UNIVERSITY OF NAIROBI

ASSESSMENT OF WATER QUALITY OF EARTH DAMS IN CHEPALUNGU SUB-COUNTY, BOMET COUNTY, KENYA

BY

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(I56/82856/2015)

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL CHEMISTRY OF THE UNIVERSITY OF NAIROBI

August, 2019

DECLARATION

This thesis is the original work of the author except where due references are made. It has not been submitted partially or wholly for the award of degree to this or any other institution of learning.

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This thesis has been submitted for examination with our approval as the University supervisors.

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DEDICATION

This thesis is dedicated to my family and all those who have enabled me acquire knowledge.

ACKNOWLEDGEMENTS

I wish to thank my supervisors; Dr. Fredrick D. O. Oduor, Dr. Deborah A. Abong’o and Prof. D. K. Kariuki for consistent academic guidance and support, without which the completion of this work would have been impossible.

I am grateful to all my friends and family members who along the way have greatly assisted me.

Many colleagues assisted in numerous ways. My particular thanks go to Mr. Joram K. Wambua who is the chief laboratory technologist at Ministry of Petroleum and Mining and lecturers of the Department of Chemistry, University of Nairobi.

ABSTRACT

An assessment of water quality from six selected earth dams in Chepalungu Sub-County, Bomet County was carried out by determining the levels of pH, TDS, TSS, nitrate, ammonia, fluoride, phosphorus, copper, lead, zinc, cadmium and chromium. The objective of the study was to determine water quality from the six selected earth dams and compare with WHO (2011) drinking water guidelines. These earth dams are the alternative source of household water since large population in Chepalungu Sub-County are unable to get access to chlorinated drinking water supply. Three water sampling points were identified in each of the six earth dams. The total number of sampling points were 18. Samples collection was done in July, 2016 (dry) and April, 2017 (wet) seasons. Total of 36 earth dam water samples were collected in duplicate. 6 soil samples in duplicate, 2 fertilizers samples in duplicate and 2 rain water samples in duplicate were also collected. Metals were analyzed using Atomic Absorption Spectrophotometer. Nitrate, ammonia and phosphate were analyzed using UV/VIS spectrophotometer. pH and fluoride were analyzed using ion selective electrode meters. TDS and TSS were analyzed using gravimetric method. From the study, pH level and total suspended solids were within the recommended range by WHO (2011) drinking water guideline. Total suspended solids had range of between 8.91±0.64 mg/L and 175.9 ±4.91 mg/L which was higher than the allowable level of 30 mg/L. Nitrate ranged between 2.71±0.03 mg/L and 11.50 ±0.017 mg/L which was lower than maximum recommended level by WHO (2011). Copper ranged between <0.003 mg/L and 0.89±0.031 mg/L which was below maximum recommended level by WHO (2011). Zinc ranged from 0.07±0.01 mg/L to 4.92±0.040 mg/L and was higher than the maximum recommended level by WHO (2011). Chromium was detected during dry season in two earth dams only Cheboloigo and Kapewot with concentration of 0.46±0.055 mg/L and 1.98±0.053 mg/L respectively. Fluoride was higher than the maximum recommended level of 1.5 mg/L drinking water guideline except for Kapewot (1.25±0.031 mg/L) and Kaposur (1.42±0.02 mg/L) earth dams during dry season. The range of fluoride was between 1.25±0.031 mg/L and 5.33±0.05 mg/L. The level of the selected parameters in rain water were within the recommended levels. From the study high fluoride levels in water may have been from soils leaching in the area, soil from this area had high concentration of fluoride with a range of between 125±1.00 mg/L and 683±3.06 mg/L. The study reveals that water from these earth dams should be treated to avoid long term health effect of high concentration of fluoride.

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
APA	American Psychological Association
APHA	American Public Health Association
AR	Analytical reagent
E	East
ECB	European Chemicals Bureau
CAN	Calcium Ammonium Nitrate
$CHCl_3$	Chloroform (Trichloromethane)
CDTA	Cyclohexelenediaminetetraacetic acid
DAP	Di-ammonium Phosphate
ECB	European Chemicals Bureau
GPS	Global positioning system
HCl	Hydrochloric acid
HNO_3	Nitric acid
IHCP	Institute for Health and Consumer Protection
IPCS	International Program on Chemical Safety
KNBS.	Kenya National Bureau of Statistics
KNO_3	Potassium nitrate
LVEMP	Lake Victoria Environmental Management Project
Mg/L	milligrams per liter
ml	volume in milliliters
MPCA	Minnesota Pollution Control Agency
NaCl	Sodium chloride
NaF	Sodium fluoride
NaOH	Sodium hydroxide
Na_2PO_3F	Sodium monofluorophosphate
NO_3^{-1}	Nitrate
PACN	Pan Africa Chemistry Network
pH	$-\log[H^+]$
ppm	Parts Per Million
S	South

SnF_2	Stannous fluoride (Tin Fluoride)
SPSS	Statistical Package for the Social Science
TDCE.	Technology Driven Company Environmental
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USDHHS	United State Department of Health and Human Services
USEPA	United States Environmental Protection Agency
UV/VIS	Ultraviolet/ visible
WHO	World Health Organization

UNITS OF MEASUREMENT

cm	Centimeter
cm^3	Cubic centimeter
℃	Degree Celsius
g	gram
kg	Kilogram
km^2	Square kilometer
L	Liter
m	meter
M	Molarity
mg	milligram
mg/L	milligram per liter
mg/Kg	milligram per kilogram
ml	milliliter
mm	millimeter
m^2	square meter
N	Normality
nm	Nanometer
ppm	parts per million
µg/L	microgram per liter

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CHAPTER ONE

1.0 Introduction

1.1 Background of the study

Water is necessity for all living things and approximately 71 % of planet Earth constitute water. Water which is abundant and safe is essential to our ability to fulfil our potential and prosper (Annan, 2005). Without water, we face an increase in poverty level, well-being, hunger and conflict level (PACN, 2010). Water quality is affected by both natural processes, for example seasonal trends, underlying hydrology and geology, climate and weather or by human activities which include domestic, industry, environmental engineering and agriculture (PACN, 2010). In the past few decades, the quality of surface water has decline in many countries due to extensive anthropogenic inputs of nutrients and sediments (Tessema *et al.*, 2014). In 2009, Africa's population was over 1 billion and it continues to elevate at a rate of 2.4 % per annum (PACN, 2010). 341 million of this population does not access clean drinking water and about 589 million have no adequate sanitation, resulting in loss of productivity due to water-related illnesses (PACN, 2010).

Safe drinking water is a basic requirement for humans and other organisms, although it doesn't contain any organic nutrients or calories (Khatri and Tyagi, 2014). Safe drinking water is one that doesn't cause significant health risk over a long time of consumption which include different sensitivities which may occur in between stages of life (KWR, 2004). Those at greater risk of suffering from unsafe drinking water are children and the elderly (KWR, 2004). The demand for safe drinking water is increasing as the world population increases in the backdrop of inadequate fresh drinkable water in many countries worldwide. Kenya is among the countries in Africa affected by water quality challenges. The total population of Kenya is 40 million and out of this, urban population constitutes 32.3 %, rural population constitute 67.7 % KNBS (2009). 13.4 % of the rural population and 38.4 % of the urban population use piped water and over 86 % of the rural population does not access clean water (KWAHO/UNDP, 2007). Lack of clean water for household use has become a global problem. According to WHO (2001), about 1.8 billion people had no access to quality safe drinking water and approximately 2.6 billion either had no or little sanitation. According to Montgomery and Elimelech (2007), water borne diseases kills about 3,900 children daily. For meaningful prosperity to be realized clean and safe drinking water that is readily available should be the point of focus by governments and local authorities according to water quality assessment of 2007 by the Ministry of Water and Irrigation [KWR, 2004].

Residents of Chepalungu Sub-County in Bomet County use earth dam water for drinking because they are unable to access treated tap water. There are a total of 51 earth dams in this Sub-County. Comprehensive studies in Chepalungu Sub-County have not been done to establish whether the earth dam water meets the safety standards for human and animal consumption. Therefore, human population in areas whose water quality is not known faces a risk of illness such as osteomalacia and fluorosis caused by high levels of dissolved ions (Montgomery and Elimelech, 2007).

This study therefore to assessed the concentrations of copper, zinc, cadmium, lead, chromium, nitrate, fluoride, phosphorus, pH, ammonia, TSS and TDS in water from six selected earth dams in Chepalungu Sub-County and compared them with WHO (2011) water guidelines levels for drinking water.

1.2 Sources of water contamination

The two main sources of contamination of water are natural sources and anthropogenic sources. Natural sources which include weathering of rocks releases minerals to water, atmospheric deposition, climate change and natural disaster (Withers and Lord, 2002). Anthropogenic sources include agricultural activities such as livestock farming since according to Withers and Lord (2002), Livestock farming might be a source of nitrogen and phosphorus in streams, therefore contributing to surface water resources eutrophication. The use of fertilizers is another example of anthropogenic sources, according to Pendias and Pendias (2001), Phosphate and Nitrogenous fertilizers contain traces of heavy metals.

1.3 Statement of the Problem

Activities within a water catchment area affect both physical and chemical constituent of water bodies (Liebi, 2009). The quality of water is influenced by substances that are suspended or dissolved and can affect the usefulness of water for a specific purpose (Venter *et al.*, 2004). Water pollutants from both non-point sources and point sources affect water quality (Venter *et al.*, 2004). Non-point sources are sources in which its discharge cannot be traced to any single source while point sources the discharge of pollutants originates from a specific location for example from a specific industry through pipes into water bodies (Nawn *et al.*, 2004). The source of water contamination in Chepalungu Sub-County earth dams are from point sources as well as non-point sources. Chepalungu is characterized by farming activities which include the use of manure and fertilizers. This elevate the plants nutrients and levels of heavy metals in environment. According to Pendias and Pendias (2001), nitrogenous fertilizers, phosphate fertilizers and Manure contain traces of heavy metals in certain concentrations. Residents of Chepalungu Sub-County use earth dam water for drinking and there is no comprehensive data concerning quality of water from these earth dams. This study will create awareness and help key policy agencies responsible for food safety inspection, pollution control, horticulture, public health and nutrition in developing strategies to manage the environment and control pollution.

1.4 Research Hypothesis

1) The selected parameters may be present in six selected earth dams in Chepalungu Sub-County.
2) Fertilizers, soil and rain water from this area may affect the water quality of earth dams.
3) The levels of the selected parameters might be higher than the maximum recommended levels by WHO (2011).
4) The level of selected parameters might be lower during wet season than during dry season.

1.5 Objectives

1.5.1 Main Objective

To determine the water quality from the six selected earth dams in Chepalungu Sub-County and compare with WHO (2011) drinking water guidelines.

1.5.2 Specific Objectives

The specific objectives were;

1. To assess the levels of pH, nitrate, fluoride, ammonia, phosphorus, TDS and TSS in the water from the six selected earth dams during dry and wet seasons.
2. To determine the concentrations of lead, cadmium, zinc, copper and chromium in six selected earth dams water during dry and wet seasons.
3. To compare the concentrations of fluoride, nitrate, ammonia, phosphorus, copper, cadmium, zinc, lead and chromium in the different selected earth dams.
4. To investigate the contribution of pH, nitrate, fluoride, ammonia, phosphorus, TDS, TSS, copper, cadmium, zinc, lead and chromium from soil, fertilizer and rain water to water quality in earth dams.
5. To compare the levels of the selected parameters with WHO (2011) drinking water guidelines.

1.6 Justification of the study

Chepalungu Sub-County is an area associated with farming activities. These farming activities are possible sources of nitrate, ammonia, phosphorus, fluoride, changes in pH and heavy metals in the earth dam water in this area. There is lack of comprehensive data concerning quality of water from earth dams in this area. Human population in areas whose water quality is not known faces a risk of illness such as osteomalacia and fluorosis caused by high levels of dissolved ions (Montgomery and Elimelech, 2007). Farming activities have been carried out in this area for several decades and it is important to investigate their effect on water quality. Most of the residents in this area have been affected by dental fluorosis which is significant of high fluoride. This study will provide information on levels of the contaminants in earth dam water that will help the County Government put stringent management measures in place to safeguard water from earth dams in Chepalungu Sub-County.

1.7 Introduction of other Chapters

- Chapter two is the literature review of all selected parameters in water, WHO (2011) Drinking water guidelines and rainfall pattern of Kericho County.
- Chapter three is materials and methods that includes Study area, Sampling and standard procedures used during analysis.
- Chapter four is the discussion of the research results of all selected parameters.
- Chapter five is the conclusions derived from chapter four and the recommendations to be made.

CHAPTER TWO

2.0 Literature Review

2.1 pH

pH is the degree of alkalinity or acidity of a substance and is a way of expressing the hydrogen-ion activity in water, in processes such as corrosion control, chemical coagulation, water softening and other similar processes, pH is a factor which must be considered (WHO, 2007). It is a parameter that determines the quality of all waters, which also affects most physical, biological and chemical processes in water supply treatment (WHO, 2007). pH should be controlled during the biological treatment of waste water to favor the specific organism that is involved, (Sidhu and William, 2000). High or low pH levels in water imply that micro-organism activities are hindered hence self-purification of rivers is inhibited (Sidhu and William, 2000). Increase in pH also increases the toxicity of ammonia (Sidhu and William, 2000). Water in its pure state has a pH of 7 which is neutral; the exact value depends on temperature (USEPA, 2006). For water that are natural, the pH ranges from 6.5 to 8.5, values below 7 (acidic) in waters that are high in organic content and values above 7 (alkaline) in eutrophic waters, ground water brines and salt lakes (USEPA, 2006). For clean water, the pH may be due to, among other reasons, the type of rocks and vegetation within watershed (WHO, 2007). Respiration and photosynthesis of algae in eutrophic waters can cause fluctuation of pH in water (WHO, 2007).

2.2 Total Dissolved Solids (TDS)

TDS is the total content of all inorganic and organic substances that are dissolved in water (WHO, 1996). Calcium, sodium, potassium and magnesium carbonate and cations, hydrogen carbonate, sulfate, chloride and nitrate anions are the principal constituents (WHO, 1996). TDS in water supplies originate from urban run-off and agricultural run-off, sewage, natural sources and industrial wastewater (Ravindra and Gargl, 2005). Salts that are used for de-icing road may also contribute to the water supplies TDS loading (WHO, 1996). A concentration lower than 1000 mg/L of TDS in water is acceptable to customers but acceptability usually varies depending on circumstances (WHO, 1996). High concentrations of TDS in water may not be acceptable to consumers because of its tasteless, flat taste and may also cause corrosion to water-supply systems (WHO, 1996). There is a strong correlation between TDS and parameters like chloride, sulfate and sodium indicating their availability in solution (Ravindra and Gargl, 2005).

Therefore, this shows that it can be used to give an estimate of several other parameters (Ravindra and Gargl, 2005).

2.3 Total Suspended Solids (TSS)

TSS are substances that are suspended in water (Liebi, 2009). Many types of industrial and sanitary wastewater contain Suspended Solids (Liebi, 2009). Nonpoint sources such as soil erosion from construction and agricultural sites can also contribute to high amount of suspended solids in water (Liebi, 2009). The definition of TSS does not include course materials for example street sand and trash, and dissolved chemicals such as chloride (Liebi, 2009). TSS is used only to measure fine particles of sediment, and the pollutants that are attach to them (Liebi, 2009).

2.4 Nitrate

In the environment, nitrate which is an inorganic compound and does not cause health problems occurs under different conditions and when it is reduced to nitrite it becomes harmful to living organisms (Sidhu and William, 2000). Nitrate present in water can be measured in terms of both nitrogen and oxygen or amount of nitrogen present only (Sidhu and William, 2000). Nitrate is very soluble, stable and negatively charged ion in water and due to its low potential for adsorption, it is difficult to be removed from water (Luk and Au-Yeung, 2002). If nitrite is present in digestive tract of babies, they can be affected by methemoglobinemia (Sidhu and William, 2000). Methemoglobinemia is a disease which is brought about by the presence of nitrates in drinking water (Sidhu and William, 2000). Hemoglobin is a compound which is composed of iron in blood that carries oxygen and if nitrate is present it can change hemoglobin to methemoglobin which inhibits oxygen transportation in blood (Sidhu and William, 2000). The levels of methemoglobin in adults are usually below one percent, this is because methemoglobin is converted back to hemoglobin by enzymes but the enzyme in infants are in lower levels and their methemoglobin level is usually in the range of one to two percent (Sidhu and William, 2000). Levels higher than these will result in Methemoglobinemia (Sidhu and William, 2000). Methemoglobinemia is the conversion of nitrate to nitrite in the stomach whereby nitrite combines with haemoglobin to form methemoglobin, hence reducing the transportation of oxygen by blood leading to blue baby syndrome, which in extremes can damage brain and finally lead to death in humans (Levalloisa *et al.*, 1998). Signs of cyanosis usually appear at higher levels and babies having these symptoms usually have bluish mucous membranes, respiratory and digestive problems (Levalloisa *et al.*, 1998). If methemoglobin levels are above 30 percent, it can lead to anoxia which is as a result of severely reduced the capacity of oxygen which is carried in blood (Sidhu and William, 2000). Brain damage or even death may occur at the levels of 50 to 70 percent of methemoglobin, (Sidhu and William, 2000). In animal’s high nitrates can lead to damages in the reproductive system (Luk and Au-Yeung, 2002).

Most people consume eighty to ninety percent of nitrates which comes from vegetables which is unlikely to cause health effects because a small amount of nitrates present in vegetables is usually converted to nitrites. Less than 10 percent of nitrates is present in meat products but the amount of nitrite consumed is 60 to 90 % because food such as hot dogs, bacon and ham are added sodium nitrite (Sidhu and William, 2000). Dairy products, Fruits and grains do not significantly contribute nitrite or nitrate levels to human. (Mussaiger and Khunji, 1990). In animals, high nitrate can lead to damages in the reproductive system (Luk and Au-Yeung, 2002).

2.5 Ammonia

Ammonia is present in water which result from natural reduction process while unpolluted surface water does not have ammonia (De, 2010). It is produced through the deamination of organic nitrogen-containing compound and hydrolysis of urea (De, 2010). Surface water may acquire ammonia from animal proteins and decomposition of plants, ammonia is quickly converted by dissolved oxygen if present in water to nitrate by bacteria (Mussaiger and Khunji, 1990). The toxicity of ammonia is increased due to increase in pH but the oxygen carrying ability in trout will be reduced by ammonia at the levels of 0.3 mg/L (De, 2010). Bacterial conversion from nitrite and ammonia may increase levels of nitrate when oxygen is present in surface water (De, 2010). Increase in nitrate can lead to eutrophication of stream and lakes (Mussaiger and Khunji, 1990). If it is present in ground water, it indicates an oxidizing condition (processes) in the aquifer (Mussaiger and Khunji, 1990). If the levels of ammonia become greater than 50 mg/l it will indicate the influence of man’s activities such as the use of nitrate fertilizers (Mussaiger and Khunji, 1990).

2.6 Fluoride

Fluoride (F^-) is required as essential element and is necessary for human life (Breiter *et al.*, 2006 and Zhu *et al.*, 2007). It exists naturally in water sources and is more active and is the most electronegative element (Zhu *et al.*, 2007). In drinking water fluorine is totally in an ionic form and hence it quickly and passively goes through the intestinal mucosa and affects metabolic activities of the living organism (Zhu *et al.*, 2007). It is present in biological chains in living organisms and also present in water, rocks and soils (Breiter *et al.*, 2006 and Zhu *et al.*, 2007). The principal source of fluoride is either natural by emission from volcanic activities or through man-made additives like fluoride in toothpaste (NaF, SnF_2, Na_2PO_3F) and water fluoridation (Fouskaki *et al*., 2003). Weathering of rocks which contain fluoride rich mineral such as apatite and fluorite can naturally produce fluoride (Breiter *et al.*, 2006 and Zhu, *et al.*, 2007). Rift valley has volcanic rocks which are rich in sodium and fluoride and it is mostly affected by climatic conditions which favor chemical weathering (Fouskaki *et al*., 2003). Anthropogenic sources such as phosphate fertilizers and electronic waste material can leach fluoride into water (Arnesen and Singh, 1998). Several factors contribute to the abundance of fluoride in water (Totsche and Kogel-Knabner, 2004). Water with higher sodium and lower calcium level contain fluoride (Totsche and Kogel-Knabner, 2004). Farming and other anthropogenic activities can increase the level of fluoride in water (Totsche and Kogel-Knabner, 2004).

Once in the environment, it directly or through intermediate steps passes into water body systems, food chain and finally to the human body through ingestion (Konieczka *et al.*, 2000). In the human body, fluoride deposit itself to the targeted organ especially where there is presence of calcium (Konieczka *et al.*, 2000).

2.7 Phosphorus

Phosphorus (P^{3-}) can be carried into the water reservoirs through water runoff (soil erosion) from croplands and pastures (Kroening and Ferrey, 2013). Though phosphorus is an essential element to living things, it can accelerate the reduction of dissolved oxygen in water when it is in excess and leads to eutrophication (Kroening and Ferrey, 2013). It can also promote the excessive growth of algae thus causing water pollution (Kroening and Ferrey, 2013).

2.8 Copper

Copper is a group 11 element, highly ductile and good conductor of electricity (Brewer, 2007). It is key element required by human and animals for carbohydrate metabolism and functioning of enzymes together with the formation of hemoglobin in blood for transport of hemoglobin in vertebrates and shellfish (IHCP, 2008). Copper does not biodegrade, hence it accumulates in the environment and may eventually reach concentration levels that are hazardous (IHCP, 2008). Copper is found in chalcopyrite deposits along with Cd, Zn and Pb which is used in construction of vehicles, manufacture of medicine, electroplating and transmission of electricity (Gustavo, 2007). It is released from plumbing systems (Gustavo, 2007). Copper can cause various types of chronic and acute disorders and health hazards in human beings, flora and fauna when ingested beyond the permissible level of 1.3 ppm (Gustavo, 2007). In human beings it causes Wilson's disease (IHCP, 2008). Excess exposure of copper in human beings can cause anemia, stomach and intestinal irritation, kidney and liver damage (Padey and Madhuri, 2014).

2.8.1 Occurrence of copper in water

Copper (Cu) naturally exists in soil, rocks, sediments and water (USDHHS, 2004). In water, sources of copper are extensive (TDCE, 2004). In addition to natural levels originating from rocks weathering and atmospheric deposition, anthropogenic release can be through factories effluents and sewages or diffuse runoffs from land and roofs (TDCE, 2004). It can also naturally occur in living things (USDHHS, 2004). All living organisms which include human and animal require copper as an essential element at optimum intake levels (USDHHS, 2004). Excessive levels can result in toxic effects (USDHHS, 2004). Runoffs due to natural weathering or anthropogenic soil disturbances will transport copper into waterways and streams (TDCE, 2004). It may originate from dry and wet depositional process, various emissions from automobiles and roofs of building (Davis *et al.*, 2001). In estuarine sediments, copper binds to organic matter, unless organic matter content has low sediment. (Davis *et al.*, 2001).

2.9 Cadmium

Cadmium is a group 12 element in the periodic table along with mercury and zinc (Morrow, 2010). It has atomic number of 48 and a main oxidation state of +2 (Morrow, 2010). It occurs naturally in deposits such as ores containing other elements and its average concentration ranges between 0.01 ppm and 0.05 ppm (Pandey and Madhuri, 2014). In solution it readily forms complexes with ammonium, halides and cyanides species and it has strong attraction to organic matter (Lawler and Tippings, 2003). At high pH level, humic substance binds Cd^{2+} than the major inorganic ligands (Lawler and Tippings, 2003). Global mean of cadmium for surface soil has an estimate of 0.530 mg/Kg with mean cadmium in soil ranging between 0.06 mg/Kg and 1.10 mg/Kg (Kabata and Pendias, 2001). The high concentrations reflect anthropogenic influence (Kabata and Pendias, 2001).

Exposure to cadmium has long been identified as a health hazard, both in general populations and in industry with high exposure (Kabir *et al*.,2014). Exposure of cadmium can lead to the damage of body organs such as liver and kidney and central nervous system (Kabir, *et al*., 2014). It can also affect reproduction, development and immunity (Apostoli and Catalani, 2011). It leads to lung cancer and it is still under investigation as a risk factor of prostate cancer (Pandey and Madhuri, 2014).

The main uses of cadmium include metal coating and plating operations, nickel-cadmium solar batteries and as an impurity in products such as refined petroleum, detergents and fertilizers (Pandey and Madhuri, 2014).

2.9.1 Occurrence of cadmium in water

Cadmium (Cd) naturally occurs in the earth's crust mainly as sulfide minerals which are associated with zinc ores or zinc containing lead ores and is widely distributed element in the earth's crusts (Morrow, 2001). Due to natural weathering, cadmium is released into water (Morrow, 2001). Other processes that include atmospheric deposition discharge from industrial facilities, leaching from landfills, leaching from phosphate fertilizers and discharge from treatment plants may also lead to increase of cadmium in water (Morrow, 2001). In the aquatic systems, sources of cadmium can be through runoff from agricultural sites especially where there is application of phosphate fertilizer (Huang and Zhang, 2004).

2.10 Zinc

Zinc is a group 12 element with atomic number 30, lustrous and diamagnetic metal (Blake, 2007). It is an essential element required by the body which in high levels can be harmful to health (WHO, 2001). Acute effects of zinc include vomiting, nausea, diarrhea pancreatitis and vascular shock (Ndunge *et al.*, 2014). Exposure of excess zinc can cause system dysfunction leading to impairment growth and reproduction while its deficiency has been associated with poor wound healing, depressed mental function and dermatitis (Nolan, 2003).

Zinc is extensively used as metals protective coat, in dye casting industry and in the construction industry (Akan *et al*., 2010). Its organic and inorganic compounds can be applied as fungicides, topical antibiotics, lubricants and in medical and household applications, automotive equipment, dental applications and dry cell batteries (Akan *et al*., 2010).

2.10.1 Occurrence of zinc in water

Sources of zinc (Zn) in water includes industrial and municipal effluent, mine drainage and urban runoff (Davis *et al.*, 2001). Household plumbing and distribution system may elevate the concentration of zinc in drinking water (Davis *et al.*, 2001). This is because in distribution system the common piping material contains Zinc (Davis *et al.*, 2001). Ligands which are associated with zinc are affected by pH of the solution and concentrations of minerals in water which affects water environmental toxicity of zinc (WHO, 2001). In the earth's crust compounds of zinc exist and are also present in most rocks and certain minerals which include carbonate sediments and when these materials undergo weathering it forms soluble zinc compounds which can be released into water (WHO, 2001).

2.11 Lead

Lead is an element that occur naturally and in periodic table it belongs to group 14 (Raja and Namburu, 2014). Lead is malleable, soft, poor conductor of electricity, ductile and resistance to corrosion but when exposed to air it tarnishes (Bergeson, 2008).

Chronic exposure of lead has been connected to cerebrovascular and kidney disease in humans and for lifetime exposure it can cause cancer (Sharma and Pervez, 2003). High level exposure of Lead can affect body organs and system and eventually death (Pandey and Madhuri, 2014). Children have rapid growth rate and metabolism thus vulnerable to the neurotoxic effects (USDHHS, 2004). According to Raja an Namburu (2014), exposure of lead in children less than five years affects nervous system. It can damage human organs such as bones, brain, blood, kidneys and thyroid gland (Owusu-Donkor, 2011). Consumption of foods and water which are contaminated with lead can impair respiration by interfering with functioning of mitochondria which may cause constipation, paralysis, brain swelling and may lead to death (Oluyemi *et al*., 2008).

2.11.1 Occurrence of lead in water

In aquatic environment lead (Pb) originates from atmospheric deposition and urban runoff (Denaix *et al*., 2001). Sediments and Suspended Solids can absorb lead in surface waters (Denaix *et al*., 2001). Lead in aqueous solution is found in multiple forms and with major anions in water, it forms compounds with low solubility (Denaix *et al*., 2001). The amount of dissolved salt and the pH in surface water affects the solubility of lead and this solubility reduces at pH<5.4 due the formation of lead sulfate, but at pH>5.4, its solubility is inhibited by the formation of lead carbonates (Denaix *et al*., 2001). The presence of ligands in water determines the speciation of lead (Denaix *et al*., 2001). Organic matter and humic acids form strong complexes with lead (Denaix *et al.,* 2001).

2.12 Chromium

Chromium is a common element of rocks, especially those of basic and ultramafic igneous origin, and soils derived from them are correspondingly enriched (Kabir *et al*., 2014). Chromium is a transition metal of group 6 of the Periodic Table (Kim *et al*., 2008). It is naturally found in living things, soil, rocks and dust either as trivalent or hexavalent (Kim *et al*., 2008). In nature chromium is mostly found in form of trivalent while hexavalent is found in small quantities. Trivalent chromium is an essential dietary element and is found in many fruits, vegetables, grains and meat while hexavalent chromium compounds are toxic to human and may cause cancer (Pandey and Madhuri, 2014). Chromium (IV) is toxic both to human and animal health (Yousef *et al.,* 2006). In male New Zealand rabbits, plasma testosterone and reduced sperm count were observed after administering 3.6 mg of chromium (VI)/kg/day in form of potassium dichromate which was done by gavage for 10 weeks (Yousef *et al.,* 2006). 25.9 % of total sperm output was reduced, 18 % of sperm count was reduced, 34.3 % of the total number of mobile sperm was reduced and 23.9 % of number of dead sperm were increased (Yousef *et al.,* 2006). 22.2 % of the relative weight of epididymis and testes were reduced and 20.8 % of plasma testosterone was also reduced (Yousef *et al*., 2006). Chromium can be used in making alloys, pigments for paints rubber paper and cement production (Pandey and Manduri, 2014).

2.12.1 Occurrence of chromium in water

Chromium (Cr) is an element that exists with oxidation states ranging from +2 to +6 (WHO, 1996). Rocks and soils may contain low concentrations of chromium (WHO, 1996). Rain water has an average chromium concentration from 0.2-1.0 µg/L (WHO, 1996). In seawater, natural chromium exists from 0.02-0.50 µg/L (WHO, 1996). In surface water the total natural chromium content is about 0.5-2 µg/L while chromium that is dissolved, concentration ranges from 0.02-0.3 µg/L (WHO, 1996).

Exposure to chromium (IV) also cause aberrations of chromosome and exchange of sister chromatid (WHO, 1996). Exposure to chromium (VI) compound can leads to mortality cause by lung cancer (WHO, 1996).

The drinking water guidelines (WHO, 2011) are presented in Table 2.1 below.

Table 2.1: WHO (2011) drinking water guidelines of selected parameters

	Maximum levels in drinking water
Parameters	WHO
pH	6.5-8.5
TDS	1200 mg/L
TSS	30 mg/L
Nitrate	50 mg/L
Ammonium	0.5 mg/L
Fluoride	1.5 mg/L
Phosphorus	NC
Copper	2 mg/L
Cadmium	0.003 mg/L
Zinc	3 mg/L
Lead	0.01 mg/L
Chromium	0.05 mg/L

NC- Not classified

2.13 Rainfall pattern for Kericho County (2015, 2016 and 2017)

Sampling for dry season was carried out in July, 2016, while that for wet season was done in April 2017. Figure 2.1 shows the rainfall pattern of Kericho County for the year 2015, 2016 and 2017.

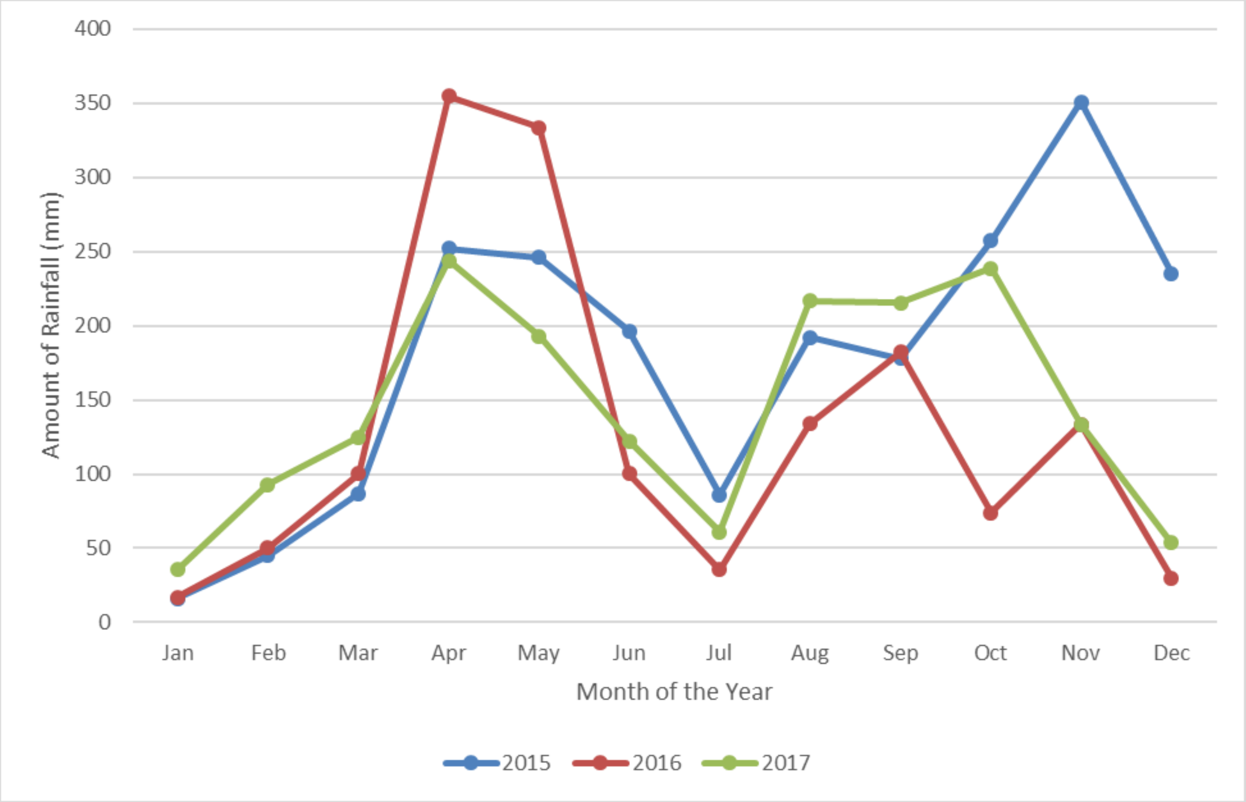


Figure 2.1 Rainfall Pattern of Kericho County

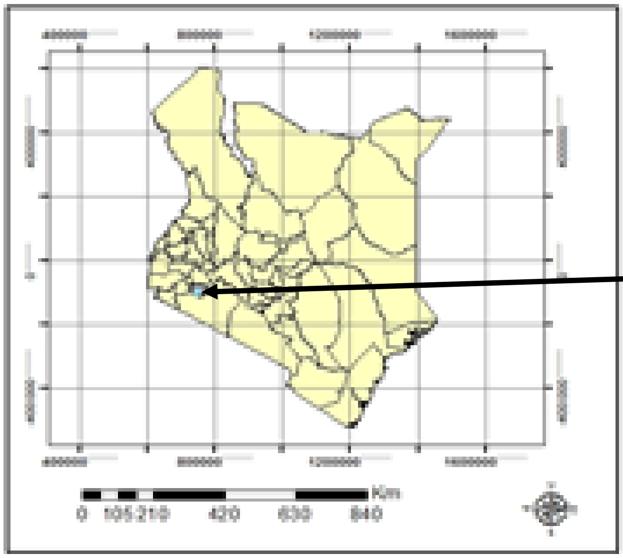
Source: LVEMP, 2015- 2017.

CHAPTER THREE

3.0 Materials and Methods

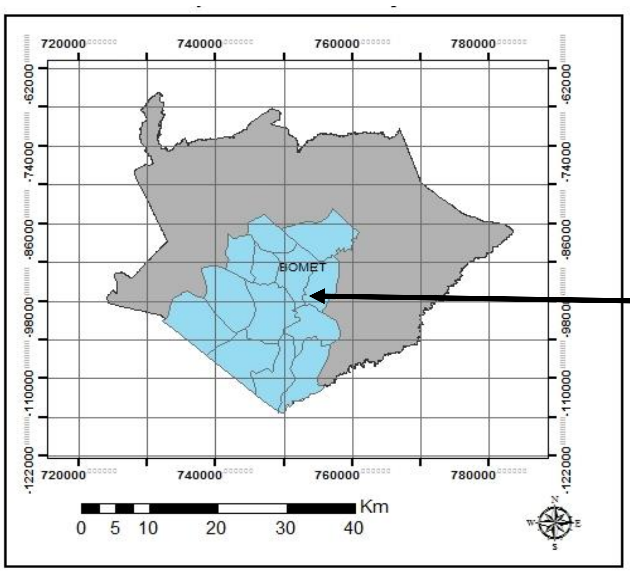
3.1 The study area

Chepalungu Sub-County spans an area of 490.60 km^2 and a population of 163,833 people in Bomet County (KNBS, 2009). It has a total of 51 earth dams. It lies at latitude (00° 56' 00" S) and longitude (35° 12' 00" E) and is among the five Sub-Counties of Bomet County. Figure 3.1 and 3.2 shows map of Kenya and map of Bomet County respectively while Figure 3.3 is a map of Chepalungu Sub-County showing the six selected earth dams.



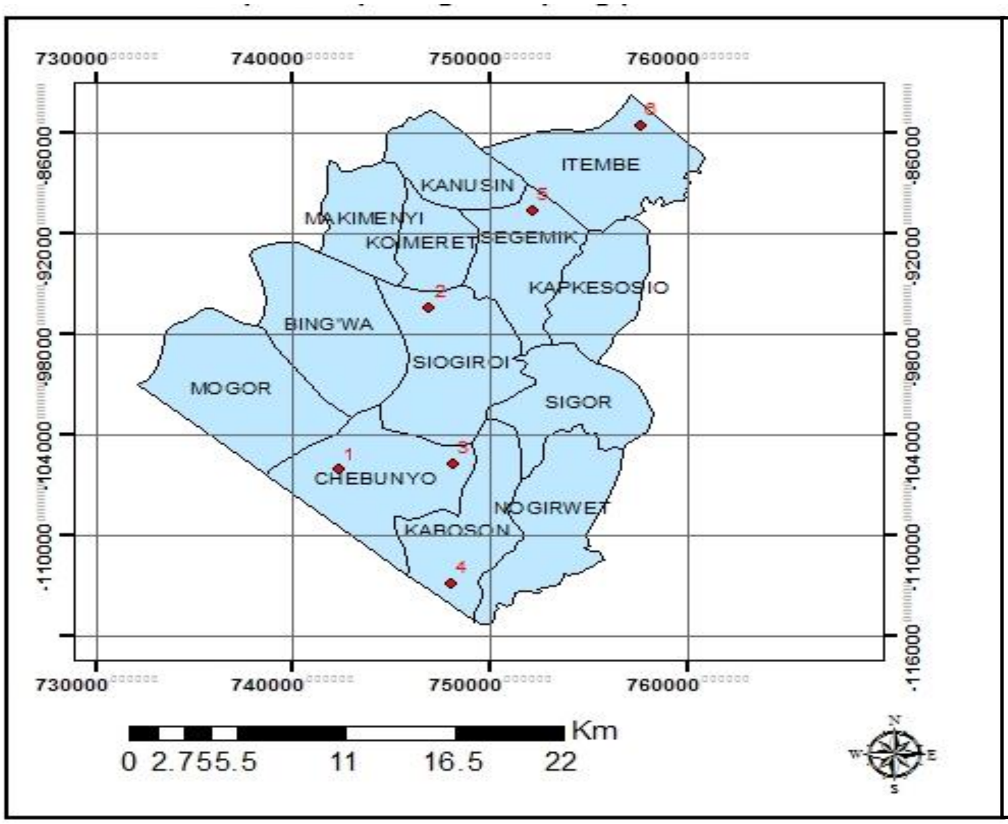
Light blue colour shows Bomet County in Kenya

Figure 3.1 Map of Kenya



Light blue colour shows Chepalungu Sub-County in Bomet County

Figure 3.2 Map of Bomet County



Key:

1=Birir earth dam

2=Cheboloigo earth dam

3=Kamogiboi earth dam

4=Sogororbei earth dam

5=Kaposur earth dam

Figure 3.3 Map of Chepalungu Sub-County showing six selected earth dam.

Table 3.1 shows the six selected earth dams in Chepalungu Sub-County with their depth, area, altitude, coordinates and human activities around each earth dam while figure 3.4 to figure 3.9 shows the images of all studied earth dams.

Table 3.1 Sampling sites, depth, Area, coordinates and human activities around the sampling site

Site	**Dam name**	**Depth(m)**	**Area(m^2)**	**altitude (m)**	**Coordinates**	**Human activities around the sampling site**
1	Birir	4	7,633	1,851	S00° 57' 45.5" / E035° 11' 12.7"	Shopping center, Maize farming and Livestock keeping
2	Cheboloigo	4	360	1,830	S00° 49" 16.1' / E0.35° 11' 12.7"	Maize farming and Livestock keeping
3	Kamogiboi	3	9,123	1,806	S00° 56' 58.4" / E035° 12' 40.2"	Maize farming and Livestock keeping
4	Sogororbei	3	6,782	1,767	S00° 59' 04.0" / E035° 12' 08.6"	Maize farming and Livestock keeping
5	Kaposur	2	14,027	1,890	S00° 46' 55.7" / E035° 16' 24.5"	Maize farming and Livestock keeping
6	Kapewot	3	15,928	1,930	S00° 46' 37.5" / E035° 18' 38.4"	Shopping center, Maize farming and Livestock keeping

The main types of fertilizers used in this area for faming are DAP and CAN and approximately 5940 metric tons of fertilizers are used per annum.

Figure 3.4 Birir Earth Dam

Figure 3.4 is the image of Birir earth dam with an area of about 7,633 square meters. Water from this earth dam is clear and about a quarter of the earth dam has been covered by water lily.

Figure 3.5 Cheboloigo Earth Dam

Figure 3.5 is the image of Cheboloigo earth dam with an area of about 360 square meters and it is the smallest compared to all other studied earth dams. Water from this earth dam is not clear. The embankment of the earth dam has been covered by thick grass.

Figure 3.6 Kamogiboi Earth Dam

Figure 3.6 shows Kamogiboi earth dam with an area of about 9,123 square meters. The earth dam has clear water and has been fenced by the County Government of Bomet. The main human activity around this area is maize farming.

Figure 3.7 Sogororbei Earth Dam

Figure 3.7 is the image of Sogororbei earth dam with an area of about 6,782 square meters. The earth dam has been covered by reeds. Water from this earth dam is not clear it contain suspended particles.

Figure 3.8 Kaposur Earth Dam

Figure 3.8 is the image of Kaposur earth dam with an area of about 14,027 square meters. It is the second largest earth dam among the studied earth dam.

Figure 3.9 Kapewot Earth Dam

Figure 3.9 is an image of Kapewot earth dam. Its area covers about 15,928 square meters and it is the largest earth dam compared to other studied earth dams.

3.2 Sampling

Sample collection was done in both seasons; dry season on July, 2016 and wet season on April, 2017. Geographic Information System (GIS) data was obtained from the six selected dam sites during sample collection using GPS instrument. The pictorial views of the studied earth dams are shown in Figure 3.4 to Figure 3.9.

3.2.1 Earth dam water sample collection

Collection of earth dam water samples was done from the three selected sampling points from each earth dam. These sampling points were selected by dividing each earth dam into three equal points such that point A to B is equal to point B to C and point C to A. The sampling bottle was submerged to about 10 cm below the water surface and samples were transferred into 1litre plastic containers from three different sampling points in each of the six earth dams, mixed to form one composite sample from each earth dam. The samples were put in two separate 1litre plastic containers. One of each of these containers was treated with 3 drops of concentrated nitric acid (APHA, 2005). This was used in the analysis of metals ions while the other sample was used in the determination of pH, TDS, TSS, phosphorus, fluoride, ammonia and nitrate. 6 samples in duplicate were collected during dry season and another 6 samples also in duplicate were collected during wet season. Total of 6 water samples in duplicate were collected during dry season and 6 water samples in duplicate were collected during wet season. The total number of samples were 12 and these were in duplicate. Each container was corked immediately, labeled and transported to the laboratory.

3.2.2 Rain water sample collection

Collection of rain water samples was done from the roofs of two residential houses closely adjacent to Birir and Kapewot earth dams. 10 liters of water was collected in each residential house and divided into two portions of 5 liters each. One portion was treated with 3 drops of concentrated nitric acid (APHA, 2005). The portion treated with nitric acid was used to analyze metals while the other portion was for fluoride, nitrate, pH, ammonia, TDS, TSS and phosphorus analysis. The total number of rain water samples collected in duplicate were 2.

3.2.3 Soil samples collection

For the determination of copper, zinc, cadmium, lead, chromium, nitrate, ammonia, phosphorus, pH and fluoride contents, soil samples were collected from the land 5 meters from the sampling site of each earth dam where water samples were collected during each sampling regime. By use of a hoe, soil was dug and scooped down to the depth of 30 cm from the three different points from the land adjacent to the water sampling points and about 100 g of the scooped core was taken. The core was mixed thoroughly in order to give a composite sample. Two replicate samples of about 150 g were taken from the composite samples, labeled, placed in plastic bag and transported to laboratory. A total of 6 soil samples in duplicate were collected.

3.2.4 Fertilizer samples collection

Fertilizers were sourced from farmers in Chepalungu Sub-County. Fertilizers namely DAP and CAN that remained after farmers used were collected. These fertilizers were packed in sampling bags and transferred to laboratory for analysis. The weight of each sample was 1 kilogram. A total of 3 di-ammonium phosphate fertilizers samples and 3 calcium ammonium nitrate samples were collected. The total number of fertilizer samples collected were 6.

3.3 Sample treatment and storage in the laboratory

The samples for nitrate and ammonia were decolorized using activated carbon followed by filtration using filter papers (0.45 mm). sample storage was done by keeping all samples in the fridge at temperature of 4 °C.

Table 3.2 Is the list of equipment used in various methodology together with their model, manufacturer and specific parameter analyzed with each equipment.

Table 3.2: List of equipments used in methodology

	Equipment	**Model**	**Manufacturer**	**Parameters analyzed**
1	Atomic Absorption Spectrophotometer	Spectra AA-10	Varian Techtron PTY LTD	Cu^{2+}, Cd^{2+}, Zn^{2+}, Cr^{3+} and Pb^{2+}
2	UV/VIS Spectrophotometer	T80+	PG Instrument Limited	NH_3, NO_3^- and P^{3-}
3	Ion selective electrode Meter	HI 2216	Hanna Instrument (Romania)	pH
4	Ion selective electrode Meter	Orion 290A	Orion Research Inc. (Boston)	F^-
5	Weighing balance	ASB-220-C2-V2	MRC LTD	Weighing Soil and fertilizer samples
6	Hot plate	SH-7C	Huaghua Fasithfull Instrument Co Limited	Heating of sample during digestion.
7	Oven	LDO-150F	Daihan Labtec Co Limited	Drying of samples for TDS and TSS
9	GPS	Etrex 30	Optace Limited	Taking co-ordinates of Earth dams

3.4 Chemicals and Reagents

The following chemicals were used in methodology; nitric acid with purity of 69 %, hydrochloric acid with purity of 37 %, and 99.0 % pure ammonium metavanadate all sourced from Loba Chemi Pvt Ltd. sulfuric acid 98 % pure, tri-chloromethane, 98 % pure sodium fluoride and cyclohexene-diaminetetraacetic acid all sourced from Finar Chemical. Sodium hydroxide pellets with a purity of 98.0 %, potassium nitrate with a purity of 99.0 %, di-ammonium hydrogen phosphate, sodium chloride with a purity of 99.9 %, 99.0% pure ammonium molybdate, copper metal strip, zinc granules, lead metal strip, chromium metal strip, cadmium metal strip all were sourced from The British Drug House Ltd. Distilled water which was distilled at Ministry of Petroleum and Mining.

3.5 Preparation of Reagents

The following reagents were prepared at Ministry of Petroleum and Mining laboratories:

3.5.1 Nessler's reagent preparation

A mixture of 70 g and 100 g iodide salts of potassium and mercury in 1liter beaker, was dissolved in 100 ml of distilled water and slowly added to 160 g cooled solution of NaOH pellets in 700 ml of distilled water while stirring. The precipitate formed was allowed to stand for at two days in which the bale yellow supernatant liquid was ready for use. The solution was kept stoppered in a dark colored bottle (APHA, 2005).

3.5.2 1 N Hydrochloric acid

1 N hydrochloric acid was prepared by dissolving gram equivalent weight (36.46 g ÷ (0.37×1.19)) in one liter of distilled water.

3.5.3 1 M Sodium Hydroxide

1 mole (39.997 g) of Sodium hydroxide pellets in was dissolve in 1 liter of distilled water.

3.5.4 1:3 Aquaragia

1:3 Aquaragia was prepared by mixing 1 part of concentrated AR nitric acid with 3 parts of concentrated AR hydrochloric acid.

3.5.5 Fluoride Buffer

Fluoride buffer was prepared by adding approximately 500 ml distilled water into a 1liter beaker, followed by 58 g NaCl, 57 ml acetic acid and 4.0 g 1,2 Cyclohexene-diaminetetraacetic acid

(CDTA). The mixture was dissolved by stirring. The beaker was then placed in a cold water bath followed by adding 125 ml of 6N NaOH slowly while stirring until the pH was between 5.3 and 5.5 and topped up to 1 liter using distilled water.

3.5.6 6 N Sodium Hydroxide

6 moles (39.9997 g×6×100÷98) of Sodium hydroxide was dissolved in one liter of distilled water.

3.5.7 Ammonium Molybdivanadate

This was prepared by mixing two ammonium salts solutions and diluting to one liter. The preparation of salts solutions was as follows; 400 ml of 50% HNO_3 was used to dissolved 50 g of ammonium molybdate.

3.5.8 Phenolphthalein Indicator

0.5 g of phenolphthalein was dissolved in 100 ml of 50% ethyl alcohol solution.

3.5.9 Dilute Acids

Concentrated nitric acid was added to distilled water in a ratio of 1:1 to make 1:1 nitric acid and 1:1 hydrochloric acid was prepared by adding concentrated hydrochloric acid to distilled water in a ratio of 1:1.

3.6 Laboratory Apparatus

The following apparatus were sourced from Ministry of Petroleum and Mining laboratories: Whatman Filter paper 0.45 mm, beakers with volume size in ml of 50, 100, 250 and 1000, spatula, 100 ml measuring cylinder, drying dish, Magnetic stirrer, Laboratory tray, plastic container of 1 liter and 5 liters, gloves, safety goggles, volumetric flask of volume size in ml of 50, 100, 500 and 1000, conical flask of 100 ml and 250 ml, droppers, Automatic dispensers**,** Wash bottle**,** Polyurethane cool box**,** Filter funnel**,** Hot water bath and Stirring rod.

3.7 Determination of pH

pH meter was first calibrated with pH standards of 4.0, 7.0 and 10.0. Electrodes were rinsed twice using distilled water. 50 ml of each of samples was measured, transferred to 100 ml beaker and electrodes immersed. After stabilization of the meter, the readings were recorded for each sample (Radojevic and Bashkin, 1999).

For soil and fertilizer, 5.000 g of the samples were weighed into 100 ml beaker in triplicates followed by adding 50 ml of distilled water and stirred for about 30 min. pH electrode was then immersed and allowed to stabilize. After stabilization of the meter, the readings of each sample was recorded (Radojevic and Bashkin, 1999).

3.8 TDS Determination

The sample was first mixed thoroughly and filtered using pre-weighed filter paper (0.45 mm). 200 ml of filtrate was transferred into weighed evaporating dish and evaporated to near dryness in the hot plate. It was dried for 1 hour in the oven at 105 ˚C and placed in a desiccator to cool. The drying was repeated three times (APHA, 2005).

The calculation of Total dissolve solids was done using the formula

TDS mg /L= (C-D) x 1000/SV

Where; C= Weight of dried residue (mg) + dish in mg

D= Dish weight in mg

SV= Sample volume

3.9 TSS Determination

Samples were first mixed thoroughly and 200 ml was measured and then filtered using filter paper (0.45 mm). The filter paper together with the residue was dried in the oven at 105 ˚C for 1 hour and cooled. The drying was repeated three times (APHA, 2005).

The Total Suspended Solids were calculated as follows:

TDS mg /L= (C-D) x 1000/SV

Where;

C= weight of dried residue (mg) + filter in mg.

D= filter paper weight alone (mg).

S.V = Sample volume

3.10 **Determination of nitrate in water, soil and fertilizer samples**

Stock nitrate standard solution was prepared by drying potassium nitrate (KNO_3) in an oven for 24 hours at 105 ˚C and cooled in the desiccator. 0.7218 g was weighed accurately and dissolved in 1 liter of distilled water to make 100 µg NO_3^- per ml. It was then added 2 ml $CHCl_3$ to make it stable for one month. Working standards was prepared in the range of 0 ppm to 3 ppm. The working standards were treated using the same procedure as the samples.

Samples were filtered to remove interferences due to the suspended solids. 50 ml of each sample was mixed thoroughly with one ml of 1N HCl.

For soil and fertilizer, 5.000 g of the samples were weighed into a beaker in triplicate. 30 ml of distilled water with 1 N hydrochloric acid was added and heated in the hot plate for 30 min. The samples were then cooled and filtered into 50 ml volumetric flask and neutralized using 1 M NaOH and topped up using distilled water. It was then analyzed using UV/VIS spectrometer at 220 nm wavelength (APHA, 2005).

Actual concentration was obtained using the following formula

$C = (A-B) \times FV \div SW$

Where C= Concentration, A= Sample reading, B= Blank reading, FV= Final Volume and SW=Sample Weight.

3.10.1 Preparation of the nitrate calibration curve

UV/VIS Spectrophotometer model T80+ was calibrated using the prepared working standards of 0.20, 0.50, 1.00 and 3.00 ppm. The wavelength used was 220 nm, detection limit was 0.02 ppm. The standard concentration and absorbance are shown in Table 3.3 and the calibration curve in Figure 3.10.

Table 3.3: Concentration against absorbance for nitrate

Standards	Concentration (mg/L)	Absorbance
1	0.20	0.050
2	0.50	0.126
3	1.00	0.255
4	3.00	0.765

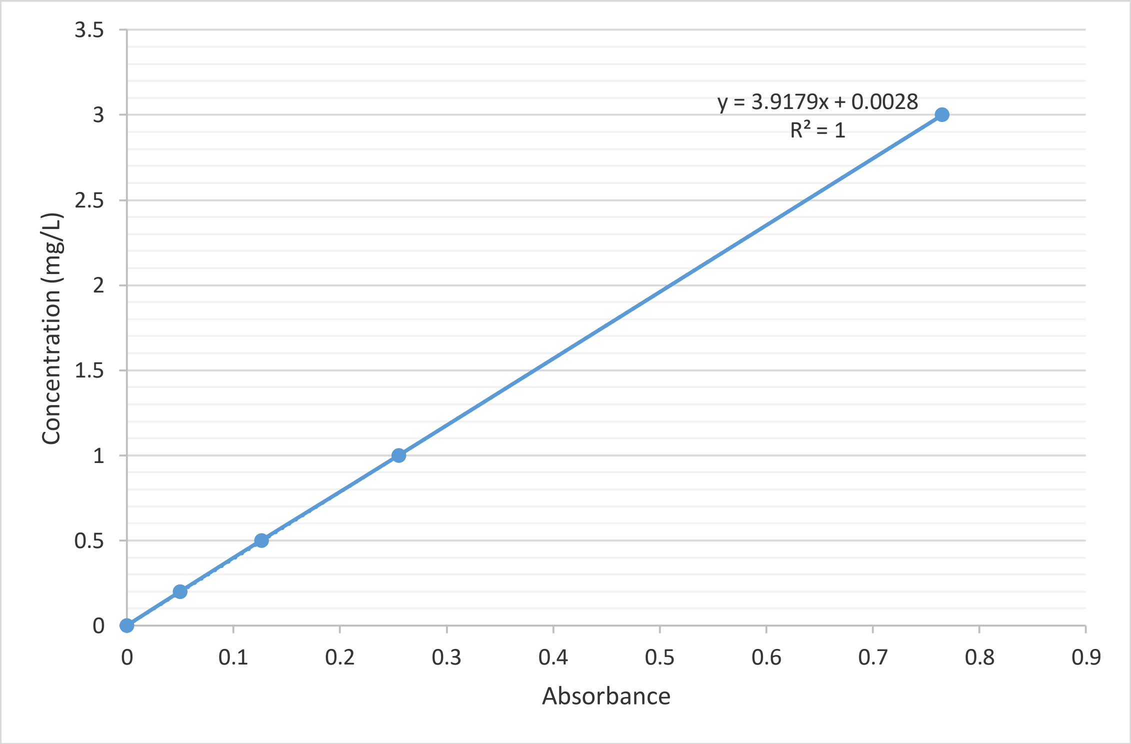


Figure 3.10 Nitrate calibration curve

3.11 Determination of Ammonia

Ammonia reacts with Nessler reagent to form a yellow colour which was determined at 425 nm. Ammonia was determined calorimetrically using Nessler's reagents. An orange brown compound was formed from the reaction of Nessler's reagent with ammonia which was formed as a result of the reaction between Nessler's reagents a dilute ammonium salt solution. The orange brown compound remained in colloidal solution and on standing it flocculates. Measurements was done before flocculation occurred.

3.11.1 Preparation of standard ammonia solution

3.141 g of Analytical reagent (AR) ammonium chloride was dried at 100 ˚C for about 30 minutes. After drying it was then dissolved to one liter using distilled water. The solution formed contains 1000 ppm ammonia. From this 1000 ppm a standard of 100 ppm was prepared using serial dilution formula $C_1V_1=C_2V_2$. From 100 ppm working standard of 0.50, 1.00, 3.00 and 5.00 ppm were prepared using the same formula. The ammonia standards were used in the calibration of ultraviolet/visible spectrophotometer at 420 nm (T80+) for ammonia determination (APHA, 2005).

3.11.2 Colorimetric method for ammonia determination in water

1ml of Nessler's reagent was mixed with 50 ml of the sample in a 250 ml flask. UV/VIS spectrophotometer was used to measure the absorbance at 420 nm. A series of standard ammonia solutions was prepared and treated likewise. From the absorbance values, the ammonia content in the sample was computed (APHA, 2005).

The actual concentration was obtained using the following formula;

$C = (A-B) \times FV \div SV$

Where C= Concentration, A= Sample reading, B= Blank reading, FV= Final Volume and SV= Sample Volume.

3.11.3 Colorimetric method for ammonia determination in soil and fertilizer samples

5.000 g of each sample was accurately weighed followed by addition of 5 cm^3 of hydrochloric acid and about 30 ml of distilled water and digested on the hot plate for approximately 30 minutes. It was cooled, filtered and neutralized using 1M NaOH solution and diluted to 50 ml using distilled water. This was then transferred into 100 ml water and 1ml of Nessler's reagent was added. The absorbance was measured using ultraviolet/visible spectrophotometer (T80+) at 420 nm (Figure 3.12). A series of standard ammonia solutions was prepared and treated likewise (APHA, 2005).

The actual concentration was obtained using the following formula;

$C = (A-B) \times FV \div SW$

Where C= Concentration, A= Sample reading, B= Blank reading, FV= Final Volume and SW= Sample Weight

3.11.4 Preparation of the ammonia calibration curve

The wavelength used was 420 nm, detection limit was 0.02 ppm. The standard concentrations and absorbance are shown in Table 3.4 and the calibration curve in Figure 3.11

Table 3.4 Concentration against absorbance for ammonia

Standard	Concentration (mg/L)	Absorbance
1	0.50	0.079
2	1.00	0.152
3	3.00	0.451
4	5.00	0.758

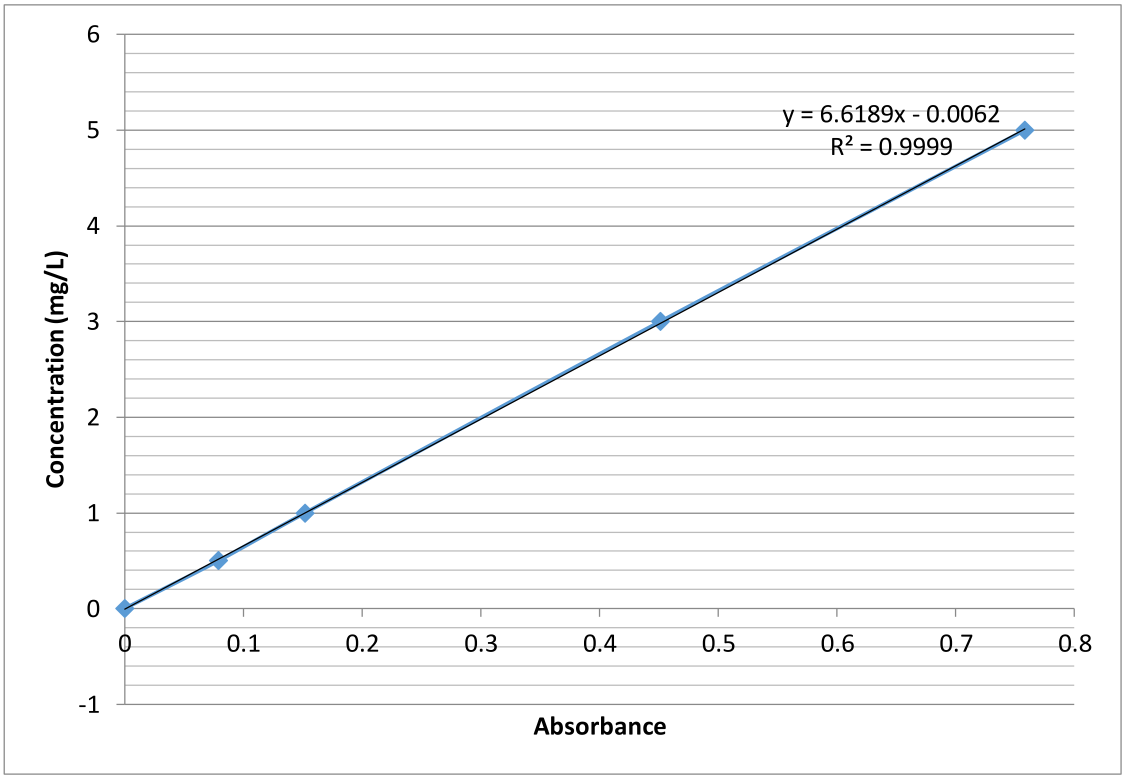


Figure 3.11 Ammonia calibration curve

Figure 3.12 Ultraviolet Visible Spectrophotometer (Model: T80+)

Figure 3.12 above shows UV/VIS spectrophotometer used in the determination of nitrate, phosphorus and ammonia concentration in all the samples.

3.12 Determination of fluoride in water, fertilizer and soil samples

3.12.1 Electrode method for fluoride determination in water

Fluoride was determined using ion selective electrode method. Apparatus used were Ion selective electrode meter with combined fluoride electrode. Stock fluoride solution was prepared using the following procedure; 221.0 mg of anhydrous NaF was dissolved in 1 liter of distilled water to make 100 mg/ml of fluoride. A series of standards solutions (1 ppm, 5 ppm and 10 ppm) were prepared from the stock fluoride solution. To 100 ml beaker, 25 ml of standard and an equal volume of buffer was added. The ion selective meter was calibrated using the prepared standards and the concentrations were read in mg/l. The determination was done after calibrating the meter.

25 ml of samples were measured into 100 ml beakers and a buffer solution of 25 ml was added. The electrode was frequently calibrated between sample measurements by checking the potential of any of the prepared standards and the calibration control was adjusted until the meter read as before (APHA, 2005).

3.12.2 Electrode method for fluoride determination in fertilizer and soil samples

For fertilizer and soil samples, 5.000 grams was accurately weighed accurately into a beaker. 5 ml of aquaragia and 30 ml of distilled water was added and digested for about 30 minutes in the hot plate. It was cooled, filtered, neutralized using 1 M sodium hydroxide and diluted to 50 ml using distilled water. 25 ml of this solution was transferred to 100 ml beaker and 25 ml of fluoride buffer solution was added and analyzed using Ion selective meter (APHA, 2005).

Figure 3.13 Ion selective meter (Model: Orion 290A)

Figure 3.13 above is the image of analyst operating Ion selective meter which was used in the analysis of pH and fluoride. The meter uses different electrodes depending on the type of analysis for example when analyzing fluoride, it requires fluoride electrode.

3.13 Determination of phosphorus in water, fertilizer and soil using Sulphuric acid-Nitric acid digestion method

Phosphorus solution: 4.258 g of A.R. di-ammonium hydrogen phosphate was dissolved in 1 liter of distilled water to make 1000 ppm phosphorus stock solution. 100 ppm was prepared from this solution and from 100 ppm a working standard of 1.00, 2.50, 5.00 and 10.00 ppm were prepared using $C_1V_1=C_2V_2$ serial dilution formula.

1 ml concentrated H_2SO_4 and 5 ml concentrated HNO_3 was mixed with 50 ml of each of the water samples and reduced to about 1 ml by heating on the hot plate. The sample was then cooled and approximately 20 ml distilled water and 0.05 ml phenolphthalein indicator solution (one drop) was added followed by 1N NaOH solution dropwise until a faint tinge color was produced and diluted to 100 ml with distilled water. The blank solutions were treated using the same procedure as samples. 10 ml each of the samples, blank and standard solutions were pippeted and transferred into 100 ml beakers followed by 10 ml of molybdivanadate solution and mixed while adding 25 ml of distilled water. It was then allowed to stand for at least 5 minutes. The solutions were analyzed at 430 nm wavelenght under a control of blank solution. This analysis was done using UV/VIS Spectrophotometer (APHA, 2005). The actual concentration was obtained using the following formula;

For soil samples 5 ml nitric acid and about 30 ml of distilled water was added to 5.000 grams of each sample and digested in the hot plate for approximately 30 minutes. It was then cooled and filtered into 250 ml beaker and 0.05 ml phenolphthalein indicator solution (one drop) was added and 1 N NaOH solution was added dropwise until a faint pink color was produced and diluted to 100 ml using distilled water. Blank solutions were treated using the same procedure as sample. 10 ml each of samples, blank and standard solutions were pippeted and transferred into 100 ml beakers followed by addition of 10 ml molybdivanadate solution and 25 ml of distilled to each sample while mixing. It was allowed stand for at least 5 minutes and finally analyzed using UV/VIS Spectrophometer at a wavelength of 430 nm (APHA, 2005).

Figure 3.14 Weighing balance

Figure 3.14 above is the image of weighing balance which was used in weighing of soil and fertilizer samples. The equipment was also used in gravimetric analysis of TSS and TDS.

3.13.1 Preparation of the phosphorus calibration curve

The wavelength used was 430 nm, detection limit was 0.02 ppm. The standard concentrations and absorbance are shown in Table 3.5 and the calibration curve in Figure 3.15

Table 3.5 Concentration against absorbance for phosphorus

Standard	Concentration (mg/L)	Absorbance
1	1.00	0.006
2	2.50	0.015
3	5.00	0.031
4	10.00	0.062

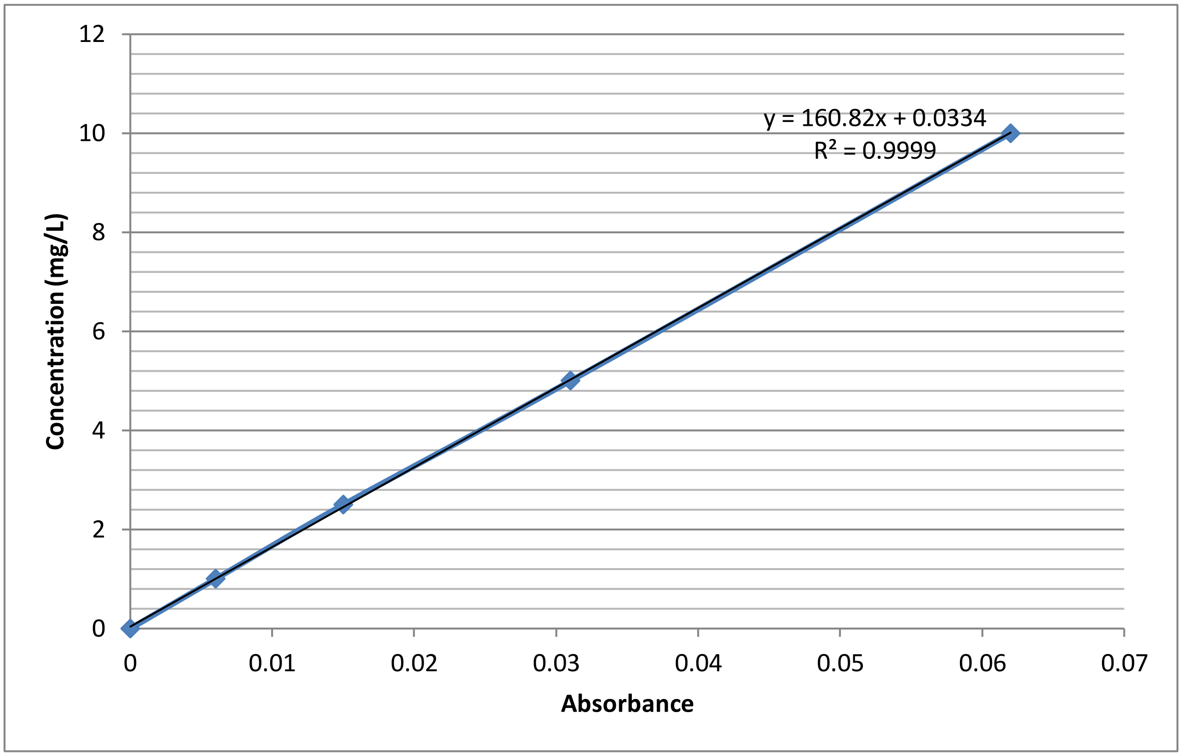


Figure 3.15 Phosphorus calibration curve

3.14 Determination of metals ions concentrations in water, soil and fertilizer samples

3.14.1 Preparation of water samples for metal ion analysis

The samples were first shaken well and a volume of 200 cm^3 of each sample was measured into 500 ml beakers using measuring cylinder. 5 ml of concentrated nitric acid was added and reduced in the hot plate to around 10 ml. It was cooled, filtered and washed thoroughly using warm distilled water and topped up to 50 ml (APHA, 2005). Finally, the samples were aspirated by AAS (Figure 3.14) at the different wave length (ƛ) specific for each metal ion and under the control using water as the blank.

3.14.2 Preparation of soil and fertilizer samples for metal ion analysis

30 ml of distilled water and 5 ml of aquaregia was added to 5.000 g of each sample and digested for about 30 minutes in the hot plate. It was cooled, filtered and washed thoroughly using warm distilled water and topped up to 50 ml (APHA, 2005). Finally, the samples were aspirated by AAS (Figure 3.14) at the different wave length (ƛ) specific for each metal ion and under the control using water as the blank.

3.14.3 Preparation of blanks for metal ion concentration analysis

Actual concentration of the blank samples was necessary for the calculation of the metal ion concentration in the water, soil and fertilizer samples. The concentration was determined by adding 5 ml of nitric acid to 200 ml of distilled water in 500 ml beakers and digested to almost dryness on a hot plate and filtered using 541 whatman filter papers and washed thoroughly with warm distilled water. The filtrate was allowed to cool and diluted to 50 ml (Mwamburi, 2003). The blanks were aspirated using AAS (Figure 3.16).

Figure 3.16 Atomic Absorption Spectrophotometer (Model: Spectra AA-10)

Figure 3.16 is the image of atomic absorption spectrophotometer which was used in the analysis of zinc, copper, lead, chromium and cadmium. It uses hollow cathode lamp as source of radiation, fuel used was acetylene gas and the type of atomizer used is flame atomizer.

3.14.4 Preparation of copper standards

1:1 HNO_3 was used to dissolve 1.000 g of copper metal strip and diluted to 1000 cm^3 using distilled water to make 1000 ppm copper stock solution. From 1000 ppm, 100 ppm solution was prepared followed by serial dilution to obtain the following working standards; 0.50, 1.00, 3.00 and 5.00 ppm. The standard solutions were aspirated by atomic absorption spectrometer model spectra AA-10.

3.14.5 Preparation of the copper ion calibration curve

Lamp current used was 3 mA, wavelength was 327 .4 nm, the slit width was 0.1 nm. The fuel used was acetylene and the oxidant was air, the detection limit was 0.003 ppm and sensitivity was 0.04 ppm. The calibration standards are given in Table 3.6 and the calibration curve in Figure 3.17

Table 3.6 Concentration and absorbance for copper

Standard	Concentration (mg/L)	Absorbance
1	0.50	0.032
2	1.00	0.066
3	3.00	0.199
4	5.00	0.331

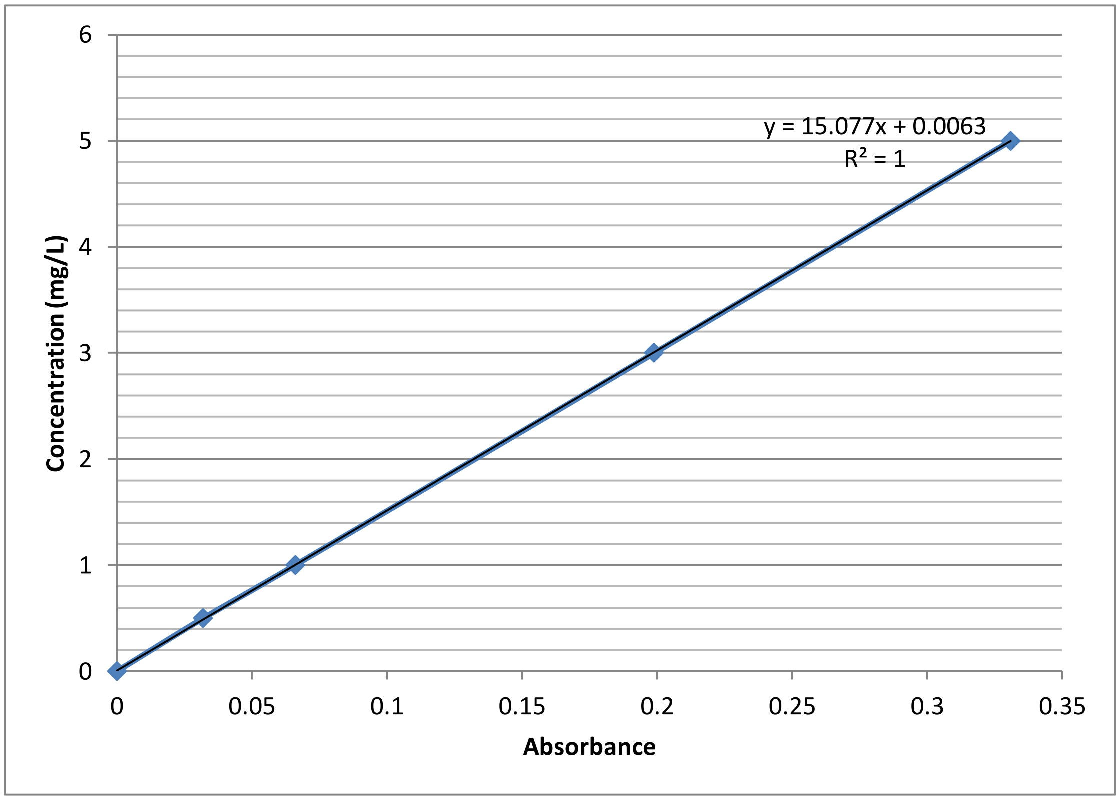


Figure 3.17 Copper calibration curve

3.14.6 Preparation of cadmium standards

1.000 g of cadmium metal strip was accurately weighed and then dissolves in 1:1 HNO_3 acid. It was then diluted using distilled water to a volume of 1000 ml to make 1000 ppm cadmium. From 1000 ppm, dilution was made to give 100 ppm. The following working standards were prepared by serial dilution; 0.50, 1.00, 1.50 and 2.00 ppm cadmium. The standard solutions were aspirated by atomic absorption spectrometer at wavelength (λ) value of 228.8 nm.

3.14.7 Preparation of the cadmium ion calibration curve

For cadmium analysis, the lamp current was 8 mA, 228.8 nm wavelength, and 0.5 nm slit width. The fuel used was acetylene and the oxidant is air, the detection limit was 0.006 ppm and sensitivity was 0.011 ppm. The calibration standards are given in Table 3.7 and the calibration curve in Figure 3.18.

Table 3.7 Concentrations and absorbance for cadmium

Standard	Concentration (mg/L)	Absorbance
1	0.50	0.050
2	1.00	0.098
3	1.50	0.147
4	2.00	0.196

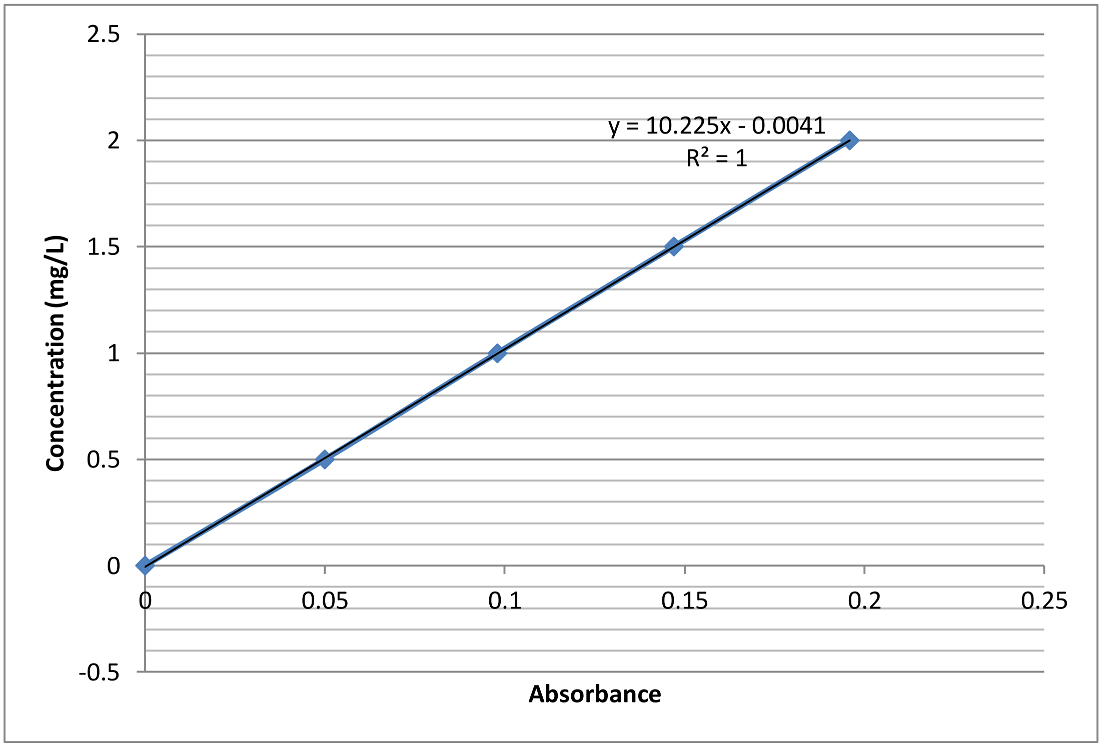


Figure 3.18 Cadmium calibration curve

3.14.8 Preparation of zinc standards

1.000 g of zinc granules was dissolved in 1:1 HNO_3 acid and thereafter diluted using distilled to 1000 ml using distilled water to make 1000 ppm zinc. The stock solution was diluted to 100 ppm and the following working standards were prepared by serial dilution; 0.50, 1.00, 3.00 and 5.00 ppm. The standard solutions were aspirated by atomic absorption spectrophotometer.

3.14.9 Preparation of the zinc ion calibration curve

The lamp current was 3 mA, wavelength was 213.9 nm, the slit width was 0.1 nm. The fuel used was acetylene and the oxidant is air, the detection limit was 0.002 ppm and sensitivity was 0.009 ppm. The calibration standards are given in Table 3.8 and the calibration curve in Figure 3.19

Table 3.8 Concentration and absorbance for zinc

Standard	Concentration (mg/L)	Absorbance
1	0.50	0.014
2	1.00	0.025
3	3.00	0.079
4	5.00	0.132

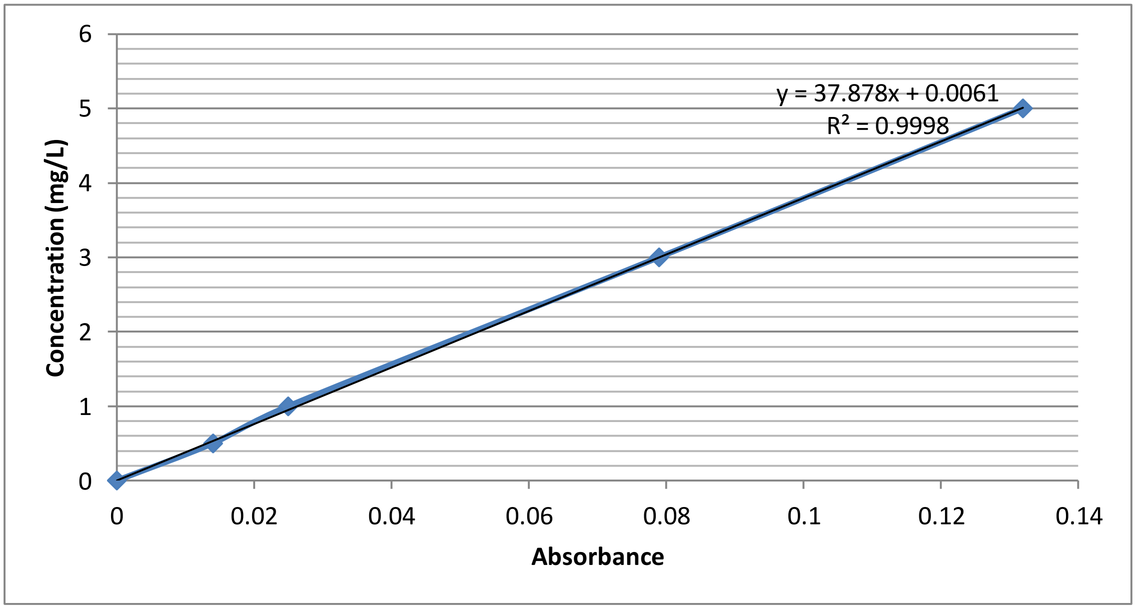


Figure 3.19 Zinc calibration curve

3.14.10 Preparation of lead standards

1.000 g of lead metal strip was dissolved in 1:1 HNO_3 acid then diluted 1000 ml using distilled water to make 1000 ppm lead. From 1000 ppm, dilution was made to give 100 ppm. Serial dilution was done to obtain the working standards with concentration of 0.50, 1.00, 2.50 and 5.00 ppm lead. The standard solutions were aspirated by atomic absorption spectrometer at wavelength (λ) value of 217.0 nm.

3.14.11 Preparation of the lead ion calibration curve

The lamp current was 5 mA, wavelength was 217.0 nm, the slit width was 1.0 nm. The fuel used was acetylene and the oxidant is air, the detection limit was 0.02 ppm and sensitivity was 0.11 ppm. The calibration standards are given in Table 3.9 and the calibration curve in Figure 3.20

Table 3.9 Concentration and absorbance for lead

Standard	Concentration (mg/L)	Absorbance
1	0.50	0.012
2	1.00	0.026
3	2.50	0.063
4	5.00	0.127

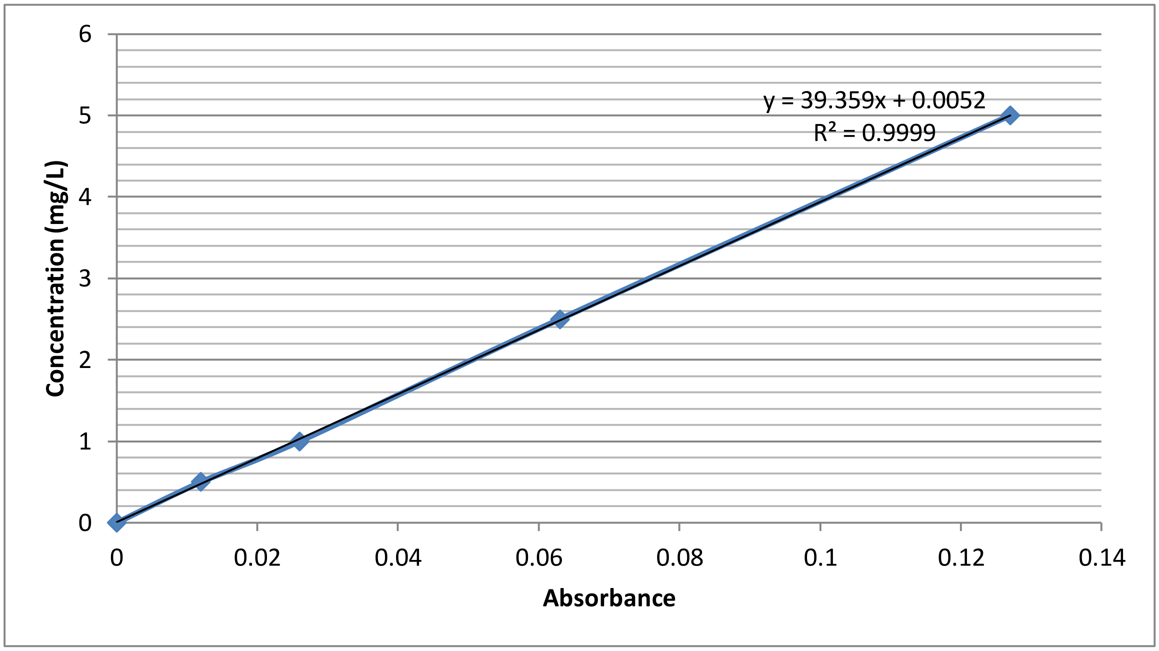


Figure 3.20 Lead calibration curve

3.14.12 Preparation of chromium standards

1.000 g of chromium metal was dissolved in 1:1 HCl acid and diluted to 1000 ppm using distilled water to make 1000 ppm chromium. The 1000 ppm solution was first diluted to 100 ppm followed by serial dilution to obtain the following working standards; 1.00, 2.50, 5.00 and 10.00 ppm. The standard solutions were aspirated by atomic absorption spectrometer.

3.14.13 Preparation of the chromium ion calibration curve

The lamp current used was 7 mA, wavelength was 357.9 nm, the slit width was 0.2 nm. The fuel used was acetylene and the oxidant is nitrous oxide, the detection limit was 0.005 ppm and sensitivity was 0.055 ppm. The calibration standards are given in Table 3.10 and the calibration curve in Figure 3.21

Table 3.10 Concentration and absorbance for chromium

Standard	Concentration (mg/L)	Absorbance
1	1.00	0.075
2	2.50	0.181
3	5.00	0.352
4	10.00	0.709

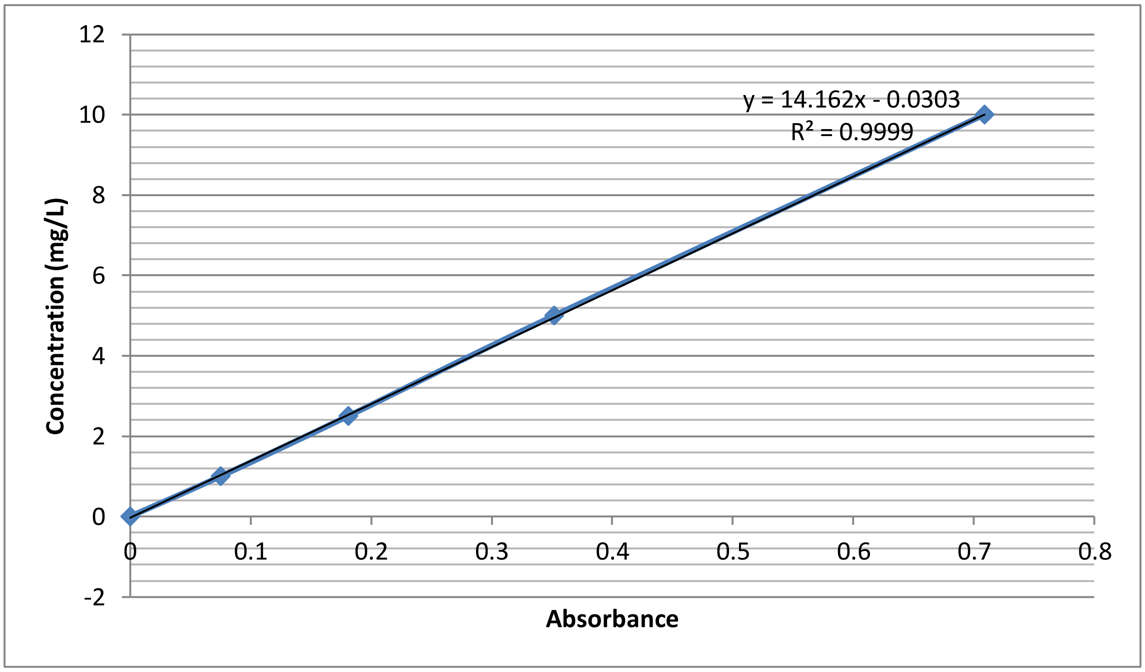


Figure 3.21 Chromium calibration curve

3.15 Determination of Soil texture

Soil texture was analyzed to indicate the extent of leaching from soil where the fertilizers are applied. Organic matter was analyzed by use of loss on ignition method where 20.00 g of soil sample was weighed, transferred into a crucible and heated at a temperature of 360℃ in a furnace for 1 hour and allowed cool. The weight was recorded and the % organic matter was obtained using the following formula;

$$\frac{B-C}{B-A} \times 100\ \%$$

Where A is mass of empty crucible, B is mass of crucible and sample before heating and C is mass of crucible + sample after heating (Heiri *et al.*, 2001; Santisteban *et al.*, 2004).

The soil texture was analyzed using the following procedure; 20.00 g of soil sample was measured into 100 ml measuring cylinder followed by addition of 70 ml distilled water. It was then shaken for 5 min and allowed to settle for 24 hours. The total volume of the mixture of water and soil was recorded and labeled as total depth. The sample was shaken for five minutes and allowed to stand for 30 seconds which enabled sand to settle. The depth of the settle soil was measured and labeled as sand depth. It was then let to stand for another 30 minutes and the depth was measured by subtracting the sand depth and labeled as silt depth. The sample was shaken for 5 minutes and after standing for 3 hours the unsettle particles depth was measured and labelled as clay depth. The total percentage of each soil texture was calculated as follows:

$\% S = (SD \div TD) \times 100$

$\% S1 = (SD1 \div TD) \times 100$

$\% C = (CD \div TD) \times 100$

Where: S= Sand, S1= Silt, C= Clay SD= Sand depth, SD1= Silt depth, CD= Clay depth, TD= Total depth

The textural class of the soil was determined using soil texture triangle. Figure 3.22 shows soil texture triangle.

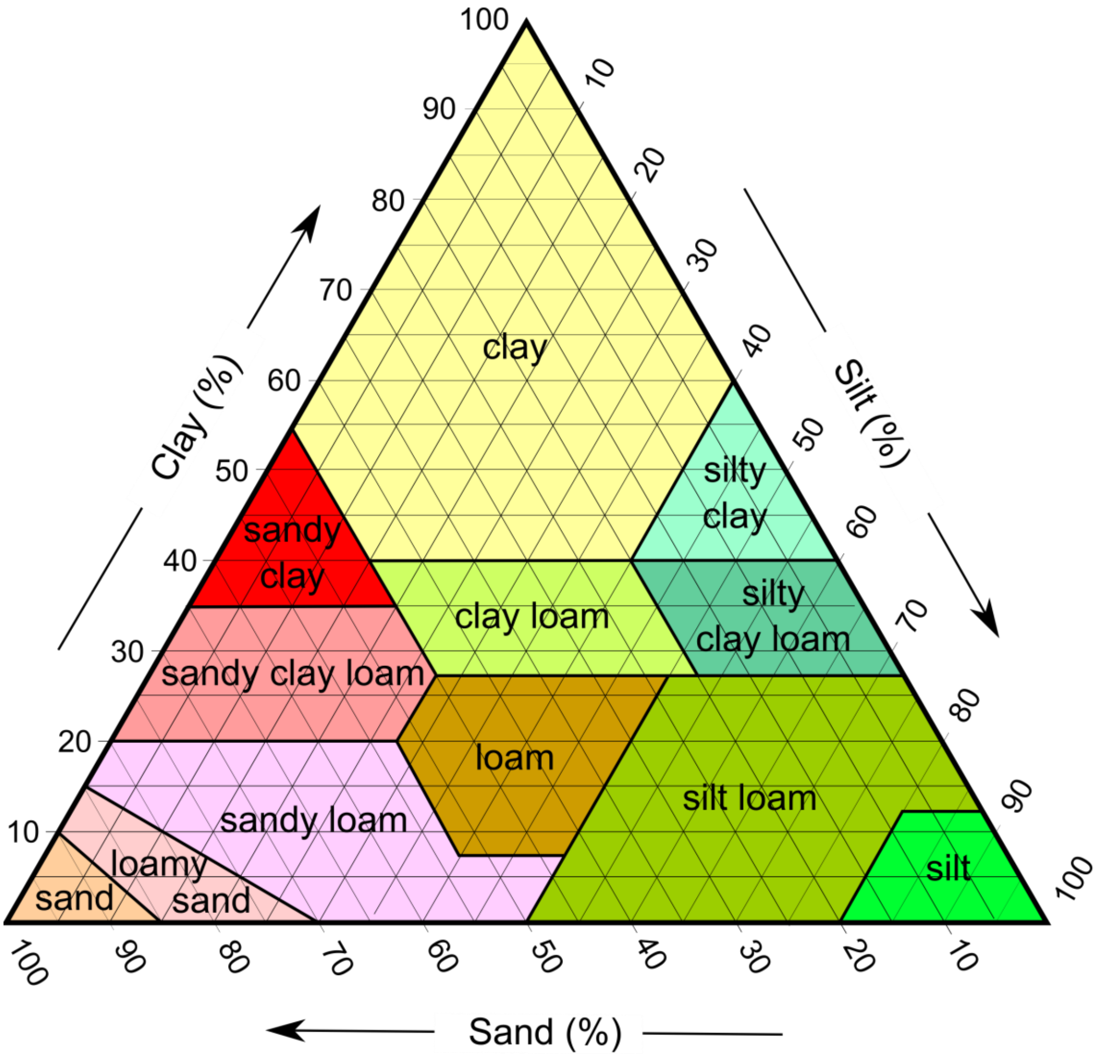


Figure 3.22 Soil texture triangle (USDA, 2018).

Source: (Christopher Aragon, 2018).

3.16 Statistical Analysis

Statistical Package for the Social Science (SPSS Inc., Chicago IL, USA) was applied for determination of Pearson's correlation coefficients which have numerical values (r) ranging between -1 and +1. Direct relationship is indicated by positive values in variables while negative values indicate inverse variation relationship. The strength of linear correlation of the variables is determined by the numerical value of r, whereby zero values implies no correlation between the data sets below 0.5 are considered weak, while those above 0.5 are strong. The significance of the correlations is indicated by the p value. Correlations are significant if p< 0.05 and are not significant if p>0.05 (APA, 2001). Analysis was carried out at the significant level of p= 0.05.

Results obtained was represented by use of standard deviation, text, graphs and statistical tables to show the interrelationships of various variables such as fluoride, nitrate, ammonia, TDS, TSS, phosphorus and selected heavy metals.

CHAPTER FOUR

4.0 Results and Discussions

4.1 Seasonal variation of the selected parameters in Earth dam water samples

Table 4.1.1 shows the seasonal variations of the selected parameter in the six selected Earth Dams in Chepalungu Sub-County.

Section 4.1.1 to 4.1.7 covers the parameters; pH, TDS, TSS, NO_3^-, NH_3, F^-, and P respectively. While Cu, Cd, Zn, Pb and Cr are covered in sections 4.1.8 to 4.1.12 in that order. The data presented were processed from Appendix A

Table 4.1.1 Seasonal variations in water from six earth dams in Chepalungu Sub-County

Parameter/Dam	Birir		Cheboloigo		Kamogiboi		Sogororbei		Kaposur		Kapewot	
	Dry	wet	Dry	Wet	Dry	wet	Dry	wet	Dry	wet	Dry	wet
pH	8.41±0.10	7.49±0.03	7.60±0.10	7.57±0.01	8.11±0.01	7.44±0.02	8.23±0.03	7.36±0.04	7.50±0.01	7.48±0.08	7.42±0.03	7.49±0.01
TDS	112.20±1.44	95.10±3.97	184.90±1.03	154.50±3.42	110.70±1.33	103.70±4.02	99.40±0.80	95.90±1.03	108.70±0.64	87.90±2.9	132.00±0.72	99.30±4.31
TSS	11.60±1.11	90.70±7.89	21.30±3.08	71.60±3.40	8.91±0.64	16.60±4.44	25.60±2.46	120.20±9.63	36.20±1.40	175.90±4.91	13.30±1.33	26.10±3.61
Nitrate	7.26±0.01	5.45±0.23	4.79±0.01	4.11±0.12	4.44±0.02	2.71±0.03	5.68±0.01	3.35±0.20	5.51±0.01	5.42±0.06	11.50±0.02	6.75±0.08
Ammmonia	0.34±0.02	0.37±0.01	0.13±0.02	0.15±0.06	0.28±0.01	0.19±0.02	0.32±0.01	0.15±0.04	0.55±0.04	0.54±0.01	0.46±0.05	0.50±0.01
Fluoride	4.26±0.01	5.33±0.05	2.53±0.02	3.09±0.06	3.31±0.04	3.72±0.07	3.10±0.05	4.61±0.04	1.42±0.02	2.38±0.05	1.25±0.03	1.67±0.04
phosphorus	2.44±0.01	2.37±0.03	1.23±0.01	1.11±0.04	1.02±0.02	0.91±0.05	6.26±0.01	5.85±0.08	0.61±0.04	0.62±0.06	0.80±0.04	0.71±0.03
Copper	0.29±0.01	0.14±0.02	0.46±0.02	<0.00	0.23±0.07	0.22±0.03	0.17±0.02	<0.00	0.25±0.03	<0.00	0.89±0.03	<0.00
Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	<0.00	0.45±0.03	1.89±0.03	1.38±0.09	0.12±0.03	0.26±0.02	0.08±0.01	1.12±0.06	3.59±0.05	0.41±0.04	4.92±0.04	0.07±0.01
Lead	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.87±0.04	<0.02
Chromium	<0.01	<0.01	0.46±0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.98±0.05	<0.01

Note: all the results are express in mg/L except pH, < indicates ‘less than

4.1.1 pH

From Figure 4.1.1 below, water pH values were in the range of 7.42±0.027 to 8.41±0.01 in dry season and 7.36±0.04 to 7.57±0.01 in the wet season which were within the recommended range by WHO (2011). The lowest pH value 7.42±0.027 was obtained from water from Kapewot earth dam and the highest 8.41±0.01 from Birir earth dam respectively in dry season. During wet season, the lowest pH value 7.36±0.04 was obtained at Sogororbei earth dam and the highest at 7.57±0.01 at Cheboloigo earth dam respectively. The pH levels during wet season were lower than during dry season for Birir, Cheboloigo, Kamogiboi, Sogororbei and Kaposur earth dams this was because during wet season the materials applied during farming including fertilizers were carried into the dams by rain water thereby decreasing the pH level while in Kapewot dam, the level was higher during wet season than during dry season this was because Kapewot earth dam was located near a busy shopping center where there was activities which during wet season the acid were carried into dams by rain water thereby decreasing the pH level.

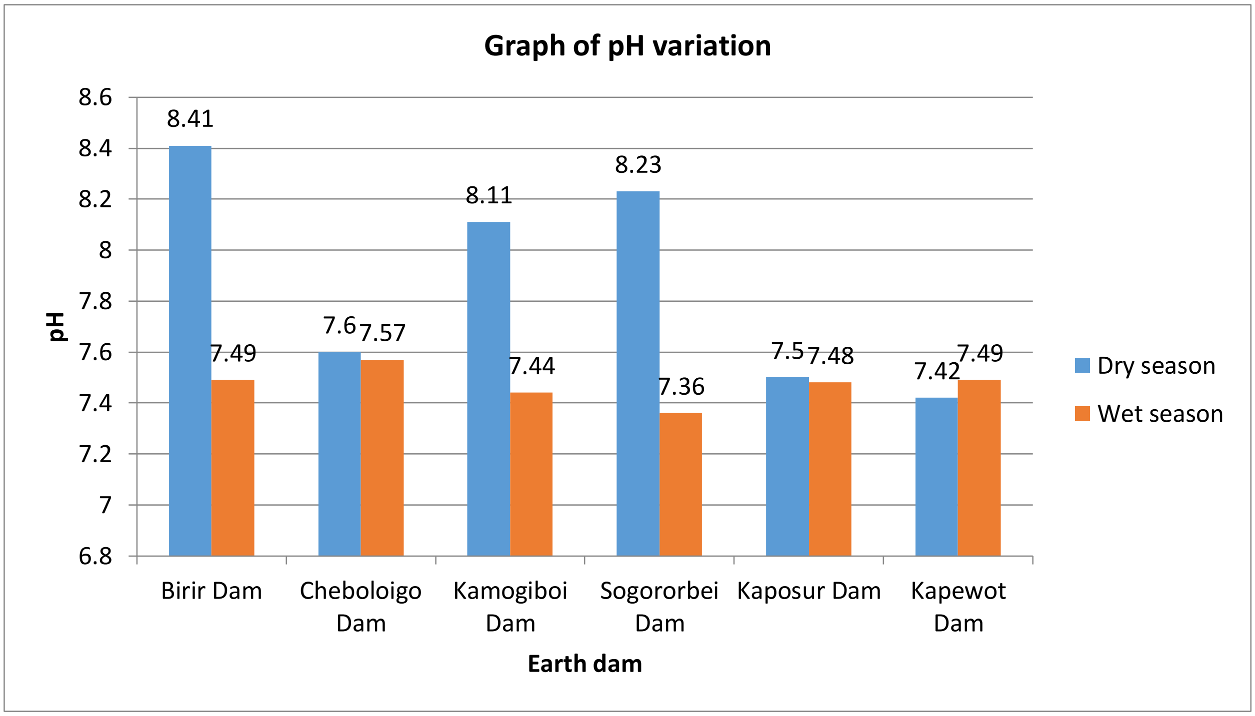


Figure 4.1.1 Variation of pH during dry and wet seasons.

4.1.2 TDS

TDS was higher (184.9±1.03) mg/L in Cheboloigo earth dam than the other studied earth dams during both the dry and wet seasons (Table 4.1.1); the levels during dry season were higher than during wet season. TDS values obtained in all earth dams were much lower than the maximum recommended level by WHO (2011) for both seasons (Table 4.1.1.). The comparison is shown in Figure 4.1.2 below.

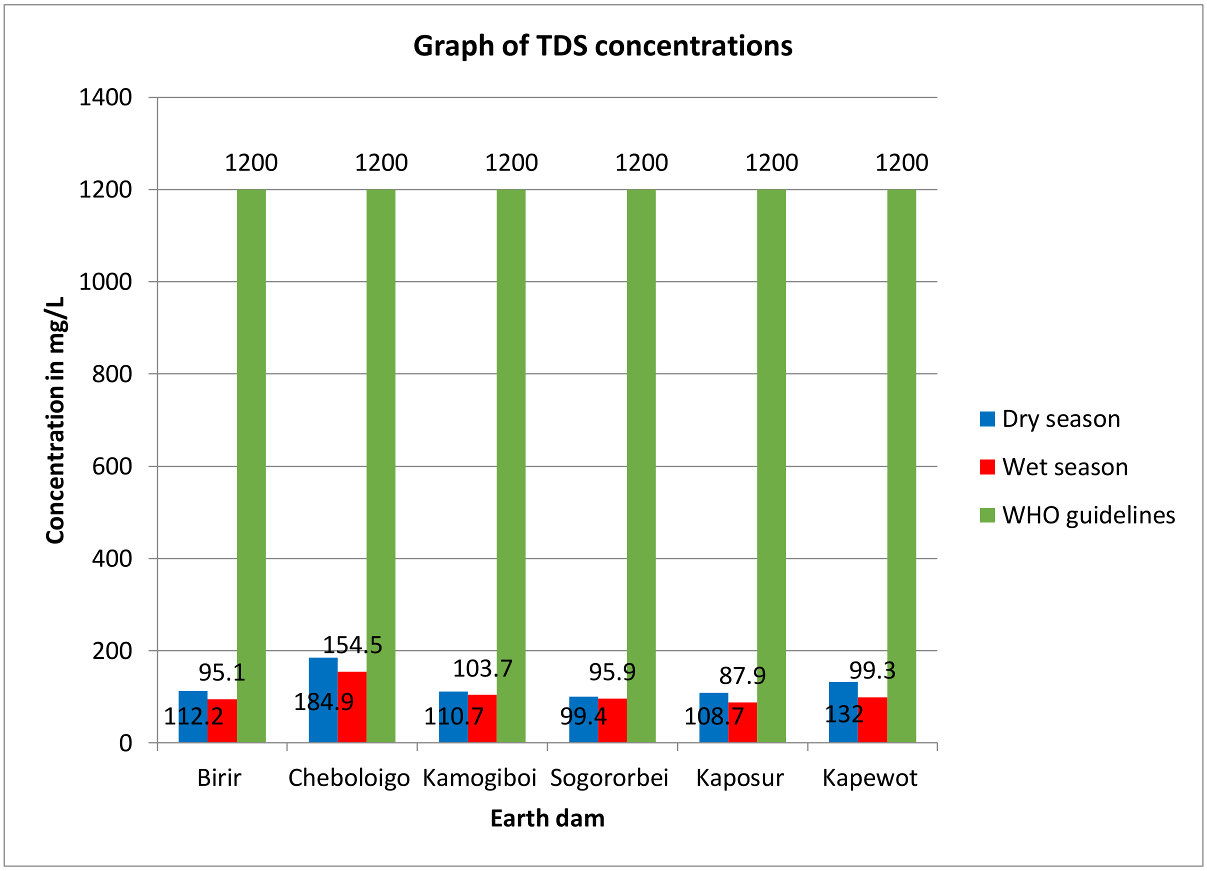


Figure 4.1.2 Total Dissolved Solids concentrations during dry and wet seasons compared to WHO (2011) drinking water guidelines.

4.1.3 TSS

The levels of TSS were higher during wet season than during dry season for all the earth dams studied. The levels were higher than the maximum recommended value by WHO (2011) in all earth dams except for Kamogiboi and Kapewot. The highest being that of Kaposur earth dam with a concentration of 175.9 mg/L during wet season while the lowest concentration was that of Kamogiboi earth dam with a concentration of 8.91 mg/L during dry season as shown in Figure 4.1.3

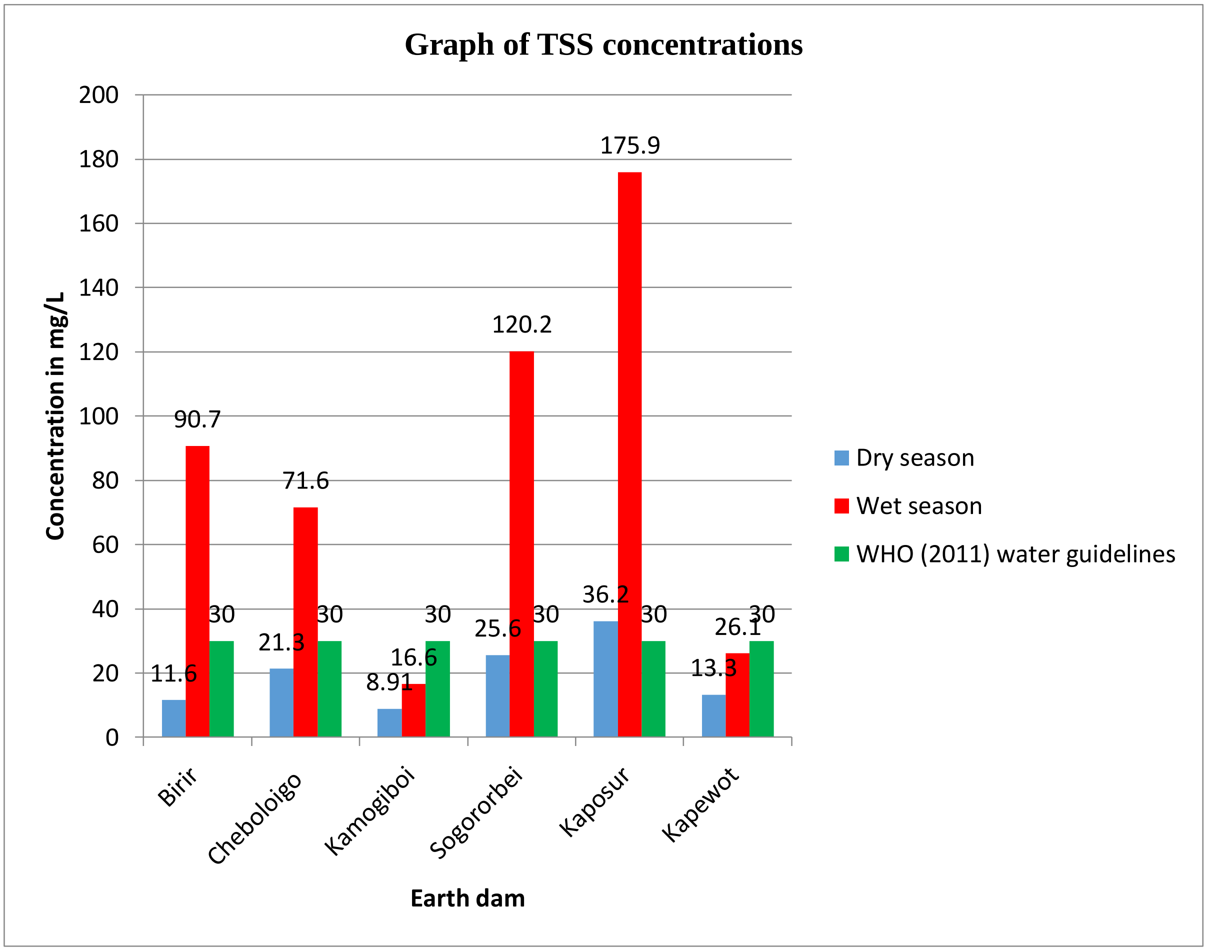


Figure 4.1.3 Total Suspended Solids concentrations during dry and wet seasons compared to WHO (2011) drinking water guideline.

4.1.4 Nitrate

Nitrate levels were below the maximum recommended water guidelines level by World Health Organization (50 mg/L) in all the six selected earth dams. The levels of nitrate were lower during wet season than during dry season in all earth dams. This was because nitrate was diluted during wet season but during dry season nitrate were concentrated as a results of evaporation of water. Kapewot earth dam had the highest nitrate levels 11.50±0.02 mg/L and 6.75±0.08 mg/L during dry and wet seasons respectively followed by Birir earth dam with 7.26±0.01 and 5.45±0.23 mg/L during dry and wet seasons respectively. Kamogiboi earth dam had the lowest nitrate level 4.44±0.02 mg/L and 2.71±0.03 mg/L during dry and wet seasons respectively. Figure 4.1.4 below shows the comparison of nitrate concentrations (mg/L) in earth dam water samples during dry and wet seasons with WHO (2011) drinking water guideline.

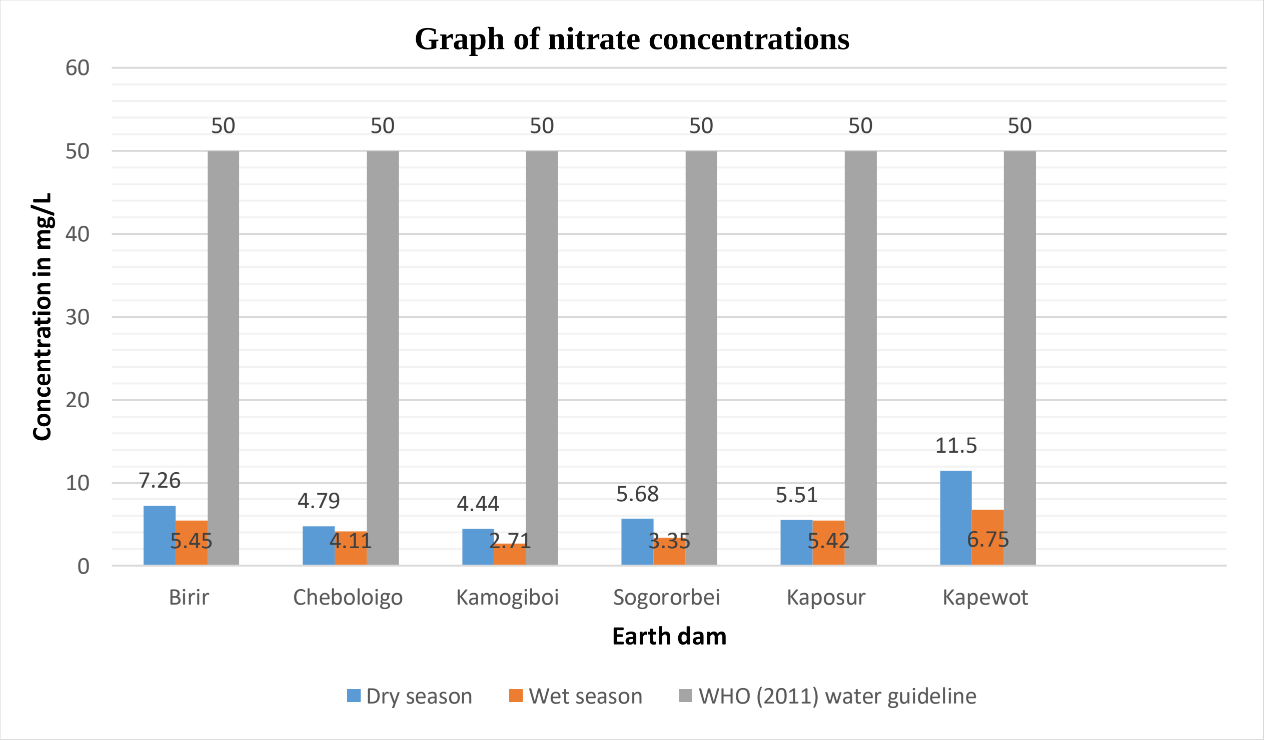


Figure 4.1.4 Comparison of nitrate concentrations during dry and wet seasons with the WHO (2011) drinking water guideline.

4.1.5 Ammonia

The levels of ammonia in all earth dams were below the maximum recommended level by World Health Organization except Kaposur earth dam which had a concentration of 0.55±0.04 mg/L and 0.54±0.01 mg/L during dry and wet seasons respectively. Kaposur earth dam had the highest level of ammonia concentration followed by Kapewot earth dam. The earth dam with the lowest ammonia level was Cheboloigo earth dam which had ammonia concentration of 0.13±0.02 mg/L and 0.15±0.06 mg/L during dry and wet seasons respectively. Birir earth dam, Cheboloigo earth dam and Kapewot earth dam had high concentrations during wet season than during dry season but Kamogiboi earth dam, Sogororbei earth dam and Kaposur earth dam had high ammonia concentrations during dry season than during wet season this was due to dilution of ammonia during wet season. Figure 4.1.5 below shows the comparison of ammonia concentrations (mg/L) in earth dam water samples during dry and wet seasons with WHO (2011) drinking water guideline.

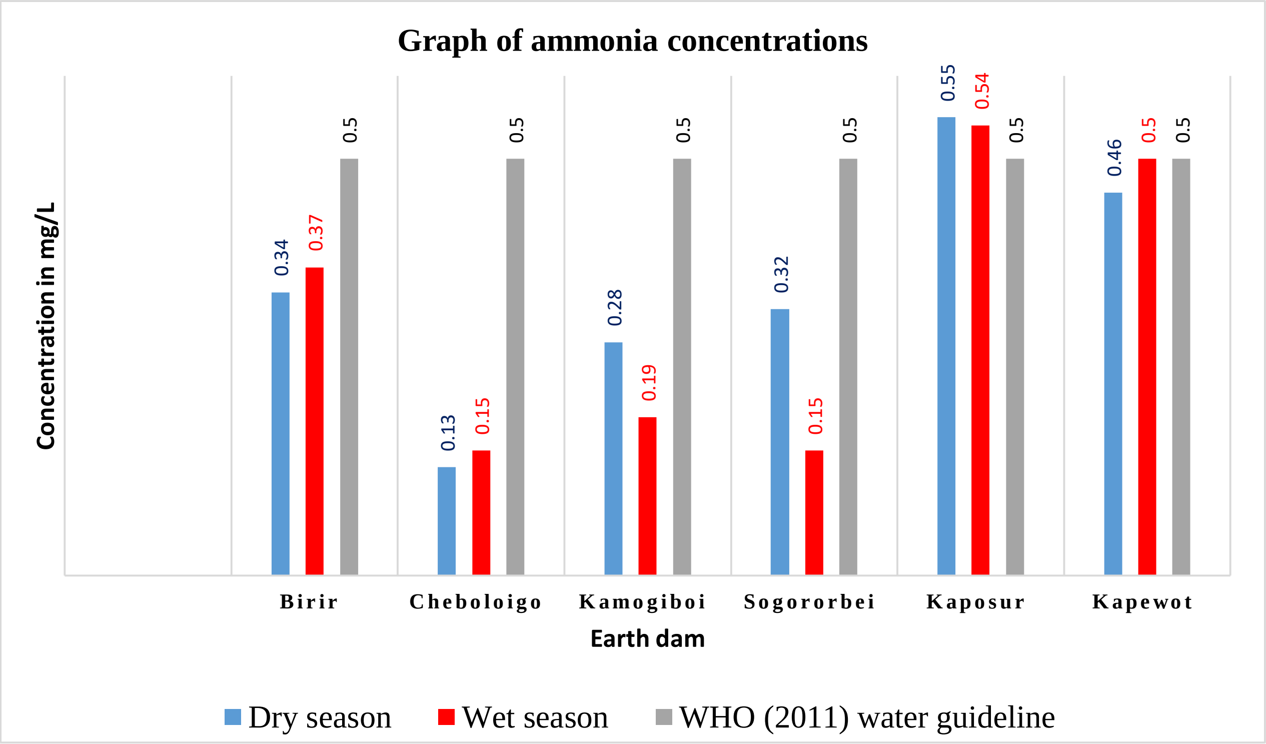


Figure 4.1.5 Comparison of ammonia concentrations during dry and wet seasons with the WHO (2011) drinking water guideline.

4.1.6 Fluoride

The levels of fluoride were higher during wet season than during dry season in all studied earth dams. This was because the fluoride present in soil were washed into the earth dam water thereby increasing its concentration. Birir earth dam had the highest fluoride concentration compared to other studied earth dams with concentration of 4.26 ±0.06 mg/L during dry season and 5.33±0.05 mg/L during wet season. Kapewot earth dam had the lowest concentration of 1.25±0.031 mg/L during dry season and 1.67± 0.24 mg/L during wet season (Table 4.1.1). All the samples showed higher fluoride levels than the WHO (2011) recommend levels for drinking water (Table 2.1) except Kapewot earth dam and Kaposur earth dam. Figure 4.1.6 show the comparison of fluoride concentrations (mg/L) in earth dams water samples during dry and wet seasons with WHO (2011) drinking water guideline.

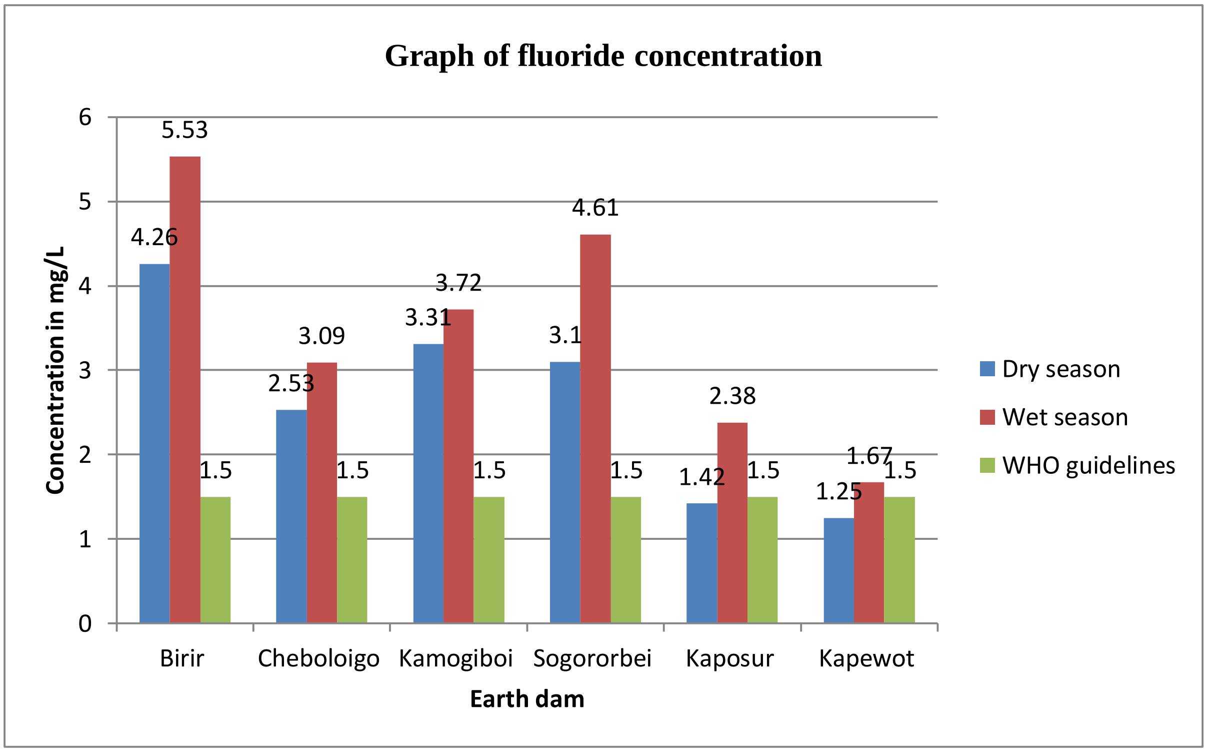


Figure 4.1.6 Comparison of fluoride concentrations during dry and wet seasons with WHO (2011) drinking water guideline.

4.1.7 Phosphorus

Sogororbei earth dam had the highest level of phosphorus of 6.26±0.01 mg/L and 5.85±0.08 mg/L during dry and wet seasons respectively followed by Birir earth dam with a concentration of 2.44±0.01 mg/L and 2.37±0.03 mg/L during dry and wet seasons respectively. The earth dam with the lowest phosphorus level was Kaposur earth dam with concentration of 0.61±0.04 mg/L and 0.62±0.06 mg/L during dry and wet seasons respectively. During dry season the level of phosphorus in all earth dams were higher than during wet season except Kaposur earth dam which had concentration of 0.61±0.04 mg/L during dry season and 0.62±0.06 mg/L during wet season. Figure 4.1.7 below show the comparison of phosphorus concentrations (mg/L) in earth dam water samples during dry and wet seasons.

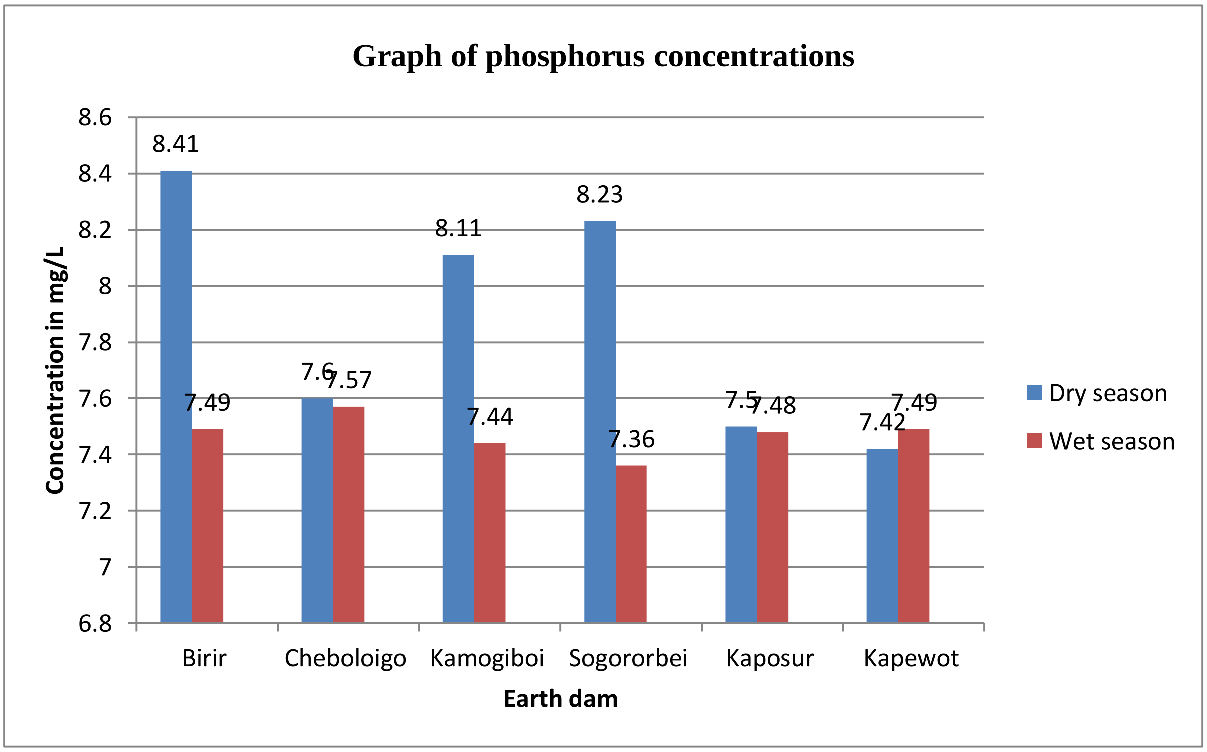


Figure 4.1.7 Comparison of phosphorus concentrations in mg/L during dry and wet seasons.

4.2 Seasonal Variations of Heavy Metals in Earth Dams

4.2.1 Copper

The levels of copper ions concentration in all earth dams were below the maximum recommended levels of 2 mg/L by WHO (2011). Kapewot had the highest level of copper concentration of 0.89±0.04 mg/L during dry season followed by Cheboloigo earth dam with a copper concentration of 0.46±0.02 mg/L. During wet season the levels of copper in all earth dams were below 0.003 mg/L except Kamogiboi earth dam with a concentration of 0.22±0.03 mg/L and Birir earth dam with concentration of 0.14±0.02 mg/L. In all earth dams, the levels of copper concentrations were higher during dry season than during wet season. This was because during wet season copper ions were diluted. Figure 4.2.1 show the comparison of copper concentrations (mg/L) in earth dam water samples during dry and wet seasons with the WHO (2011) drinking water guidelines.

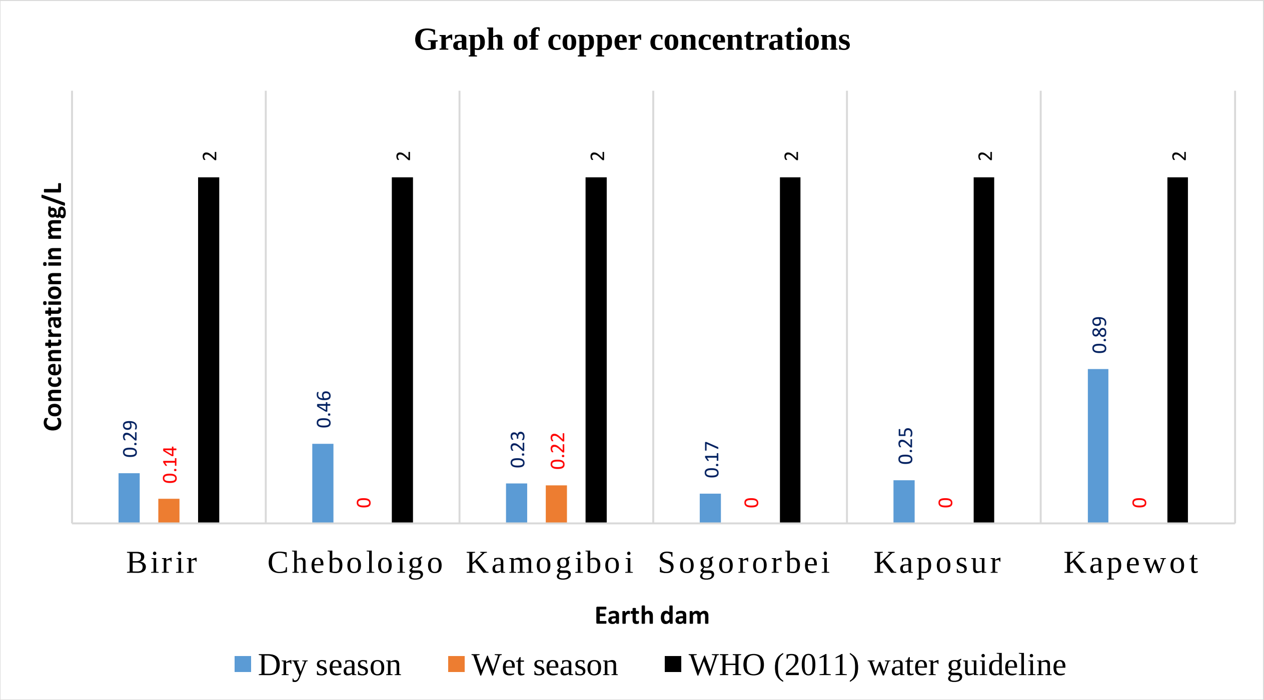


Figure 4.2.1 Comparison of copper concentrations during dry and wet seasons with the WHO (2011) drinking water guideline.

4.2.2 Cadmium

The levels of cadmium in all the dams were below detection limit during both seasons. The levels of cadmium were below the maximum recommended level by WHO (2011). Figure 4.2.2 below show the comparison of cadmium concentrations (mg/L) in dam water samples during both seasons with the maximum recommended value by WHO (2011).

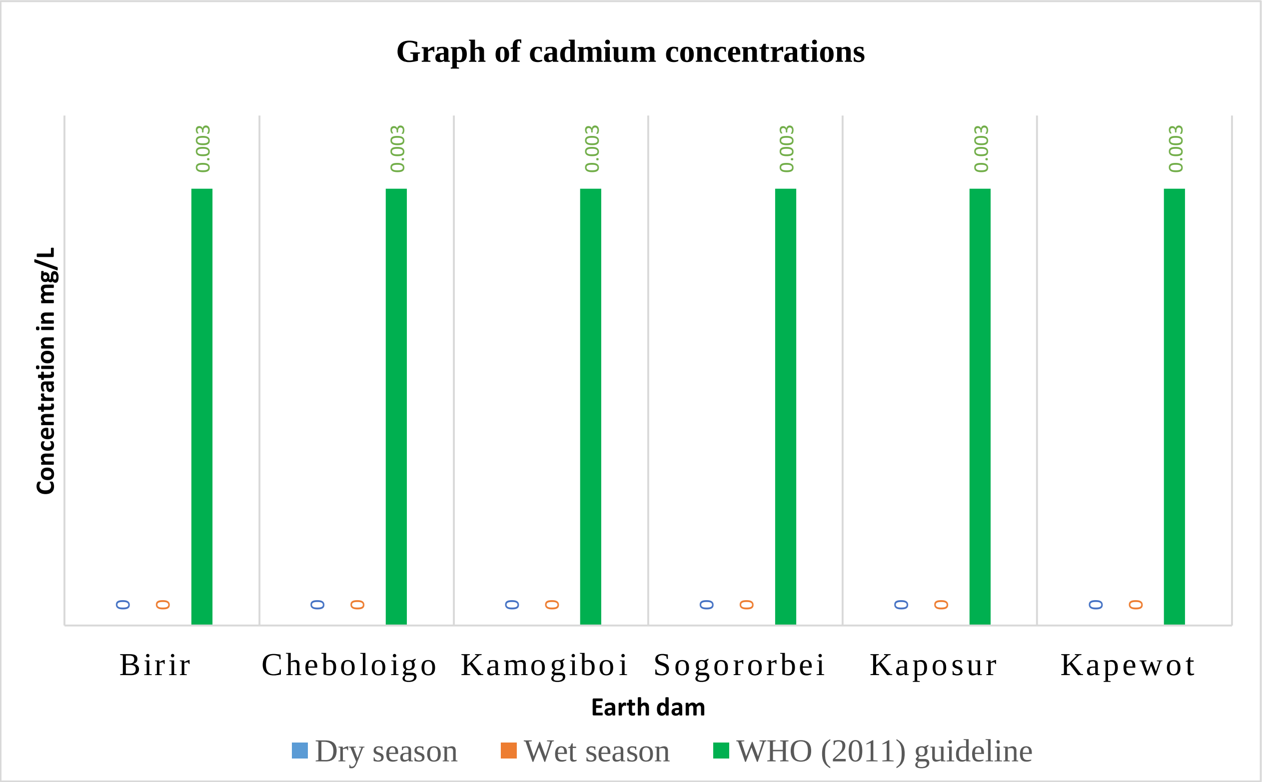


Figure 4.2.2 Comparison of cadmium concentrations during dry and wet seasons with the WHO (2011) drinking water guideline.

4.2.3 Zinc

The levels of zinc in all earth dams were below the maximum recommended level by World Health Organization of 3 mg/L. Kapewot earth dam had the highest level of zinc ions with a concentration of 4.92±0.04 mg/L during dry season followed by Kaposur earth dam with a concentration of 3.59±0.05 mg/L during dry season. Birir earth dam had the lowest level of zinc with a concentration of <0.002 mg/L during dry season. Cheboloigo earth dam, Kaposur earth dam and Kapewot earth dam had higher concentration during dry season than during wet season while Birir earth dam, Kamogiboi earth dam and Sogororbei earth dam had high concentration of zinc during wet season than during dry season. Figure 4.2.3 show the comparison of zinc concentrations (mg/L) in earth dam water samples during dry and wet seasons compared with the WHO (2011) drinking water guidelines.

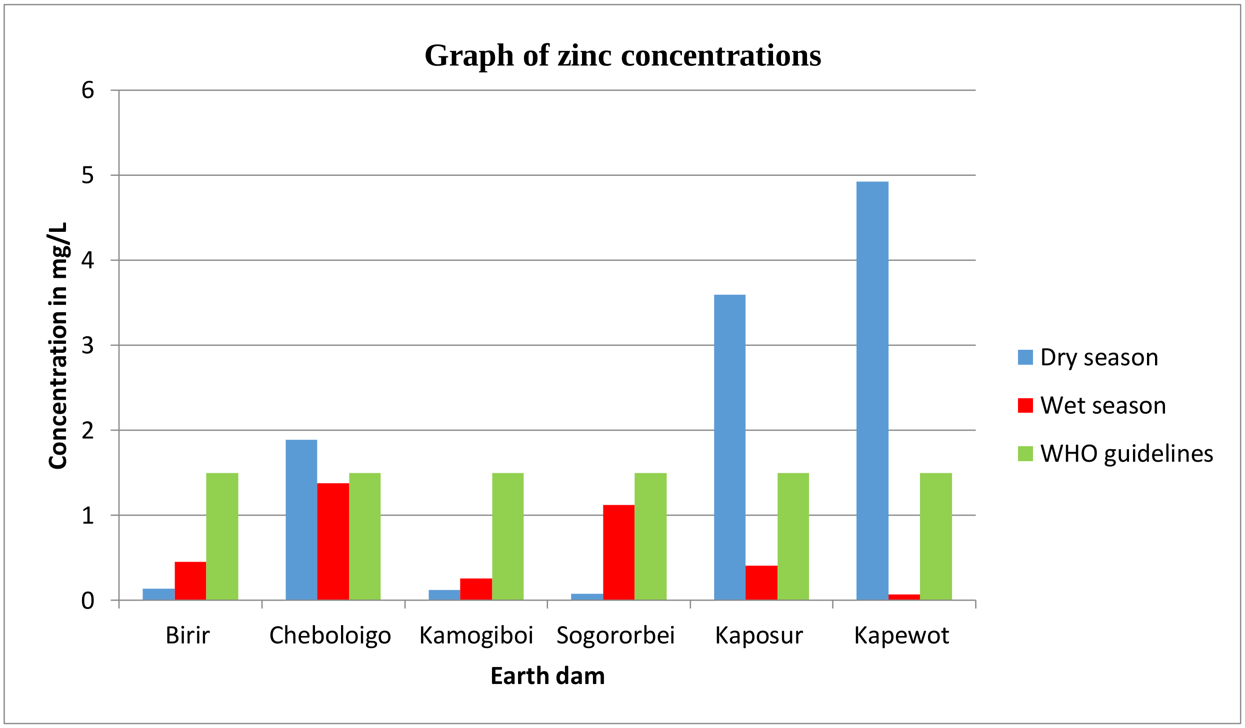


Figure 4.2.3 Comparison of zinc concentrations during dry and wet seasons with the WHO 2011 drinking water guidelines.

4.2.4 Lead

The levels of lead in all the earth dams were below 0.02 mg/L except for Kapewot dam which had a concentration of 0.87±0.04 mg/L during dry season which was above the maximum recommended level by World Health Organization. Figure 4.2.4 below show the comparison of lead concentrations (mg/L) in earth dam water samples during dry and wet seasons with the WHO (2011) drinking water guideline.

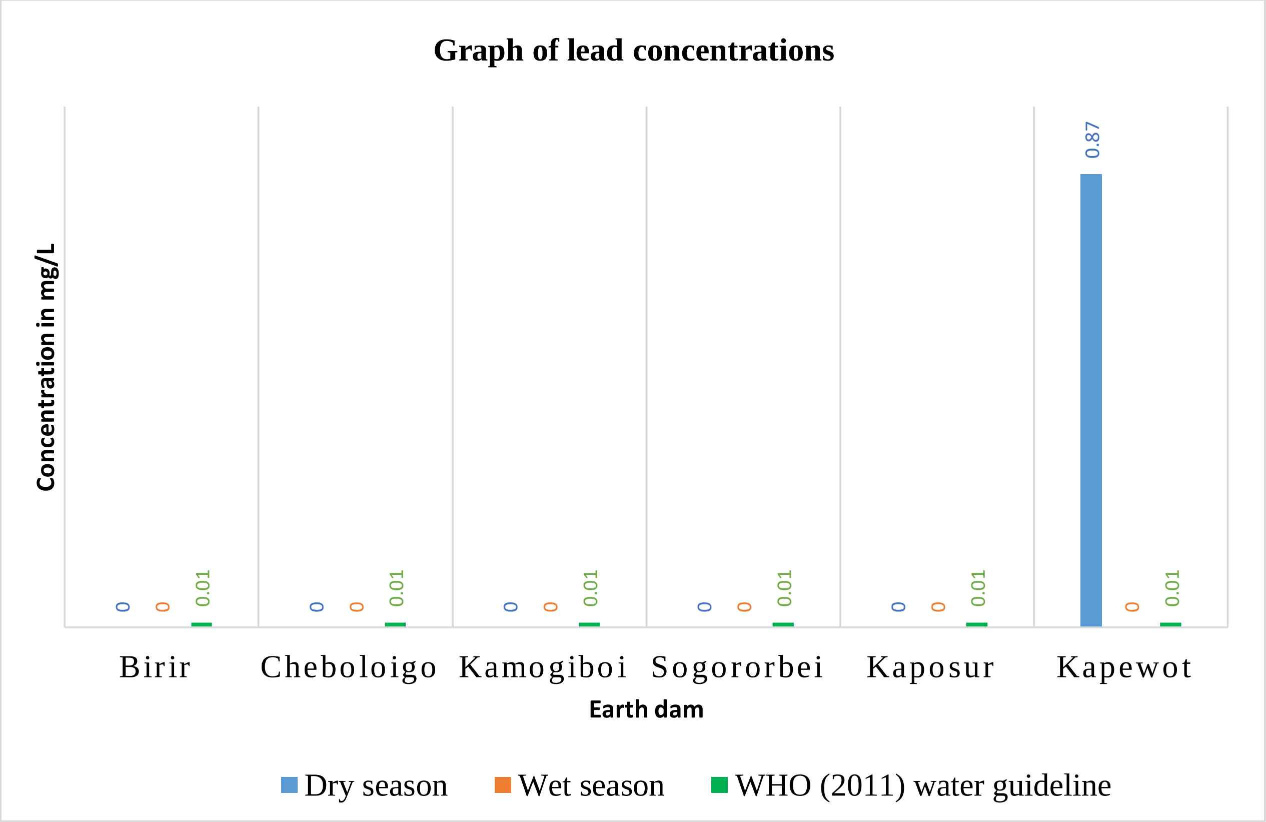


Figure 4.2.4 Comparison of lead concentrations during dry and wet seasons with the WHO (2011) drinking water guidelines.

4.2.5 Chromium

The levels of chromium in all the dams were below 0.005 mg/L except Cheboloigo earth dam and Kapewot earth dam during dry season with a concentration of 0.46±0.06 mg/L and 1.98±0.05 mg/L respectively which were higher than the maximum recommended level of 0.05 mg/L by World Health Organization. Figure 4.2.5 below show the comparison of chromium concentrations (mg/L) in earth dam water samples during dry and wet seasons with the WHO (2011) drinking water guideline.

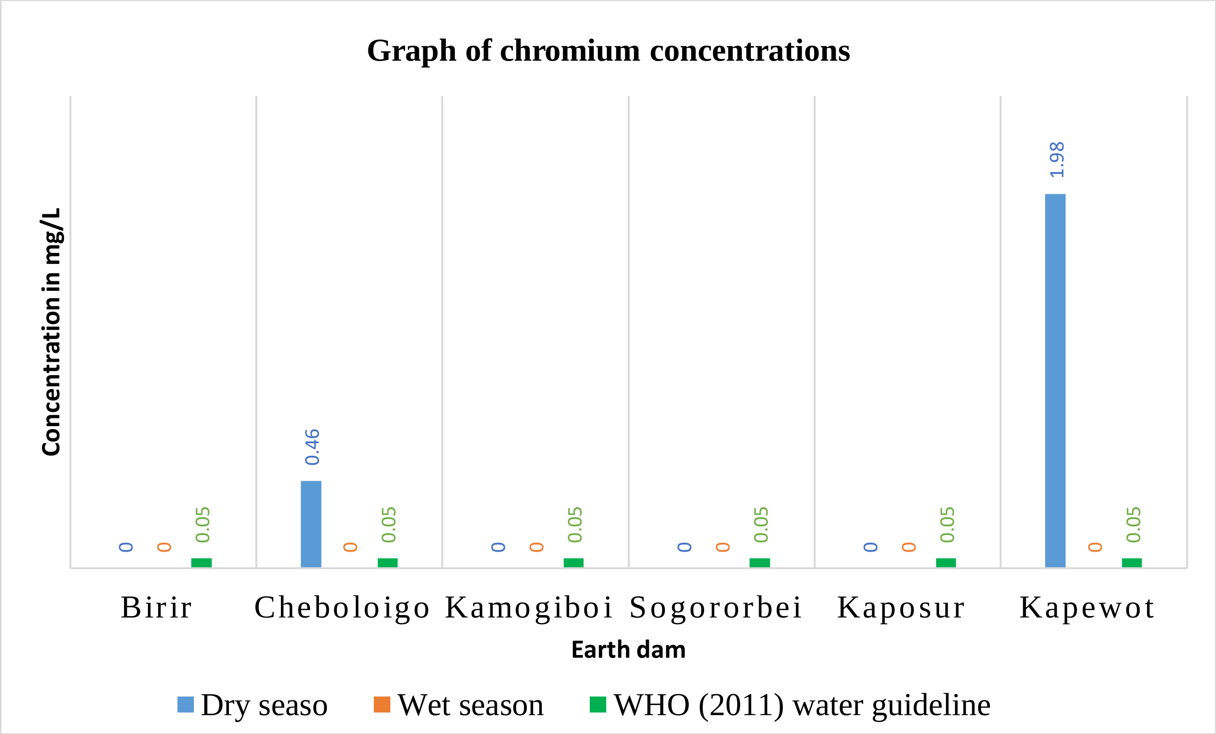


Figure 4.2.5 Comparison of chromium concentrations during dry and wet seasons with WHO (2011) drinking water guidelines.

4.3 Overall Mean Seasonal Variation for all Earth Dams

Table 4.3.1 shows the range and mean of selected parameters in water from all earth dams.

Table 4.3.1 Mean Seasonal Variation for all Earth Dams

Parameters	Mean ± SD		Range	
	Dry season	Wet season	Dry season	Wet season
pH	7.88±0.42	7.47±0.07	7.42 to 8.41	7.36 to 7.57
TDS	124.65±31.39	106.07±24.29	99.40 to 184.90	87.90 to 154.50
TSS	19.49±10.31	83.52±59.75	8.91 to 36.20	16.60 to 175.90
Nitrate	6.53±2.62	4.63±1.51	4.44 to 11.50	2.71 to 6.75
Ammmonia	0.35±0.15	0.32±0.18	0.13 to 0.55	0.15 to 0.54
Fluoride	2.65±1.16	3.47±1.37	1.25 to 4.26	1.67 to 5.33
Phosphorus	2.06±2.16	1.93±2.02	0.61 to 6.26	0.62 to 5.85
Copper	0.38±0.22	0.06±0.10	0.17 to 0.89	<0.003 to 0.22
Cadmium	<0.006	<0.006	<0.006	<0.006
Zinc	1.77±2.10	0.62±0.52	<0.002 to 4.92	0.07 to 1.38
Lead	0.16±0.36	<0.02	<0.02 to 0.87	<0.02
Chromium	0.41±0.79	<0.005	<0.005 to 1.98	<0.005

NB: All results are expressed in mg/L except pH.

From table 4.3.1 above, pH ranged from 7.42 to 8.41 and 7.36 to 7.57 during dry and wet seasons respectively with a mean of 7.88 during dry season and 7.47 during wet season which was within the recommended range by WHO (2011) of 6.5 to 8.5. TDS ranged from 99.40 mg/L to 184.90 mg/L and 87.90 mg/L to 154.50 mg/L during dry season and wet seasons respectively with a mean of 124.65 mg/L during dry season and 106.07 mg/L during wet season which was below the maximum recommended value by WHO (2011) of 1200 mg/L. TDS was lower during wet season than during dry season. TSS ranged from 8.91 mg/L to 36.20 mg/L and 16.60 mg/L to 175.90 mg/L during dry season and wet seasons respectively with a mean of 19.49 mg/L during dry season and 83.52 mg/L during wet season. During wet season TSS was averagely higher than the maximum recommended level by WHO (2011) of 30 mg/L. This was because water runoff carries insoluble small solid particles into the earth dam thereby increasing the suspended solids. Nitrate ranged from 4.44 mg/L to 11.50 mg/L during dry season and 2.71 mg/L to 6.75 mg/L during wet season with an average of 6.53 mg/L and 4.63 mg/L during dry season and wet season respectively which was below the maximum recommended level by WHO (2011). Ammonia ranged from 0.13 mg/L to 0.55 mg/L during dry season and 0.15 mg/L to 0.54 mg/L during wet season with a mean of 0.35 mg/L during dry season and 0.32 mg/L during wet season which was below the maximum recommended level by WHO (2011). Fluoride ranged from 1.25 mg/L to 4.26 mg/L during dry season and 1.67 mg/L to 5.33 mg/L during wet season with a mean of 2.65 mg/L during dry season and 3.47 mg/L during wet season which was higher than maximum recommended level by WHO (2011). The level of fluoride was higher during wet season than during dry season this was because fluoride was being washed into the dams from soil by rain water thereby increasing fluoride levels. Phosphorus ranged between 0.61 mg/L to 6.26 mg/L during dry season and 0.62 mg/L to 5.85 mg/L during wet season. The mean of phosphorus in all earth dams was 2.06 mg/L during dry season and 1.93 mg/L during wet season. During dry season the levels of phosphorus were higher than during wet season because phosphorus was diluted by rain water. The level of copper ranged from 0.17 mg/L to 0.89 mg/L during dry season and <0.003 mg/L to 0.22 mg/L during wet season with a mean of 0.38 mg/L during dry season and 0.06 mg/L during wet season which was below the maximum recommended level by WHO (2011). The level of cadmium was below 0.006 mg/L in all earth dams during both dry season and wet seasons. Zinc ranged from <0.002 mg/L to 4.92 mg/L during dry season and 0.07 mg/L to 1.38 mg/L during wet season with a mean of 1.77 mg/L during dry season and 0.62 mg/L during wet season which was below the maximum recommended level by WHO (2011) drinking water guideline. Lead was below 0.02 mg/L during wet season and the range was <0.02 mg/L to 0.87 mg/L during dry season with a mean of 0.16 mg/L which was above the maximum recommended value by WHO (2011). Chromium was below 0.005 mg/L during wet season and ranged <0.005 mg/L to 1.98 mg/L during dry season with a mean of 0.41 mg/L which were higher than the recommended value by WHO (2011) drinking water guidelines.

4.4 Concentrations (mg/kg) of selected parameters in soil samples

The concentrations of selected parameters in soil are given in table 4.4.1. Birir and Kapewot earth dams had the highest and lowest levels of fluoride respectively, this was followed by Kaposur, Kamogiboi and Sogororbei earth dams respectively which are the mean and standard deviation of results obtained from appendix B.

Table 4.4.1 Concentration (mg/kg except pH) of selected parameters in soil samples

Parameters/Site	Birir	Cheboloigo	Kamogiboi	Sogororbei	Kaposur	Kapewot
pH	7.64±0.04	7.50±0.12	7.42±0.06	7.70±0.04	7.40±0.02	7.46±0.08
Nitrate	6.04±0.10	5.67±0.14	4.80±0.08	2.82±0.22	4.60±0.18	6.42±0.12
Ammonia	0.22±0.04	0.11±0.21	0.20±0.10	0.26±0.06	0.28±0.16	0.18±0.24
Phosphorus	1.64±0.12	1.24±0.07	0.98±0.14	1.80±0.02	0.25±0.20	0.84±0.06
Fluoride	683.00±3.06	602.00±2.52	661.00±3.06	608.00±2.00	279.00±2.31	125.00±1.00
Copper	9.35±0.13	5.18±0.27	8.44±0.21	8.27±0.31	7.61±0.19	7.68±0.10
Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	23.50±0.62	12.83±0.25	32.60±0.20	25.40±0.82	27.50±0.63	15.23±0.40
Lead	45.87±0.83	43.93±0.91	39.43±0.97	19.10±1.08	54.93±0.64	61.30±1.05
Chromium	13.22±0.37	9.31±0.35	18.10±0.61	21.07±0.81	9.37±0.21	9.73±0.42

The pH of soil ranged between 7.40 and 7.70 with an average level of 7.52. Nitrate ranged from 2.82 mg/Kg to 6.42 mg/Kg with an average concentration of 5.06 mg/Kg. The earth dam with the highest nitrate concentration was Kapewot. Ammonia ranged from 0.11 mg/Kg to 0.28 mg/Kg with an average of 0.21 mg/Kg. Phosphorus ranged from 0.25 mg/Kg to 1.80 mg/Kg with an average of 1.13 mg/Kg. Fluoride had the highest concentration compared to other selected parameters in all earth dams. Fluoride ranged from 125 mg/Kg to 683 mg/Kg with an average of 493 mg/Kg. Fluoride in this area were attributed to weathering of rocks containing fluorides. Copper ranged from 5.18 mg/Kg to 9.35 mg/Kg with an average of 7.76mg/Kg. Cadmium levels were below 0.006 mg/Kg in soil from all the sampling sites. Lead ranged from 19.10 mg/Kg to 61.30 mg/Kg with an average of 44.09 mg/Kg. Kapewot had the highest concentration of lead 61.30±1.05 mg/kg followed by Kaposur 54.93±0.64 mg/kg. Zinc levels ranged from 12.83 mg/Kg to 32.60 mg/Kg with an average of 22.84 mg/Kg. Kamogiboi earth dam had the highest zinc level 32.60±0.20 mg/kg followed by Sogororbei 25.40±0.82 mg/kg while Cheboloigo had the lowest concentration of 12.83 mg/Kg. Chromium ranged from 9.31 mg/Kg to 21.07 mg/Kg with an average of 13.47 mg/Kg. Sogororbei earth dam had the highest level of Chromium 21.07±0.81 mg/L while Cheboloigo earth dam had the lowest chromium concentration. Among the metals analyzed, cadmium had the lowest levels in all the studied earth dams compared to other selected parameters.

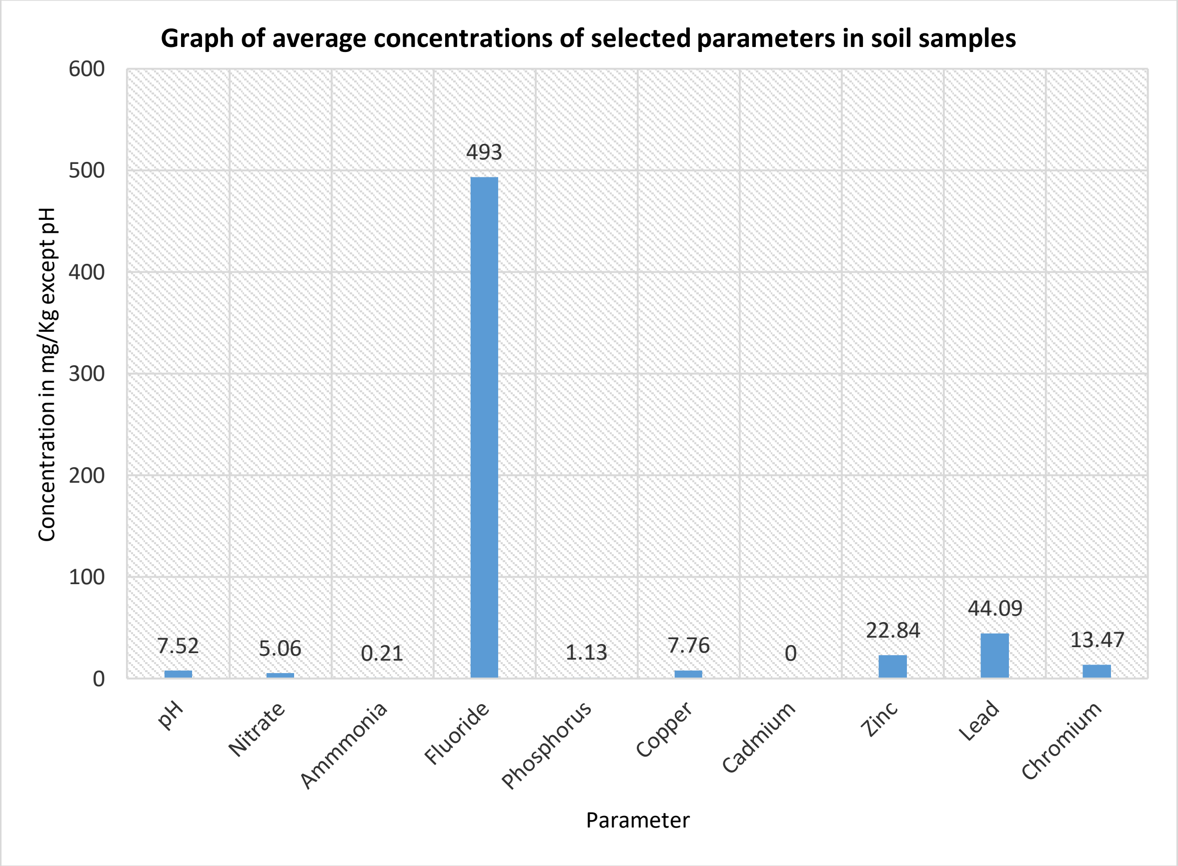


Figure 4.4.1 Average concentration (in mg/Kg except pH) of selected parameters in soil samples.

From figure 4.4.1 above, the level of fluoride in soil was the highest with concentration of 493 mg/Kg than other studied parameters followed by lead with concentration of 44.09 mg/Kg and the parameter with the lowest concentration was cadmium which was below 0.006 mg/Kg. The average concentration of nitrate was 2.06 mg/Kg, Ammonia was 0.21 mg/Kg, Phosphorus was 1.13 mg/Kg, pH was 7.52, Copper was 7.76 mg/Kg, Zinc was 22.84 mg/Kg and Chromium was 13.47 mg/L.

Table 4.4.2 Soil texture

Parameters/Site	Birir	Cheboloigo	Kamogiboi	Sogororbei	Kaposur	Kapewot
Clay	32.00	37.00	32.00	32.00	27.00	28.00
Silt	17.00	18.00	16.00	17.00	19.00	19.00
Organic carbon	3.03	3.45	2.96	3.06	2.98	2.98
Sand	51.00	45.00	52.00	51.00	54.00	53.00

From table 4.4.2 above and figure 3.20, the soil texture of Chepalungu Sub-County was Sandy clay loam which ease the leaching of fertilizer applied into the soil (USDA, 2018).

4.5 Concentrations in fertilizer samples

Table 4.5.1 show the mean and standard deviation of results presented in appendix D. pH was 7.80±0.21 and 7.29±0.14 for DAP and CAN respectively. Nitrate was 12.82±0.19 % for DAP and 18.12±0.14 % CAN. Ammonia was 24.68±0.20 % and 48.14±0.12 % for DAP and CAN fertilizers respectively. Phosphorus was 19.82±0.04 % for DAP and 2.07±0.15 % for CAN. Cadmium and chromium metal ion concentration levels were below 0.006 mg/Kg and 0.005 mg/L respectively in the fertilizer samples analyzed. Di-Ammonium Phosphate (DAP) fertilizer had the highest level of fluoride 7.84±0.02 mg/kg than calcium ammonium nitrate (CAN) fertilizers respectively. The DAP and CAN fertilizers had high levels of copper ion than zinc and lead.

Table 4.5.1 Concentration of selected parameter in fertilizer samples

Parameters/Fertilizer	DAP	CAN
pH	7.80±0.21	7.17±0.14
Nitrate	12.82±0.19	18.12±0.14
Ammonia	24.68±0.20	48.14±0.12
Phosphorus	19.82±0.04	2.07±0.15
Fluoride	7.84±0.02	1.26±0.03
Copper	22.40±0.53	18.67±0.42
Cadmium	<0.01	<0.01
Zinc	7.83±0.21	1.00±0.02
Lead	7.77±0.12	5.36±0.42
Chromium	<0.01	<0.01

Note: DAP- Di-Ammonium Phosphate, CAN- Calcium Ammonium Nitrate. The concentration for NO_3^-, NH_3 and $P^{3-}$are expressed in % while the concentration of F^-, Cd, Zn, Pb, Cr and Cu are in mg/Kg. pH has no units.

4.6 Concentrations (mg/L) of selected parameters in rain water samples

Table 4.6.1 shows the mean and standard deviation of results presented in appendix C.

Table 4.6.1 Concentrations (mg/L except pH) of selected parameters in rain water samples

Parameters/Site	A	B
pH	7.46±0.02	7.85±0.03
Nitrate	<0.001	<0.001
Ammonia	<0.002	<0.002
TSS	0.00	0.00
TDS	6.00±0.20	3.67±0.31
Phosphorus	<0.01	<0.01
Flouride	0.26±0.03	0.16±0.03
Copper	<0.003	<0.003
Cadmium	<0.01	<0.01
Zinc	1.03±0.01	1.13±0.02
Lead	<0.02	<0.02
Chromium	<0.01	<0.01

The results of rainwater samples were as follows; fluoride from roof A was 0.26±0.03 mg/L and B was 0.16±0.03 mg/L and zinc from A was 1.03±0.01 mg/L and B was 1.13±0.02 mg/L and these levels were below WHO (2011) drinking water guideline of 1.5 mg/L for fluoride and 0.002 mg/L for zinc which were higher than the maximum recommended level by WHO (2011). The level of copper was below 0.003 mg/L, cadmium was below 0.006 mg/L, lead was below 0.02 mg/l and chromium was below 0.005 mg/L, pH level was A was 7.46±0.02 and B was 7.85±0.03 while nitrate was below 0.001 mg/L in both samples, ammonia was below 0.002 mg/L in both samples, phosphorus was below 0.01 mg/L in both samples, TDS was 6.00±0.20 mg/l for sample A and 3.67±0.31 mg/L for sample B which was within the recommended level by WHO (2011) and TSS was 0.00 mg/L in both samples as shown in table 4.6.1.

The average pH in both dams was 7.66, TDS was 4.84, fluoride was 0.21, zinc was 1.08 while ammonia, nitrate, TSS, Phosphorus, Copper, Cadmium, Lead and Chromium were not detected.

4.7 Correlation Analysis

Statistical Package for the Social Science (SPSS Inc., Chicago IL, USA) was applied for determination of Pearson's correlation coefficients which have numerical values (r) ranging between -1 and +1. The results of Pearson correlation were obtained as shown in appendix E (Table E1, E2, E3, E4 and E5).

4.7.1 Correlation of selected parameters in earth dam water and soil sample.

Fluoride in soil had strong inverse relationship with fluoride in earth dam water with a correlation of r = -0.830, p = -0.377 which indicate that a decrease in fluoride in soil increases fluoride in earth dam water. The concentrations of Copper, Chromium, pH, Ammonia and Phosphorus in soil and earth dam water had correlations value of r = 0.749 p = 0.461, r=0.716 p= 0.492, r=0.892 p=0.299, r=0.857 p= 0.345 and r= 0.766 p= 0.445 respectively which indicates that the above parameters in soil had a direct effect on earth dam water quality. Zinc and Lead in soil had an inverse relationship with Zinc and Lead in earth dam water with a correlation of r= -0.407, p= 0.733 and r= -0.503, p= 0.664 respectively as indicated in Table E1 and E2.

4.7.2 Correlation of selected parameters in earth dam water and fertilizer samples.

pH in fertilizers had strong direct relationship with pH in earth dam water as shown by correlation coefficient r= 0.942, p = 0.217 which indicate that pH in earth dam water is affected by fertilizers used in Chepalungu Sub-County (Table E3). Nitrate in earth dam water had strong inverse relationship with nitrate in fertilizers with a Pearson's correlation of r= -0.999, p= 0.022 while fluoride and ammonia in earth dam water had a correlation of r= -0.647, p=0.552 and r= -0.611, p= 0.581 respectively with fluoride and ammonia in fertilizers. The data for the correlations above are shown in table E3 in appendix E.

4.7.3 Correlation of selected parameters in earth dam water and rain water

All the parameters in rain water could not be computed except TDS and pH because at least one of the variables was constant as shown in table E4 in appendix E. The pH of earth dam water had strong inverse relationship with pH in rain water a correlation of r= -0.834, p= 0.166 which implies that pH of rain water affects the pH in earth dam water. TDS in rain water had direct relationship with TDS in earth dam water with a correlation of r= 0.180 with sig.(2-tailed) of p=0.820 which is not significant.

4.8 Discussion

The pH for all earth dams were within the WHO (2011) drinking water guidelines. In Birir and Cheboloigo earth dams, the levels of TDS, cadmium, copper, lead, chromium, nitrate, ammonia and zinc were below the water guideline except during dry season for chromium and zinc (Table. 4.3.1). Lead and cadmium were not detected in water except at Kapewot earth dam during dry season. Fluoride had higher concentration than the maximum recommended of 1.5 mg/L in both earth dams. During dry season the levels of TDS, nitrate, phosphorus and copper were higher than during wet season because of dilution effect during wet season. The levels of fluoride, TSS and ammonia were higher during wet season than during dry season because these parameters were washed to the earth dam during wet season. The level of zinc was higher during dry season in Cheboloigo earth dam than during wet season. This is because of dilution effect during wet season but it was higher during wet season in Birir earth dam and this may be attributed to use of fertilizers which was commonly used in this area.

In Kamogiboi and Sogororbei earth dams, the levels of TDS, nitrate, ammonia and zinc were below drinking water guideline. Lead, chromium and cadmium were not detected in both earth dams but fluoride had higher concentration than drinking water guideline in both earth dams. During dry season the levels of TDS, nitrate, ammonia, phosphorus and copper were higher than during wet season while the levels of fluoride, Total Suspended Solids and zinc were higher during wet season than during dry season.

The levels of TDS in Kaposur earth dam and Kapewot earth dam were below the recommended drinking water guideline. During dry season, the level of fluoride was lower than during wet than during dry season in both earth dams. Lead, cadmium and chromium was not detected in both earth dams except during dry season for Kapewot earth dam. The levels of zinc and copper were above the maximum recommended levels by WHO (2011) during dry season.

The level of all the selected parameters except cadmium were present in the entire soil samples which indicates that these parameters may be affecting earth dam water quality and the levels of selected parameters were below detection limit in rain water except zinc and fluoride which were at a low concentration that does not have effect on earth dam water quality. In fertilizer samples, the selected parameters except cadmium and chromium were present in both fertilizers which indicates that fertilizers used in this area affects water quality of earth dams.

CHAPTER FIVE

5.0 Conclusions and recommendations

5.1 Conclusions

The conclusion drawn from this study are outline below:

1) All the selected parameters had higher concentration during dry season than during wet season except TSS and fluoride.
2) The level of pH in all earth dams were within the recommended value while TSS and fluoride were above the recommended value by WHO (2011) water guidelines.
3) Soil and fertilizers in Chepalungu Sub-County affect the water quality of earth dams while rain water has no effect on earth dam water quality.
4) During dry season Cheboloigo and Kapewot earth dam had high level of Chromium than recommended level by WHO (2011) while cadmium was not detected during both seasons.

5.2 Recommendations

5.2.1 what needs to be done immediately

1) Water from these earth dams should be filtered before drinking because it has high levels of suspended solids.
2) County Government should consider setting up a water de-fluoridation plant.
3) Presence of high fluoride level (over 1.5 mg/L) in water from these earth dam should be taken seriously by public health and county authorities.
4) Residents from Chepalungu Sub-County should consider using rain water because it has low level of fluoride, zinc and Suspended Solids compare to earth dam water.
5) The contaminated water should be treated as follows; (a) zinc, lead and chromium should be reduced in Kapewot earth dam (b) zinc and chromium should be reduced in Cheboloigo earth dam (c) zinc should be reduced in Kaposur earth dam. (d) fluoride should be reduced in all earth dams.

5.2.2 Future studies

1) Further studies should be carried out to determine the concentrations of nutrients, fluoride and heavy metals in surface sediments from these earth dams.

2) Further studies should be carried out to determine if fluoride and zinc are being transferred to food crops and domestic animals in this area.

3) Further research should be carried out to determine the health effects of drinking water from these earth dams.

4) Further research should be carried out to determine dissolved oxygen and microbiological (phytoplankton/zooplanktons/bacteria(coliforms)) in these earth dams.

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APPENDICES

Appendix A: Concentration of selected parameters in earth dam water

Table A1: Concentration in mg/L of Cu^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+} and Cr^{3+} during dry season

No	copper	cadmium	Zinc	Lead	chromium
Blank A	0.020	0.000	0.010	0.000	0.000
Blank B	0.010	0.000	0.010	0.000	0.000
Blank C	0.010	0.000	0.010	0.000	0.000
Birir A	1.160	<0.011	0.010	<0.020	<0.005
Birir B	1.120	<0.011	0.010	<0.020	<0.005
Birir C	1.120	<0.011	0.010	<0.020	<0.005
Cheboloigo A	1.850	<0.011	7.550	<0.020	1.630
Cheboloigo B	1.930	<0.011	7.470	<0.020	1.840
Cheboloigo C	1.770	<0.011	7.690	<0.020	2.050
Kamogiboi A	0.650	<0.011	0.490	<0.020	<0.005
Kamogiboi B	1.210	<0.011	0.610	<0.020	<0.005
Kamogiboi C	0.930	<0.011	0.370	<0.020	<0.005
Sogororbei A	0.690	<0.011	0.350	<0.020	<0.005
Sogororbei B	0.770	<0.011	0.290	<0.020	<0.005
Sogororbei C	0.610	<0.011	0.350	<0.020	<0.005
Kaposur A	1.010	<0.011	14.340	<0.020	<0.005
Kaposur B	1.130	<0.011	14.590	<0.020	<0.005
Kaposur C	0.890	<0.011	14.180	<0.020	<0.005
Kapewot A	3.570	<0.011	19.680	3.480	7.940
Kapewot B	3.690	<0.011	19.860	3.640	7.700
Kapewot C	3.450	<0.011	19.530	3.320	8.120

Table A2: Concentration (in mg/L except pH) of pH, TSS, TDS, NO_3^-, P^{3-}, F^- and NH_3 during dry season

No	pH	TSS	TDS	NO_3^-	P^{3-}	F^-	NH_3
Blank A	7.050	0.000	0.000	0.000	0.840	0.000	0.000
Blank B	6.980	0.000	0.000	0.000	0.830	0.000	0.000
Blank C	7.250	0.000	0.000	0.000	0.840	0.000	0.000
Birir A	8.500	12.600	112.400	7.260	2.060	4.260	0.360
Birir B	8.410	10.400	113.440	7.260	2.070	4.250	0.330
Birir C	8.320	11.800	110.760	7.261	2.050	4.260	0.320
Cheboloigo A	7.500	18.500	185.930	4.783	1.460	2.540	0.150
Cheboloigo B	7.600	20.800	184.900	4.802	1.450	2.520	0.110
Cheboloigo C	7.700	24.600	183.870	4.796	1.460	2.500	0.130
Kamogiboi A	8.100	9.6400	110.700	4.441	1.350	3.270	0.280
Kamogiboi B	8.120	8.4600	112.130	4.442	1.360	3.350	0.290
Kamogiboi C	8.110	8.6200	109.270	4.440	1.340	3.310	0.270
Sogororbei A	8.200	23.800	99.400	5.669	3.970	3.060	0.320
Sogororbei B	8.260	28.400	100.200	5.686	3.980	3.110	0.310
Sogororbei C	8.230	24.600	98.600	5.674	3.970	3.140	0.330
Kaposur A	7.500	37.600	109.340	5.508	1.150	1.440	0.540
Kaposur B	7.510	34.800	108.050	5.522	1.170	1.400	0.590
Kaposur C	7.490	36.200	108.710	5.513	1.130	1.430	0.510
Kapewot A	7.390	11.800	132.700	11.509	1.240	1.220	0.400
Kapewot B	7.440	13.600	132.020	11.514	1.260	1.250	0.480
Kapewot C	7.430	14.400	131.280	11.482	1.220	1.280	0.500

Table A3: Concentration in mg/L of Cu^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+} and Cr^{3+} during wet season

No	copper	cadmium	zinc	lead	Chromium
Blank A	0.000	0.000	0.000	0.000	0.000
Blank B	0.000	0.000	0.000	0.000	0.000
Blank C	0.000	0.000	0.000	0.000	0.000
Birir A	0.560	<0.011	1.840	<0.020	<0.005
Birir B	0.640	<0.011	1.640	<0.020	<0.005
Birir C	0.480	<0.011	1.920	<0.020	<0.005
Cheboloigo A	<0.003	<0.011	5.520	<0.020	<0.005
Cheboloigo B	<0.003	<0.011	5.880	<0.020	<0.005
Cheboloigo C	<0.003	<0.011	5.160	<0.020	<0.005
Kamogiboi A	0.880	<0.011	1.040	<0.020	<0.005
Kamogiboi B	1.040	<0.011	1.120	<0.020	<0.005
Kamogiboi C	0.720	<0.011	0.960	<0.020	<0.005
Sogororbei A	<0.003	<0.011	4.470	<0.020	<0.005
Sogororbei B	<0.003	<0.011	4.240	<0.020	<0.005
Sogororbei C	<0.003	<0.011	4.730	<0.020	<0.005
Kaposur A	<0.003	<0.011	1.640	<0.020	<0.005
Kaposur B	<0.003	<0.011	1.830	<0.020	<0.005
Kaposur C	<0.003	<0.011	1.450	<0.020	<0.005
Kapewot A	<0.003	<0.011	0.250	<0.020	<0.005
Kapewot B	<0.003	<0.011	0.270	<0.020	<0.005
Kapewot C	<0.003	<0.011	0.320	<0.020	<0.005

Table A4: Concentration (in mg/L except pH) of pH, TSS, TDS, NO_3^-, P^{3-}, F^- and NH_3 during wet season

No	pH	TSS	NO_3^-	P^{3-}	F^-	NH_3	TDS
Blank A	7.650	0.000	0.000	0.000	0.000	0.000	0.000
Blank B	7.720	0.000	0.000	0.000	0.000	0.000	0.000
Blank C	7.260	0.000	0.000	0.000	0.000	0.000	0.000
Birir A	7.480	98.570	5.680	1.200	5.320	0.360	98.200
Birir B	7.520	90.720	5.230	1.190	5.380	0.370	90.600
Birir C	7.460	82.810	5.440	1.170	5.290	0.370	96.500
Cheboloigo A	7.580	75.010	4.130	0.580	3.080	0.210	156.200
Cheboloigo B	7.560	71.610	3.980	0.540	3.150	0.130	150.600
Cheboloigo C	7.580	68.200	4.220	0.560	3.040	0.100	156.700
Kamogiboi A	7.450	21.500	2.680	0.460	3.790	0.180	107.720
Kamogiboi B	7.460	15.600	2.740	0.480	3.650	0.220	103.700
Kamogiboi C	7.420	12.800	2.720	0.430	3.720	0.170	99.680
Sogororbei A	7.360	109.600	3.580	2.890	4.630	0.200	96.800
Sogororbei B	7.400	128.400	3.260	2.970	4.640	0.140	94.800
Sogororbei C	7.320	122.600	3.220	2.930	4.560	0.120	96.200
Kaposur A	7.500	170.800	5.420	0.310	2.400	0.510	90.800
Kaposur B	7.550	180.600	5.360	0.340	2.420	0.550	87.900
Kaposur C	7.400	176.200	5.480	0.280	2.320	0.590	85.010
Kapewot A	7.490	29.600	6.840	0.360	1.690	0.500	103.400
Kapewot B	7.480	26.400	6.680	0.370	1.620	0.510	99.600
Kapewot C	7.490	22.300	6.720	0.340	1.700	0.490	94.800

Appendix B: Concentration of selected parameters in soil sample

Table B1: Concentration in mg/L of Cu^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+} and Cr^{3+} in soil sample

No	copper	cadmium	Zinc	Lead	Chromium
Blank A	0.000	0.000	0.000	0.000	0.000
Blank B	0.000	0.000	0.000	0.000	0.000
Blank C	0.000	0.000	0.000	0.000	0.000
Birir A	0.938	<0.011	2.353	4.674	1.358
Birir B	0.947	<0.011	2.411	4.585	1.287
Birir C	0.921	<0.011	2.286	4.502	1.321
Cheboloigo A	0.495	<0.011	1.258	4.306	0.935
Cheboloigo B	0.542	<0.011	1.283	4.482	0.964
Cheboloigo C	0.516	<0.011	1.308	4.391	0.894
Kamogiboi A	0.867	<0.011	3.280	4.044	1.748
Kamogiboi B	0.843	<0.011	3.264	3.844	1.812
Kamogiboi C	0.822	<0.011	3.236	3.941	1.870
Sogororbei A	0.857	<0.011	2.622	1.913	2.189
Sogororbei B	0.829	<0.011	2.458	2.016	2.024
Sogororbei C	0.795	<0.011	2.541	1.801	2.108
Kaposur A	0.783	<0.011	2.755	5.557	0.937
Kaposur B	0.760	<0.011	2.811	5.493	0.958
Kaposur C	0.740	<0.011	2.684	5.429	0.916
Kapewot A	0.769	<0.011	1.563	6.134	0.935
Kapewot B	0.778	<0.011	1.483	6.233	1.013
Kapewot C	0.757	<0.011	1.523	6.023	0.971

Table B2: Concentration (in mg/L except pH) of pH, NO_3^-, P^{3-}, F^- and NH_3 in soil sample

No	pH	NO_3^-	P^{3-}	F^-	NH_3
Blank A	7.650	0.000	0.000	0.000	0.000
Blank B	7.720	0.000	0.000	0.000	0.000
Blank C	7.260	0.000	0.000	0.000	0.000
Birir A	7.620	0.614	0.082	68.301	0.023
Birir B	7.630	0.604	0.088	68.604	0.026
Birir C	7.670	0.594	0.760	67.995	0.017
Cheboloigo A	7.540	0.581	0.062	59.946	0.011
Cheboloigo B	7.610	0.567	0.066	60.202	0.012
Cheboloigo C	7.350	0.553	0.059	60.452	0.010
Kamogiboi A	7.440	0.480	0.041	66.100	0.022
Kamogiboi B	7.470	0.488	0.048	65.794	0.029
Kamogiboi C	7.350	0.472	0.058	66.406	0.009
Sogororbei A	7.740	0.303	0.092	60.800	0.024
Sogororbei B	7.720	0.281	0.091	60.600	0.021
Sogororbei C	7.640	0.262	0.087	61.000	0.033
Kaposur A	7.410	0.478	0.013	27.901	0.029
Kaposur B	7.420	0.442	0.023	27.669	0.043
Kaposur C	7.370	0.460	0.003	28.130	0.012
Kapewot A	7.540	0.632	0.047	12.300	0.025
Kapewot B	7.460	0.641	0.041	12.700	0.018
Kapewot C	7.380	0.653	0.038	12.500	0.011

Appendix C: Concentration of selected parameters in rain water sample

Table C1: Concentration in mg/L of Cu^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+} and Cr^{3+} in rain water sample

No	**copper**	**cadmium**	**Zinc**	**Lead**	**Chromium**
Blank A	0.000	0.000	0.000	0.000	0.000
Blank B	0.000	0.000	0.000	0.000	0.000
Blank C	0.000	0.000	0.000	0.000	0.000
Rain water 1A	<0.003	<0.006	4.160	<0.020	<0.005
Rain water 1B	<0.003	<0.006	4.080	<0.020	<0.005
Rain water 1C	<0.003	<0.006	4.160	<0.020	<0.005
Rain water 2A	<0.003	<0.006	4.480	<0.020	<0.005
Rain water 2B	<0.003	<0.006	4.480	<0.020	<0.005
Rain water 2C	<0.003	<0.006	4.640	<0.020	<0.005

Table C2: Concentration (in mg/L except pH) of pH, TSS, TDS, NO_3^-, P_3^-, F^- and NH_3 in rain water sample

No	**pH**	**TSS**	**TDS**	**NO_3^-**	**P^{3-}**	**F^-**	**NH_3**
Blank A	7.540	0.000	0.000	0.000	0.000	0.000	0.000
Blank B	6.980	0.000	0.000	0.000	0.000	0.000	0.000
Blank C	7.360	0.000	0.000	0.000	0.000	0.000	0.000
Rain water 1A	7.430	0.000	6.200	<0.001	<0.010	0.260	<0.002
Rain water 1B	7.400	0.000	5.800	<0.001	<0.010	0.230	<0.002
Rain water 1C	7.380	0.000	6.000	<0.001	<0.010	0.280	<0.002
Rain water 2A	**7.580**	0.000	4.000	<0.001	<0.010	0.160	<0.002
Rain water 2B	**7.500**	0.000	3.600	<0.001	<0.010	0.140	<0.002
Rain water 2C	**7.520**	0.000	3.400	<0.001	<0.010	0.190	<0.002

Appendix D: Concentration of selected parameters in fertilizer sample

Table D1: Concentration in mg/Kg of Cu^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+} and Cr^{3+} in fertilizer sample

No	**copper**	**cadmium**	**zinc**	**Lead**	**Chromium**
Blank A	0.000	0.000	0.000	0.000	0.000
Blank B	0.000	0.000	0.000	0.000	0.000
Blank C	0.000	0.000	0.000	0.000	0.000
DAP A	2.260	<0.006	0.760	0.780	<0.005
DAP B	2.280	<0.006	0.802	0.764	<0.005
DAP C	2.180	<0.006	0.788	0.788	<0.005
CAN A	1.880	<0.006	0.100	0.500	<0.005
CAN B	1.822	<0.006	0.098	0.526	<0.005
CAN C	1.898	<0.006	0.102	0.582	<0.005

Table D2: Concentration (in % except F^- and pH) of pH, NO_3^-, P^{3-}, F^- and NH_3 in fertilizer sample

No	**pH**	**NO_3^-**	**P^{3-}**	**F^-**	**NH_3**
Blank A	7.650	0.000	0.000	0.000	0.000
Blank B	7.720	0.000	0.000	0.000	0.000
Blank C	7.260	0.000	0.000	0.000	0.000
DAP A	7.960	1.282	0.991	7.850	2.488
DAP B	7.560	1.263	0.993	7.860	2.468
DAP C	7.880	1.301	0.989	7.820	2.448
CAN A	7.170	1.812	0.104	1.260	4.802
CAN B	7.260	1.826	0.111	1.280	4.826
CAN C	7.440	1.798	0.096	1.230	4.814

N/B: Fluoride concentration are in mg/Kg

Appendix E: Correlation

Table E1 : Correlation of selected heavy metals in earth dam water and soil samples.

		Soil Copper	Soil Cadmium	Soil Zinc	Soil Lead	Soil Chromium	Earth Water Copper	Earth Water Cadmium	Earth Water Zinc	Earth Water Lead	Earth Water Chromium
Soil Copper	Pearson Correlation	1	.[a]	.194	-.153	.514	.749	.[a]	.721	.873	1.000[*]
	Sig. (2-tailed)		.	.713	.773	.297	.461	.	.488	.325	.015
	N	6	6	6	6	6	3	3	3	3	3
Soil Cadmium	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.		.	.	.	.	.	.	.	.
	N	6	6	6	6	6	3	3	3	3	3
Soil Zinc	Pearson Correlation	.194	.[a]	1	-.453	.494	.877	.[a]	-.407	.756	.362
	Sig. (2-tailed)	.713	.		.367	.320	.319	.	.733	.454	.764
	N	6	6	6	6	6	3	3	3	3	3
Soil Lead	Pearson Correlation	-.153	.[a]	-.453	1	-.870[*]	-.675	.[a]	.681	-.503	-.040
	Sig. (2-tailed)	.773	.	.367		.024	.529	.	.523	.664	.974
	N	6	6	6	6	6	3	3	3	3	3
Soil Chromium	Pearson Correlation	.514	.[a]	.494	-.870[*]	1	.997[*]	.[a]	.008	.959	.716
	Sig. (2-tailed)	.297	.	.320	.024		.046	.	.995	.182	.492
	N	6	6	6	6	6	3	3	3	3	3
Earth Water Copper	Pearson Correlation	.749	.[a]	.877	-.675	.997[*]	1	.[a]	.081	.977	.765
	Sig. (2-tailed)	.461	.	.319	.529	.046		.	.948	.136	.446
	N	3	3	3	3	3	3	3	3	3	3
Earth Water Cadmium	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.	.	.	.	.	.		.	.	.
	N	3	3	3	3	3	3	3	3	3	3
Earth Water Zinc	Pearson Correlation	.721	.[a]	-.407	.681	.008	.081	.[a]	1	.290	.704
	Sig. (2-tailed)	.488	.	.733	.523	.995	.948	.		.813	.503
	N	3	3	3	3	3	3	3	3	3	3

Earth Water Lead	Pearson Correlation	.873	.[a]	.756	-.503	.959	.977	.[a]	.290	1	.884
	Sig. (2-tailed)	.325	.	.454	.664	.182	.136	.	.813		.310
	N	3	3	3	3	3	3	3	3	3	3
Earth Water Chromium	Pearson Correlation	1.000*	.[a]	.362	-.040	.716	.765	.[a]	.704	.884	1
	Sig. (2-tailed)	.015	.	.764	.974	.492	.446	.	.503	.310	
	N	3	3	3	3	3	3	3	3	3	3

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Table E2 : Correlation of selected parameters in earth dam water and soil samples.

		Soil pH	Soil Nitrate	Soil Ammonia	Soil Phosphorus	Soil Fluoride	Earth Water pH	Earth Water TDS	Earth Water TSS	Earth Water Nitrate	Earth Water Ammonia	Earth Water Fluoride	Earth Water Phosphorus
Soil pH	Pearson Correlation	1	-.296	.799	.086	-.121	.892	.991	-.887	.965	.833	-.745	.812
	Sig. (2-tailed)		.569	.056	.872	.820	.299	.083	.306	.168	.373	.465	.397
	N	6	6	6	6	6	3	3	3	3	3	3	3
Soil Nitrate	Pearson Correlation	-.296	1	-.590	-.240	-.297	-.541	-.230	-.370	.161	.466	-.589	.498
	Sig. (2-tailed)	.569		.218	.647	.567	.636	.852	.759	.897	.691	.599	.668
	N	6	6	6	6	6	3	3	3	3	3	3	3
Soil Ammonia	Pearson Correlation	.799	-.590	1	-.139	-.125	.871	.985	-.907	.976	.857	-.773	.837
	Sig. (2-tailed)	.056	.218		.793	.813	.327	.111	.277	.140	.345	.437	.369
	N	6	6	6	6	6	3	3	3	3	3	3	3
Soil Phosphorus	Pearson Correlation	.086	-.240	-.139	1	.692	-.219	.118	-.666	.490	.742	-.830	.766
	Sig. (2-tailed)	.872	.647	.793		.128	.860	.925	.536	.674	.468	.376	.445
	N	6	6	6	6	6	3	3	3	3	3	3	3
Soil Fluoride	Pearson Correlation	-.121	-.297	-.125	.692	1	.821	.964	-.942	.992	.901	-.830	.885
	Sig. (2-tailed)	.820	.567	.813	.128		.387	.171	.217	.080	.285	.377	.309
	N	6	6	6	6	6	3	3	3	3	3	3	3
Earth Water pH	Pearson Correlation	.892	-.541	.871	-.219	.821	1	.943	-.582	.743	.492	-.362	.460

	Sig. (2-tailed)	.299	.636	.327	.860	.387		.216	.605	.467	.672	.764	.696
	N	3	3	3	3	3	3	3	3	3	3	3	3
Earth Water TDS	Pearson Correlation	.991	-.230	.985	.118	.964	.943	1	-.819	.923	.754	-.651	.729
	Sig. (2-tailed)	.083	.852	.111	.925	.171	.216		.389	.251	.457	.548	.480
	N	3	3	3	3	3	3	3	3	3	3	3	3
Earth Water TSS	Pearson Correlation	-.887	-.370	-.907	-.666	-.942	-.582	-.819	1	-.977	-.994	.969	-.990
	Sig. (2-tailed)	.306	.759	.277	.536	.217	.605	.389		.138	.068	.160	.091
	N	3	3	3	3	3	3	3	3	3	3	3	3
Earth Water Nitrate	Pearson Correlation	.965	.161	.976	.490	.992	.743	.923	-.977	1	.948	-.893	.936
	Sig. (2-tailed)	.168	.897	.140	.674	.080	.467	.251	.138		.206	.298	.229
	N	3	3	3	3	3	3	3	3	3	3	3	3
Earth Water Ammonia	Pearson Correlation	.833	.466	.857	.742	.901	.492	.754	-.994	.948	1	-.990	.999*
	Sig. (2-tailed)	.373	.691	.345	.468	.285	.672	.457	.068	.206		.092	.023
	N	3	3	3	3	3	3	3	3	3	3	3	3
Earth Water Flouride	Pearson Correlation	-.745	-.589	-.773	-.830	-.830	-.362	-.651	.969	-.893	-.990	1	-.994
	Sig. (2-tailed)	.465	.599	.437	.376	.377	.764	.548	.160	.298	.092		.068
	N	3	3	3	3	3	3	3	3	3	3	3	3
Earth Water Phosphorus	Pearson Correlation	.812	.498	.837	.766	.885	.460	.729	-.990	.936	.999*	-.994	1
	Sig. (2-tailed)	.397	.668	.369	.445	.309	.696	.480	.091	.229	.023	.068	
	N	3	3	3	3	3	3	3	3	3	3	3	3

*. Correlation is significant at the 0.05 level (2-tailed).

Table E3: Correlation of selected parameters in earth dam water and fertilizer samples.

		Phosphorus fertilizer	Fluoride	Nitrate fertilizer	pH fertilizer	Ammonia fertilizer	pH Earth Water	TDS Earth Water	TSS Earth Water	Nitrates Earth Water	Ammonia Earth Water	Fluoride Earth Water	Phosphorous Earth Water
Phosphorus fertilizer	Pearson Correlation	1	.783	-.876	.998*	-.997	.917	-.044	-.538	.892	.675	-.032	-.447
	Sig. (2-tailed)		.427	.321	.044	.053	.261	.972	.638	.299	.528	.979	.705
	N	3	3	3	3	3	3	3	3	3	3	3	3
Fluoride	Pearson Correlation	.783	1	-.986	.825	-.832	.966	.587	-.945	.980	.071	-.647	.206
	Sig. (2-tailed)	.427		.106	.383	.374	.166	.601	.211	.128	.955	.552	.868
	N	3	3	3	3	3	3	3	3	3	3	3	3
Nitrate fertilizer	Pearson Correlation	-.876	-.986	1	-.907	.913	-.996	-.444	.878	-.999*	-.235	.511	-.040
	Sig. (2-tailed)	.321	.106		.276	.268	.059	.707	.318	.022	.849	.658	.974
	N	3	3	3	3	3	3	3	3	3	3	3	3
pH fertilizer	Pearson Correlation	.998*	.825	-.907	1	-1.000**	.942	.026	-.595	.921	.622	-.102	-.384
	Sig. (2-tailed)	.044	.383	.276		.009	.217	.983	.594	.255	.572	.935	.749
	N	3	3	3	3	3	3	3	3	3	3	3	3
Ammonia fertilizer	Pearson Correlation	-.997	-.832	.913	-1.000**	1	-.947	-.040	.607	-.926	-.611	.116	.371
	Sig. (2-tailed)	.053	.374	.268	.009		.208	.974	.585	.246	.581	.926	.758
	N	3	3	3	3	3	3	3	3	3	3	3	3

pH Earth Water	Pearson Correlation	.917	.966	-.996	.942	-.947	1	.359	-.830	.998*	.325	-.429	-.053
	Sig. (2-tailed)	.261	.166	.059	.217	.208		.766	.377	.038	.789	.718	.966
	N	3	3	3	3	3	3	3	3	3	3	3	3
TDS Earth Water	Pearson Correlation	-.044	.587	-.444	.026	-.040	.359	1	-.819	.414	-.766	-.997*	.913
	Sig. (2-tailed)	.972	.601	.707	.983	.974	.766		.389	.729	.444	.048	.268
	N	3	3	3	3	3	3	3	3	3	3	3	3
TSS Earth Water	Pearson Correlation	-.538	-.945	.878	-.595	.607	-.830	-.819	1	-.861	.258	.860	-.513
	Sig. (2-tailed)	.638	.211	.318	.594	.585	.377	.389		.339	.834	.341	.657
	N	3	3	3	3	3	3	3	3	3	3	3	3
Nitrates Earth Water	Pearson Correlation	.892	.980	-.999*	.921	-.926	.998*	.414	-.861	1	.268	-.482	.006
	Sig. (2-tailed)	.299	.128	.022	.255	.246	.038	.729	.339		.827	.680	.996
	N	3	3	3	3	3	3	3	3	3	3	3	3
Ammonia Earth Water	Pearson Correlation	.675	.071	-.235	.622	-.611	.325	-.766	.258	.268	1	.715	-.962
	Sig. (2-tailed)	.528	.955	.849	.572	.581	.789	.444	.834	.827		.493	.177
	N	3	3	3	3	3	3	3	3	3	3	3	3
Fluoride Earth Water	Pearson Correlation	-.032	-.647	.511	-.102	.116	-.429	-.997*	.860	-.482	.715	1	-.879
	Sig. (2-tailed)	.979	.552	.658	.935	.926	.718	.048	.341	.680	.493		.316
	N	3	3	3	3	3	3	3	3	3	3	3	3

Phosphorous Earth Water	Pearson Correlation	-.447	.206	-.040	-.384	.371	-.053	.913	-.513	.006	-.962	-.879	1
	Sig. (2-tailed)	.705	.868	.974	.749	.758	.966	.268	.657	.996	.177	.316	
	N	3	3	3	3	3	3	3	3	3	3	3	3

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table E4: Correlation of selected parameters in earth dam water and rain water

		pH Dam	TDS Dam	TSS Dam	Nitrate Dam	Ammonia Dam	Phosphorus Dam	pH Rain	Nitrate Rain	Ammonia Rain	TSS Rain	TDS Rain	Phosphorus Rain
pH Dam	Pearson Correlation	1	-.126	.085	-.031	.672	-.250	-.834	.[a]	.[a]	.[a]	.975[*]	.[a]
	Sig. (2-tailed)		.874	.915	.969	.328	.750	.166	.	.	.	.025	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
TDS Dam	Pearson Correlation	-.126	1	-.999[**]	.990[**]	-.495	-.133	.203	.[a]	.[a]	.[a]	-.180	.[a]
	Sig. (2-tailed)	.874		.001	.010	.505	.867	.797	.	.	.	.820	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
TSS Dam	Pearson Correlation	.085	-.999[**]	1	-.991[**]	.481	.162	-.160	.[a]	.[a]	.[a]	.145	.[a]
	Sig. (2-tailed)	.915	.001		.009	.519	.838	.840	.	.	.	.855	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
Nitrate Dam	Pearson Correlation	-.031	.990[**]	-.991[**]	1	-.370	-.061	.180	.[a]	.[a]	.[a]	-.067	.[a]
	Sig. (2-tailed)	.969	.010	.009		.630	.939	.820	.	.	.	.933	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
Ammonia Dam	Pearson Correlation	.672	-.495	.481	-.370	1	.487	-.267	.[a]	.[a]	.[a]	.811	.[a]
	Sig. (2-tailed)	.328	.505	.519	.630		.513	.733	.	.	.	.189	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
Phosphorus Dam	Pearson Correlation	-.250	-.133	.162	-.061	.487	1	.710	.[a]	.[a]	.[a]	-.030	.[a]
	Sig. (2-tailed)	.750	.867	.838	.939	.513		.290	.	.	.	.970	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
pH Rain	Pearson Correlation	-.834	.203	-.160	.180	-.267	.710	1	.[a]	.[a]	.[a]	-.702	.[a]
	Sig. (2-tailed)	.166	.797	.840	.820	.733	.290		.	.	.	.298	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
Nitrate Rain	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.	.	.	.	.	.	.		.	.	.	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
Ammonia Rain	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.	.	.	.	.	.	.	.		.	.	.
	N	4	4	4	4	4	4	4	4	4	4	4	4

TSS Rain	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.		.	.
	N	4	4	4	4	4	4	4	4	4	4	4	4
TDS Rain	Pearson Correlation	.975[*]	-.180	.145	-.067	.811	-.030	-.702	.[a]	.[a]	.[a]	1	.[a]
	Sig. (2-tailed)	.025	.820	.855	.933	.189	.970	.298	.	.	.		.
	N	4	4	4	4	4	4	4	4	4	4	4	4
Phosphorus Rain	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	
	N	4	4	4	4	4	4	4	4	4	4	4	4

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.