

History of environmental exposure

1. Do you live in a painted house?
   - ❖ Yes
   - ❖ No

Note: If yes go to question 2 and 3, if no go to question 4

2. Is the paint in your house peeling or chipping?
   - ❖ Yes
   - ❖ No
3. How long have you been living in the house?.....
4. Do you live in a building that is undergoing renovation or construction work?
   - ❖ Yes

- ❖ No.....

5. Do you live or work near an active lead smelter, battery recycling plant?
   - ❖ Yes.....
   - ❖ No.....
6. Does the drinking water you use, pass through old pipes and fixtures?
   - ❖ Yes.....
   - ❖ No .....
7. Do you use old painted pottery or glazed pottery in your home?
   - ❖ Yes.....
   - ❖ No .....
8. Have you at any point ingested non-food items such as soil or stones?
   - ❖ Yes.....
   - ❖ No.....
9. Do you leave near a dumpsite?
   - ❖ Yes.....
   - ❖ No.....

Appendix 15: Questionnaire in Kiswahili

Kwa majina ni Edith Aida Lumumba, mwanafunzi anayefuata mpango wa kitaalam katika Kemia ya Uchambuzi katika Idara ya kemia, Chuo cha Sayansi ya Baiolojia na Fizikia ya Chuo Kikuu cha Nairobi. Utafiti wangu unajumuisha azimio la viwango vya Lead katika damu ya mama na ya watoto wachanga kwa madhumuni ya kuelezea sera na uundaji wa ufahamu wa lead kama neurotoxicant. Dodoso hili linalenga kukagua mazingira ya mama ili kuanzisha vyanzo vya mfiduo. Asante kwa kukubali kushiriki katika utafiti. Nakuhakikishia kuwa data na habari itatumika tu kwa utafiti.

Taarifa binafsi

Kanuni ya mshiriki: .....

Umri kwa miaka: …….

Tarehe ya mahojiano: ……..

Eneo la makazi: ……..

Taarifa ya kijamii na kiuchumi

1. Kiwango chako cha juu cha elimu ni kipi?
   - ❖ Shule ya msingi.....
   - ❖ Sekondari.....
   - ❖ Elimu ya juu.....
   - ❖ Nyingine (taja)……..
2. Kazi yako ya sasa ni nini?
   - ❖ Upakaji rangi.....
   - ❖ Kuchomelea……..
   - ❖ Ujenzi……
   - ❖ Uchimbaji migodi.....
   - ❖ Kuchakata/kutengeneza betri za Lead……
   - ❖ Urekebishaji wa electroniki.....
   - ❖ Ukusanyaji/uchomaji takataka.....
   - ❖ Nyingine (taja)……..
3. Muda gani umehusika katika kazi hiyo?
   - ❖ 1-5.....
   - ❖ 5-10.....
   - ❖ >10.....
4. Je, umewahi kuskia kuhusu madini ya Lead na madhara yake?
   - ❖ Ndio.....
   - ❖ La.....

Historia ya mfinduo

5. Je,waishi katika nyumba iliyopakwa rangi?
   - ❖ Ndio.....
   - ❖ La.....

Note: ikiwa jibu ni ndio jibu swali la 2 na 3, ikiwa jibu ni la jibu swali la 4

6. Je,kuna sehemu katika nyumba yako ambapo rangi inabambuka?
   - ❖ Ndio.....
   - ❖ La.....
7. Je,umeishi katika nyumba hiyo kwa muda gani?.....
8. Je, katika nyumba unayoishi kuna ukarabati au kazi ya ujenzi inayoendelea?
   - ❖ Ndio.....
   - ❖ La.....

9. Je, waishi karibu na eneo ambapo betri ya lead inachakatwa au kutengenezwa?
   - ❖ Ndio.....
   - ❖ La.....
10. Je, maji ya kunywa unayotumia, hupita katika mabomba yenye yamezeeka?
   - ❖ Ndio.....
   - ❖ La.....
11. Je, huwa unatumia vyombo vilivyo finyangwa na kupakwa rangi nyumbani?
   - ❖ Ndio .....
   - ❖ La.....
12. Je katika hatua yoyote umewahi kula vitu visivyo chakula kama vile udongo au mawe?
   - ❖ Ndio.....
   - ❖ La.....
13. Je waishi karibu na maeneo ya utupaji takataka?
   - ❖ Ndio.....
   - ❖ La .....

Appendix 16: Participant information and consent form for enrollment in the study (English)

Title of Study:

Assessment of maternal and umbilical cord blood lead levels from informal settlements in Nairobi, Kenya.

Principal Investigator and institutional affiliation:

Lumumba Edith Aida,
Master of Science student
Chemistry department
University of Nairobi
0716732851.
Research supervisors

Faridah Hussein Were MSc, PhD
Lecturer
Department of Chemistry
University of Nairobi
P.O Box 30197-00100
Nairobi, Kenya
0729239135

John Onam Onyatta MSc, PhD
Lecturer
Department of Chemistry
University of Nairobi
P.O Box 30197-00100
Nairobi, Kenya
0729239135

Dr. Anne Riederer
Department of Environmental and Occupational Health Sciences
University of Washington
P.O Box 357234
Seattle WA, USA
anneried@uw.edu

Research background:

I would like to tell you about a study being conducted by the above listed researchers. The purpose of this consent form is to give you the information you will need to help you decide whether or not to be a participant in the study. Feel free to ask any questions about the purpose of the research, what happens if you participate in the study, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions to your satisfaction, you may decide to be in the study or not. This process is called 'informed consent'. Once you understand and agree to be in the study, I will request you to sign your name on this form. You should understand the general principles which apply to all participants in medical research:

- Your decision to participate is entirely voluntary
- You may withdraw from the study at any time without necessarily giving a reason for your withdrawal
- Refusal to participate in the research will not affect the services you are entitled to in this health facility or other facilities. We will give you a copy of this form for your records.

May I continue? YES / NO

This study has approval by The Kenyatta National Hospital-University of Nairobi Ethics and Research Committee protocol no. _P835/10/2019

What is this study about?

The researcher listed above is interviewing individuals who present to Pumwani hospital for delivery and are residents of Kariobangi or Dandora. The purpose of the interview is to request for your consent for participation in this research which will involve collection of about 5ml of blood from you and your newborn and also answering of questions in the form of questionnaires. There will be approximately 150 participants in this study randomly chosen. The research will involve determination of blood lead levels in maternal and newborn blood for purposes of informing policy and creation of awareness of lead as a neurotoxicant.

What will happen if you decide to be in this research study?

If you agree to participate in this study, the following things will happen:

You will be interviewed by a trained interviewer in a private area where you feel comfortable answering questions. The interview will last approximately 10 minutes. The interview will cover topics such as your living and work environment. After the interview about 5ml of blood will be collected from you and your newborn by a health worker for purposes of analysis of levels of lead

Are there any risks, harms discomforts associated with this study?

One potential risk of being in the study is loss of privacy. We will keep everything you tell us as confidential as possible. We will use a code number to identify you in a password-protected computer database and will keep all of our paper records in a locked file cabinet. However, no system of protecting your confidentiality can be absolutely secure, so it is still possible that someone could find out you were in this study and could find out information about you. Also, answering questions in the interview may be uncomfortable for you. If there are any questions you do not want to answer, you can skip them. You have the right to refuse the interview or any questions asked during the interview.

Are there any benefits being in this study?

The information you provide will help us provide a periodic surveillance data on maternal and new-born blood lead levels from informal settlements in Nairobi. It will also inform policy and industry regulations that pertain to lead levels in the country.

Will being in this study cost you anything?

Being in this study will not cost you anything.

Will you get refund for any money spent as part of this study?

You will not receive any token or monetary benefit by participating in the study.

What if you have questions in future?

If you have further questions or concerns about participating in this study, please call or send a text message to the study staff at the number provided at the bottom of this page.

For more information about your rights as a research participant you may contact the Secretary/Chairperson, Kenyatta National Hospital-University of Nairobi Ethics and Research Committee Telephone No. 2726300 Ext. 44102 email; uonknh_erc@uonbi.ac.ke.

What are your other choices?

Your decision to participate in research is voluntary. You are free to decline participation in the study and you can withdraw from the study at any time without injustice or loss of any benefit

Participant's statement

I have read this consent form or had the information read to me. I have had the chance to discuss this research study with a study counselor. I have had my questions answered in a language that I understand.

The risks and benefits have been explained to me. I understand that my participation in this study is voluntary and that I may choose to withdraw any time. I freely agree to participate in this research study.
I understand that all efforts will be made to keep information regarding my personal identity confidential.
By signing this consent form, I have not given up any of the legal rights that I have as a participant in a research study.

I agree to participate in this research study	Yes	No
I agree to have blood from me and my newborn preserved for later study:	Yes	No
I agree to provide contact information for follow-up:	Yes	No

Participant name……

Participant signature / Thumb stamp…… Date ……

Researcher's statement

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has willingly and freely given his/her consent.

Researcher 's Name……. Date……...

Signature…….

Role in the study…… *[i.e. study staff who explained informed consent form.]*

For more information contact Edith Aida Lumumba at 0716732851 from 0800hrs to 1700hrs

Appendix 17: Participant information and consent form for enrollment in the study (Kiswahili)

Title of study:

Assessment of maternal and umbilical cord blood lead levels from informal settlements in Nairobi, Kenya.

Mpelelezi mkuu na ushirika wa kitaasisi:

Lumumba Edith Aida,
Master of Science student
Chemistry department
University of Nairobi
0716732851.

Wasimamizi wa utafiti

Faridah Hussein Were MSc, PHD
Lecturer
Department of Chemistry
University of Nairobi
P.O Box 30197-00100
Nairobi, Kenya
0729239135

John Onam Onyatta MSc, PHD
Lecturer
Department of Chemistry
University of Nairobi
P.O Box 30197-00100
Nairobi, Kenya
0729239135

Dr. Anne Riederer
Department of Environmental and Occupational Health Sciences
University of Washington
P.O Box 357234
Seattle WA, USA
anneried@uw.edu

Utangulizi

Ningependa kukuambia juu ya utafiti unaofanywa na watafiti waliotajwa hapo juu. Madhumuni ya fomu hii ya idhini ni kukupa habari utahitaji kukusaidia kuamua ikiwa utakuwa au kutokuwa mshiriki katika utafiti. Jisikie huru kuuliza maswali yoyote juu ya madhumuni ya utafiti, nini kinatokea ikiwa unashiriki katika utafiti, hatari na faida zinazowezekana, haki yako kama mjitolea, na kitu kingine chochote kuhusu utafiti au fomu hii ambayo haijakuwa wazi. Wakati tumejibu maswali yako yote kwa kuridhika kwako, unaweza kuamua kuwa kwenye utafiti au la. Utaratibu huu unaitwa 'ridhaa iliyo na habari'. Mara tu utakapoelewa na kukubali kuwa katika utafiti, nitakuomba usaini jina lako kwenye fomu hii. Unapaswa kuelewa kanuni za jumla zinazotumika kwa washiriki wote katika utafiti wa kimatibabu:

- Uamuzi wako wa kushiriki ni hiari kabisa
- Unaweza kujiondoa kutoka kwa utafiti wakati wowote bila kutoa sababu ya kujiondoa kwako
- Kukataa kushiriki katika utafiti hautaathiri huduma unayostahiki katika kituo hiki cha afya au vifaa vingine. Tutakupa nakala ya fomu hii kwa rekodi zako

Naweza kuendelea? NDIO/ LA

Utafiti huu umedhibitishwa na Itifaki ya Kamati ya Maadili ya Kitaifa ya Kenyatta National Hospital-University of Nairobi ya Nambari ya P835 / 10/2019

Utafiti huu unahusu nini?

Mtafiti aliyeorodheshwa hapo juu anahoji watu ambao wanawasili katika hospitali ya Pumwani kwa kujifungua na ni wakaazi wa Kariobangi au Dandora. Madhumuni ya mahojiano ni kuomba ruhusa yako kwa kushiriki katika utafiti huu ambao utajumuisha ukusanyaji wa damu takriban 5ml kutoka kwako na mtoto wako mchanga na pia kujibu maswali kwa njia ya dodoso. Kutakuwa na washiriki takriban 140 katika utafiti huu waliochaguliwa kwa nasibu. Utafiti huo utajumuisha uamuzi wa viwango lead katika damu ya mama na watoto wachanga kwa madhumuni ya kuelezea sera na uundaji wa ufahamu wa lead kama neurotoxicant.

Nini kitafanyika utakapo kubali kuwa katika fundo hili la utafiti?

Ikiwa unakubali kushiriki katika utafiti huu, mambo yafuatayo yatatokea:

Utahojiwa na mhojiwa katika eneo la kibinafsi ambapo unahisi vizuri kujibu maswali. Mahojiano yatadumu takriban dakika 20. Mahojiano yatashughulikia mada kama vile mazingira yako ya kuishi na ya kazi.

Baada ya mahojiano takriban 5ml ya damu yatakusanywa kutoka kwako na mtoto wako mchanga na mfanyakazi wa afya kwa madhumuni ya uchambuzi wa viwango vya lead.

Je kuna athari zaidi, zinazoonekana na utafiti huu?

Utafiti wa matibabu una uwezo wa kuanzisha hatari za kisaikolojia, kijamii, kihemko na za mwili. Jaribio linapaswa kuwekwa kila wakati ili kupunguza hatari. Hatari moja ya kuwa katika masomo ni upotezaji wa faragha. Tutaweka kila kitu unachotwambia kama siri iwezekanavyo.

Tutatumia nambari ya kukutambulisha katika hifadhidata ya kompyuta iliyolindwa na nywila na tutaweka rekodi zetu zote za karatasi katika baraza la mawaziri lililofungwa. Walakini, hakuna mfumo wa kulinda usiri wako unaweza kuwa salama kabisa, kwa hivyo bado inawezekana kwamba mtu angegundua kuwa ulikuwa kwenye utafiti huu na anaweza kupata habari juu yako.
Ikiwa kuna maswali ambayo hutaki kujibu, unaweza kuyaruka. Una haki ya kukataa mahojiano au maswali yoyote yaliyoulizwa wakati wa mahojiano.

Je! Kuna faida zozote za kuwa mhusika katika utafifi huu?
Habari unayotoa itatusaidia kutoa data ya upimaji wa mara kwa mara juu ya viwango vya lead vya mama na watoto wachanga kutoka makazi duni jijini Nairobi. Pia itahamisha kanuni za sera na tasnia zinazohusu viwango vinavyoongoza nchini.

Kuwa katika utafiti huu utanigharimu ?
Kuwa katika utafiti huu hautakugharimu chochote.

Je, utapata pesa kwa pesa au faida kwa kushiriki?
Hautapokea faida yoyote ya ishara au pesa kwa kushiriki katika utafiti.

Je ukiwa na maswali ya ziada hapo mbeleni?
Ikiwa una maswali zaidi au wasiwasi juu ya kushiriki katika utafiti huu, tafadhali piga simu au tuma ujumbe wa maandishi kwa wafanyikazi wa utafiti kwa nambari iliyotolewa chini ya ukurasa huu.
Kwa habari zaidi juu ya haki yako kama mshiriki wa utafiti unaweza kuwasiliana na Katibu / Mwenyekiti, Kenyatta National Hospital-University of Nairobi kitengo cha Maadili cha Kenya na Kamati ya Utafiti ya Namba ya 2726300 Ext. 44102 barua pepe uonknh_erc@uonbi.ac.ke.

Wafanyikazi wa utafiti watakulipa kwa malipo yako kwa nambari hizi ikiwa simu ni ya mawasiliano yanayohusiana na masomo.

Nini uhuru wako wa ziada?
Uamuzi wako wa kushiriki katika utafiti ni wa hiari. Uko huru kukataa kushiriki katika masomo na unaweza kujiondoa kwenye masomo wakati wowote bila ukosefu wa haki au upotezaji wa faida yoyote.

Consent form in Kiswahili

Taarifa ya Mshiriki

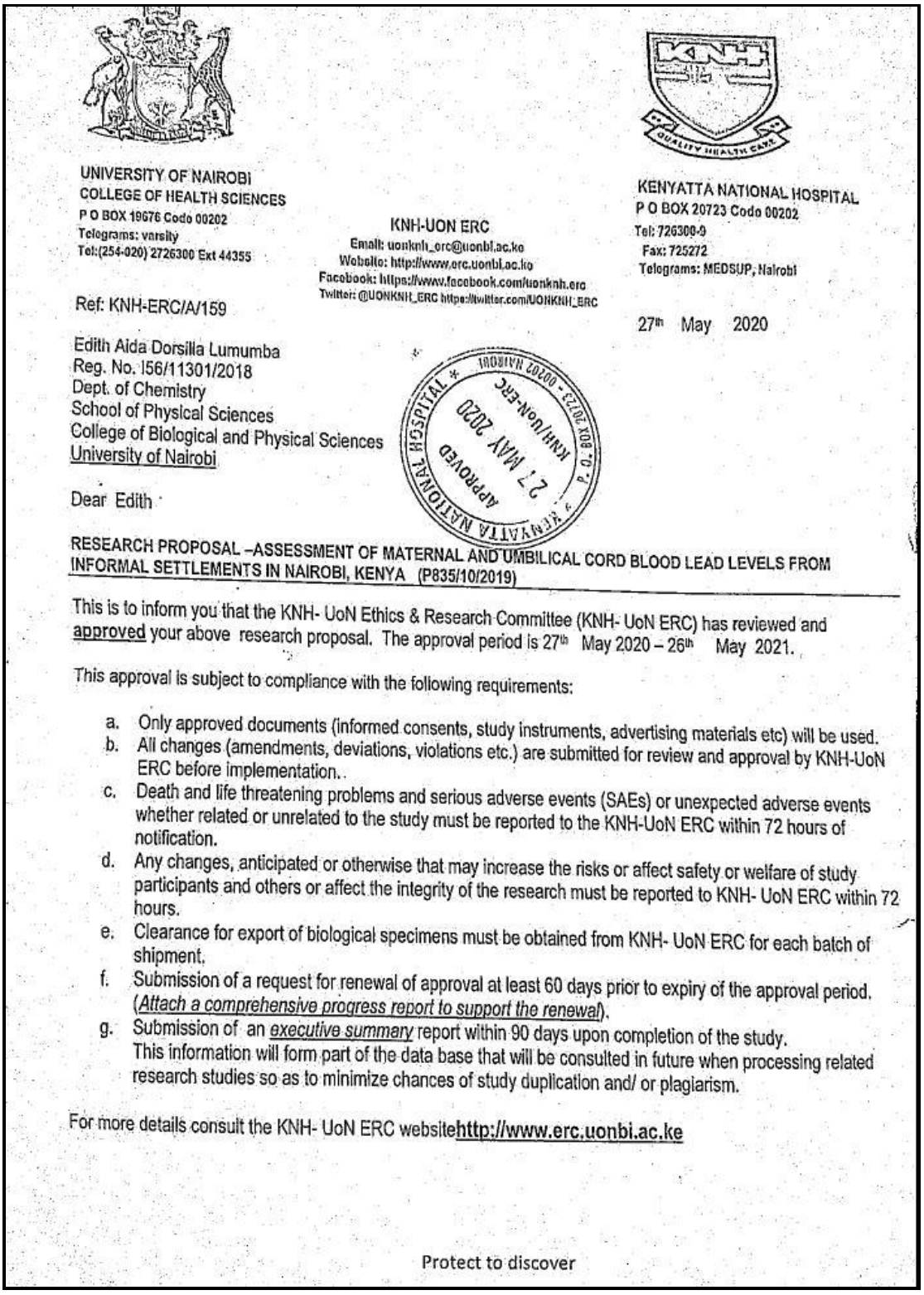
Nimesoma fomu hii ya idhini au habari imenisoma. Nimepata nafasi ya kujadili utafiti huu na mshauri wa masomo. Nimepata maswali yangu kujibiwa kwa lugha ambayo naelewa. Hatari na faida nimeelezea kwangu. Ninaelewa kuwa ushiriki wangu katika utafiti huu ni wa hiari na kwamba naweza kuchagua kujiondoa wakati wowote. Nakubali kwa bure kushiriki katika utafiti huu. Ninaelewa kuwa juhudi zote zitafanywa kuweka habari kuhusu siri yangu ya kibinafsi. Kwa kusaini fomu hii ya idhini, sijapeana haki yoyote ya kisheria ambayo ninaykama mshiriki wa utafiti.

Ninakubali kushiriki katika utafiti huu: Ndio.....Hapana.....
Ninakubali damu kutoka kwangu na mtoto wangu mchanga ihifadhiwe kwa masomo ya baadaye: Ndio..... Hapana.....
Ninakubali kutoa nabari na anwani yangu kwa mawasiliano kwa kufuata:Ndio.....
Hapana.....
Jina la msiriki…….
Saini…… Tarehe ……..

Taarifa ya mtafiti

Mimi, aliyetengwa, nimeelezea kikamilifu maelezo muhimu ya utafiti huu kwa mshiriki aliyetajwa hapo juu na ninaamini kwamba mshiriki ameelewa na ametoa ridhaa yake kwa hiari na kwa hiari yake.
Jina la mtafiti.....
Tarehe:…….....
Jukumu katika utafiti(wafanyikazi ambao walielezea fomu ya ridhaa yenye habari): ……
Kwa maelezo zaidi wasiliana na Edith Aida Lumumba kuanzia saa 0800hrs hadi saa 1700hrs.

Appendix 18: Kenyatta National Hospital University of Nairobi Ethics and Research Committee Research Permit



UNIVERSITY OF NAIROBI
COLLEGE OF HEALTH SCIENCES
P O BOX 19676 Code 00202
Telegrams: varsity
Tel:(254-020) 2726300 Ext 44355

KNH-UON ERC
Email: uonknh_erc@uonbi.ac.ke
Website: http://www.erc.uonbi.ac.ke
Facebook: https://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KENYATTA NATIONAL HOSPITAL
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/159

27th May 2020

Edith Aida Dorsilla Lumumba
Reg. No. I56/11301/2018
Dept. of Chemistry
School of Physical Sciences
College of Biological and Physical Sciences
University of Nairobi

KENYATTA NATIONAL HOSPITAL * APPROVED 27 MAY 2020 KNH/UON-ERC P. O. BOX 20723 - 00202 NAIROBI

Dear Edith

RESEARCH PROPOSAL –ASSESSMENT OF MATERNAL AND UMBILICAL CORD BLOOD LEAD LEVELS FROM INFORMAL SETTLEMENTS IN NAIROBI, KENYA (P835/10/2019)

This is to inform you that the KNH- UoN Ethics & Research Committee (KNH- UoN ERC) has reviewed and approved your above research proposal. The approval period is 27th May 2020 – 26th May 2021.

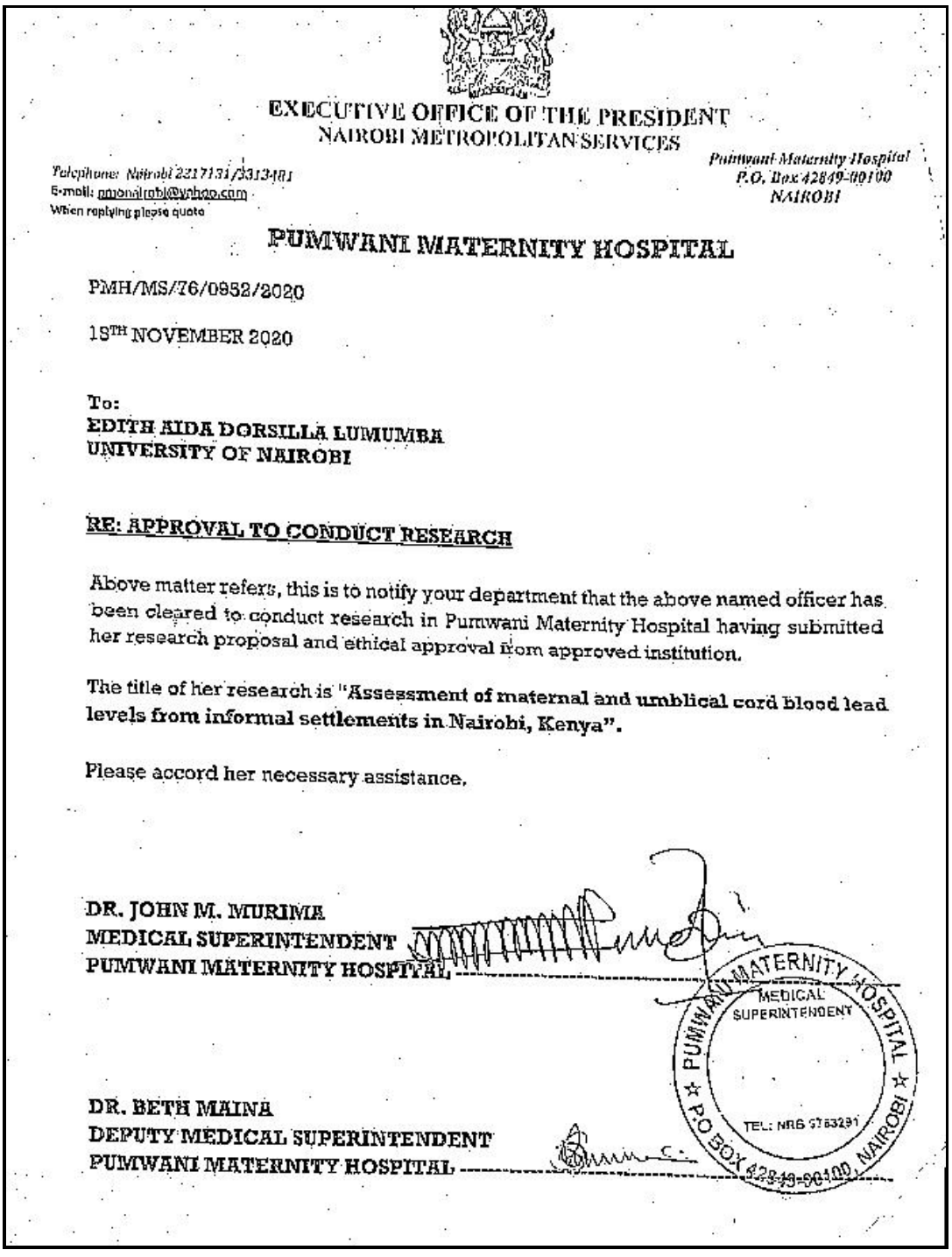
This approval is subject to compliance with the following requirements:

a. Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b. All changes (amendments, deviations, violations etc.) are submitted for review and approval by KNH-UoN ERC before implementation.
c. Death and life threatening problems and serious adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH-UoN ERC within 72 hours of notification.
d. Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH- UoN ERC within 72 hours.
e. Clearance for export of biological specimens must be obtained from KNH- UoN ERC for each batch of shipment.
f. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal*).
g. Submission of an *executive summary* report within 90 days upon completion of the study. This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/ or plagiarism.

For more details consult the KNH- UoN ERC website **http://www.erc.uonbi.ac.ke**

Protect to discover

Appendix 19: Approval to conduct research from Pumwani Maternity Hospital management



EXECUTIVE OFFICE OF THE PRESIDENT
NAIROBI METROPOLITAN SERVICES

Telephone: Nairobi 2217131/2313481
E-mail: pmonairobi@yahoo.com
When replying please quote

Pumwani Maternity Hospital
P.O. Box 42849-00100
NAIROBI

PUMWANI MATERNITY HOSPITAL

PMH/MS/76/0952/2020

18TH NOVEMBER 2020

To:
EDITH AIDA DORSILLA LUMUMBA
UNIVERSITY OF NAIROBI

RE: APPROVAL TO CONDUCT RESEARCH

Above matter refers, this is to notify your department that the above named officer has been cleared to conduct research in Pumwani Maternity Hospital having submitted her research proposal and ethical approval from approved institution.

The title of her research is "**Assessment of maternal and umblical cord blood lead levels from informal settlements in Nairobi, Kenya**".

Please accord her necessary assistance.

DR. JOHN M. MURIMA
MEDICAL SUPERINTENDENT
PUMWANI MATERNITY HOSPITAL

PUMWANI MATERNITY HOSPITAL
MEDICAL SUPERINTENDENT
P.O BOX 42849-00100 NAIROBI
TEL: NRB 2763291

DR. BETH MAINA
DEPUTY MEDICAL SUPERINTENDENT
PUMWANI MATERNITY HOSPITAL

Appendix 20: ICP-MS used for analysis of samples

Appendix 21: Mother and child- waste pickers at Dandora dumpsite

Source: EJAtlas, 2015

Appendix 22: Nairobi River which borders Dandora and Kariobangi

Source: UNEP, 2007