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Assessment of Domestic Water Quality of Dams in Chepalungu Sub-county, Bomet County, Kenya

Kipmutai Chumo Joseah
Student, Department of Chemistry, School of Physical Science,
College of Biological and Physical Sciences, University of Nairobi, Kenya
Chemist, Department of Geological Survey, Ministry of Mining, Kenya
Dr. Fredrick D. O. Oduor
Lecturer, Department of Chemistry, School of Physical Science,
College of Biological and Physical Sciences, University of Nairobi, Kenya
Dr. Deborah A. Abong'o
Lecturer, Department of Chemistry, School of Physical Science,
College of Biological and Physical Sciences, University of Nairobi, Kenya

Abstract:
An assessment of domestic water quality for six selected dams in Chepalungu sub county, Bomet County was carried out by determining the levels of pH, total dissolve solids, total suspended solids, nitrates, ammonia, fluoride, phosphorous, copper, lead, zinc, cadmium and chromium in the 6 selected dams, and their concentrations was compared with the World Health Organization (WHO) and National Environmental Management Authority (NEMA) Kenya water quality guidelines for sources of domestic water. These dams are the alternative source of household water since the appreciably large neighboring population is unable to get access to chlorinated drinking water supply, for safer use. Water samples were therefore taken from 6 selected dams. Three sampling points was identified in each of these dams and the samples were subsequently collected during the day. The sampling exercise was carried out during the dry season in September 2016 and the wet season April, 2017. Quantitative determination of each parameter was carried out using standard procedures. This report shows that pH level was within the recommended range by WHO and NEMA, Total dissolve solids were below the maximum recommended value with a range of between 87.9mg/L and 184.9mg/L, Total suspended solids ranged between 8.91mg/L and175.9mg/L which was higher than the maximum allowable level of 30mg/L, Nitrates ranged between 2.71mg/L and 11.50mg/L which was lower than the maximum recommended value by WHO (50mg/L) but slightly higher than that of NEMA (10mg/L), Phosphorous ranged between 0.61mg/L and 6.26mg/L, Ammonium ranged between 0.13mg/L and 0.55mg/L, Copper ranged between nil and 0.96mg/L which was lower than maximum recommended value by WHO (2mg/l) but slightly higher than that of NEMA (0.05mg/L), Zinc ranged from 0.07mg/L to 4.99mg/L which is higher than maximum recommended value by WHO (3mg/L), while lead were not detected in all dams except Kapewot during dry season with a concentration of 0.87mg/L which was higher than the maximum recommended value by WHO, Lead was detected during dry season in two dams only Cheboloigo and Kapewot with concentration of 0.46mg/L and 1.98mg/L respectively, Fluoride was higher than the recommended level of 1.5mg/L by both NEMA and WHO it ranged from 1.25mg/L to 5.33mg/L which indicates high fluorides in the area. According to analysis high fluoride originates from soil in the area, soil from this area has high concentration of fluorides with a range of between 125mg/L to 683mg/L. Water treatment is recommended to avoid long term adverse effect of high fluoride concentration alternatively local population can use rain water since according to analysis of rain water, these pollutants are below the detection limit except zinc which originate from iron sheets which is coated with aluminum and zinc.

1. Introduction

1.1. Water Pollution and the Environment

Environment is the total sum of external conditions which include natural forces and living things that influence or favor the life of population or even an individual (Tyagi and Mehra, 1990). The relationship between and among the physical environment (soil, water and air) and organism environment (plant and animal's life) constitutes the study of ecology (Tyagi and Mehra, 1990). Environmental pollutants can be defined as the unfavorable or negative alterations to the surrounding, largely or wholly by-products of anthropogenic action through direct or indirect change in radiation levels, chemical and physical constitution, energy patterns, and large quantity of organisms (Tyagi and Mehra, 1990).

Water is one of the major materials required to sustain all living things but it has been suspected of being the cause of human illness (Tyagi and Mehra, 1990). The major concern today is to produce adequate supplies that are hygienically safe, that is means water free of color, turbidity, nitrates; phosphates dissolved and suspended solid s and ammonia (Tyagi and Mehra, 1990). In addition, it should be free of toxic metals and wide variety of organic chemicals such as chlorinated solvents and Pesticides (Tyagi and Mehra, 1990). As the population grows, there is increase in demand for water accordingly and due to improved living standards, the demand is in much more rapid rate.

According to the World Health Organization (WHO), health is a complete state of mental, physical and social being (WHO, 2006). Environmental pollution through chemicals such as heavy metals may directly affect human health through contamination of food chain (UNEP, 2006).

Aquatic life is also at risk since pollutants have adverse effects on the aquatic ecosystem. Enhancement of water with nutrients, especially phosphorous and nitrogen is called eutrophication and can lead to increased plant growth which leads to depletion of oxygen levels as plant materials dies and decay.

1.2. Causes of Water Contamination

The use of fertilizers appears to be increasing worldwide especially in developing countries (Tyagi and Mehra, 1990). The application of nitrogen and ammonia containing fertilizers increased two or threefold in many countries from 1961 to 1981 and application rates are expected to keep on rising, leading to worse leaching in future (Tyagi and Mehra, 1990). In developing countries such as Nigeria, Kenya and India, seepage from pit latrines or septic tanks produces high levels of nitrates in ground water (Tyagi and Mehra, 1990). Metabolism and growth of aquatic organism requires low doses of nutrients which are essential. However anthropogenic sources of such nutrients include municipal waste water's organic matter and run off from field fertilizers which contains chemicals and manure which can alter the natural balance of organism which lives in water, (Tyagi and Mehra, 1990). The dams in Chepalungu sub-county having originated from similar area of the country are not an exception. This study was carried out on six selected dams in Chepalungu to determine the levels of selected physico-chemical parameters. Three sampling sites were selected on each of the six dams on the basis of accessibility and human activities.

1.3. Statement of the Problem

Activities within a water catchment area affect both physical and chemical constituent of water bodies and therefore also affect the biotic integrity of the community (clean stream environmental services, 2005). The quality of water is influence by substances that are dissolved or suspended in water and can affect the usefulness of water for a specific purpose (Venter, 2004). Water pollutants from both non-point sources and point sources affect water quality (Venter, 2004). Non-point sources are sources which its discharge cannot be trace to any single site 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 dams are from point sources as well as non-point sources. Chepalungu is characterized by farming activities which involve use of fertilizers and manure. This may elevate the plants nutrients and heavy metal levels in the environment since according to Pendias (2001), nitrogenous fertilizers contain lead in the range of 2 to 27 ppm, copper (1-15 ppm), zinc (1-42 ppm), chromium (3.2-19 ppm) and cadmium (0.05-8.5 ppm) while phosphate fertilizers contain lead (7-225 ppm), chromium (66-245 ppm), zinc (50- 500), cadmium (0.1-170 ppm), copper (1-300 ppm). Manure contain lead (6.6-15 ppm), copper (2-60 ppm), zinc (15-250 ppm), chromium (5.2-55 ppm), while pesticides contain lead (0-60 ppm), zinc (1.3-25 ppm) and copper (12-50 ppm). And lastly most of the residents in this area use dam water for domestic purposes. If heavy metals such as lead, zinc, Chromium and copper are present in drinking water at a level higher than the maximum recommended levels by NEMA (EMCA, 2006) it may cause health effects such as kidney damage for Cadmium, Lead causes memory deterioration and kidney damage, Chromium causes damage to liver and nerve tissues, Zinc leads to copper deficiency and copper causes gastrointestinal effects. Other water pollutants such as Fluorides cause effects on skeletal tissues while Nitrates and ammonia causes methemoglobinemia. High level of phosphorous triggers algal boom. This study will create awareness and help key policy agencies responsible for public health, pollution control, food safety inspection, horticulture and nutrition in developing strategies to manage the environment and control pollution.

1.4. Previous Studies

Oyhakilome *et al.,* (2012) reported that the levels of turbidity, iron, manganese and color in Owena dam, Ondo state, south western Nigeria was higher than the recommended standards of drinking water and they concluded that water should be treated probably before being released to public for consumption.

Ndeda L.A, Manohar S, (2014) reported that the levels of heavy metal in Nairobi dam was higher than maximum permissible level by KEBS, WHO and EU

Tessema *et al*, (2014) reported that the turbidity value for Bira dam was higher compare to that of other dams studied in Ethiopia and concluded that watershed should be managed by inclusion and with full participation of all dam users.

(Muchina Fridah, 1998,) reported that pH of lake Simbi ranged from 9.98 to 10.02 which was higher than the permissible levels of 6.5 to 8.5, total dissolved solids were 13,304 to 13,640 mg/L which was higher than the permissible levels of 5000 g/l, fluorides were 51mg/L which was higher than permissible value of 1.5 mg/l and she also found that the levels of nitrates were 0.165 mg/l which was less than the permissible limit value of 50 mg/l.

Odhiambo, O R, (2005) reported that the pH of Nairobi dam was 7.05, total dissolve solids were 448mg/l, Total suspended solid was 570 mg/l, nitrates was 1.0 mg/l and copper was not detected.

Okoo, G. O, (2009) found that the lead concentrations in Nairobi River ranged from 0.04 to 0.08mg/l during the wet season, Lead concentrations ranges between 0.07 and 0.16mg/L and mean value of 0.11 mg/l during the dry season. Cadmium was not detected in all the sampling sites during both seasons

Oyoo. G, (2006) reported that pH in Mathare River ranged from 7.5 to 8 with mean of 7.8 and total suspended solids varied from 336 to 382 mg/l.

2. Materials and Method

2.1. The Study Area

Chepalungu sub county spans an area of 490.60 km^2 with a current population of 163,833 people (National Geospatial-Intelligence Agency, Bethesda, MD, USA) in Bomet County. 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 3.1.1 shows location of Bomet county in Kenya while figure 3.1.2 shows the location of Chepalungu sub-county in Bomet county and Figure 3.1.3 shows the sampling sites.

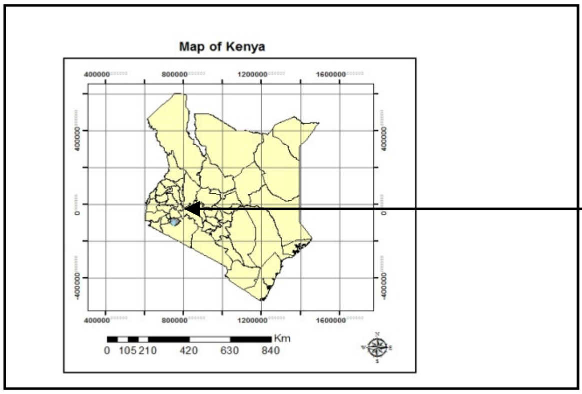

Figure 1: Map of Kenya

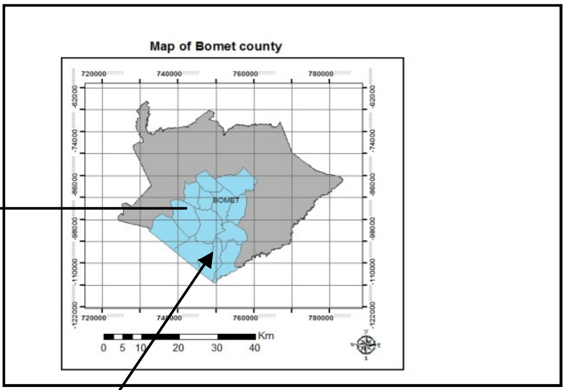

Figure 2: Map of Bomet County

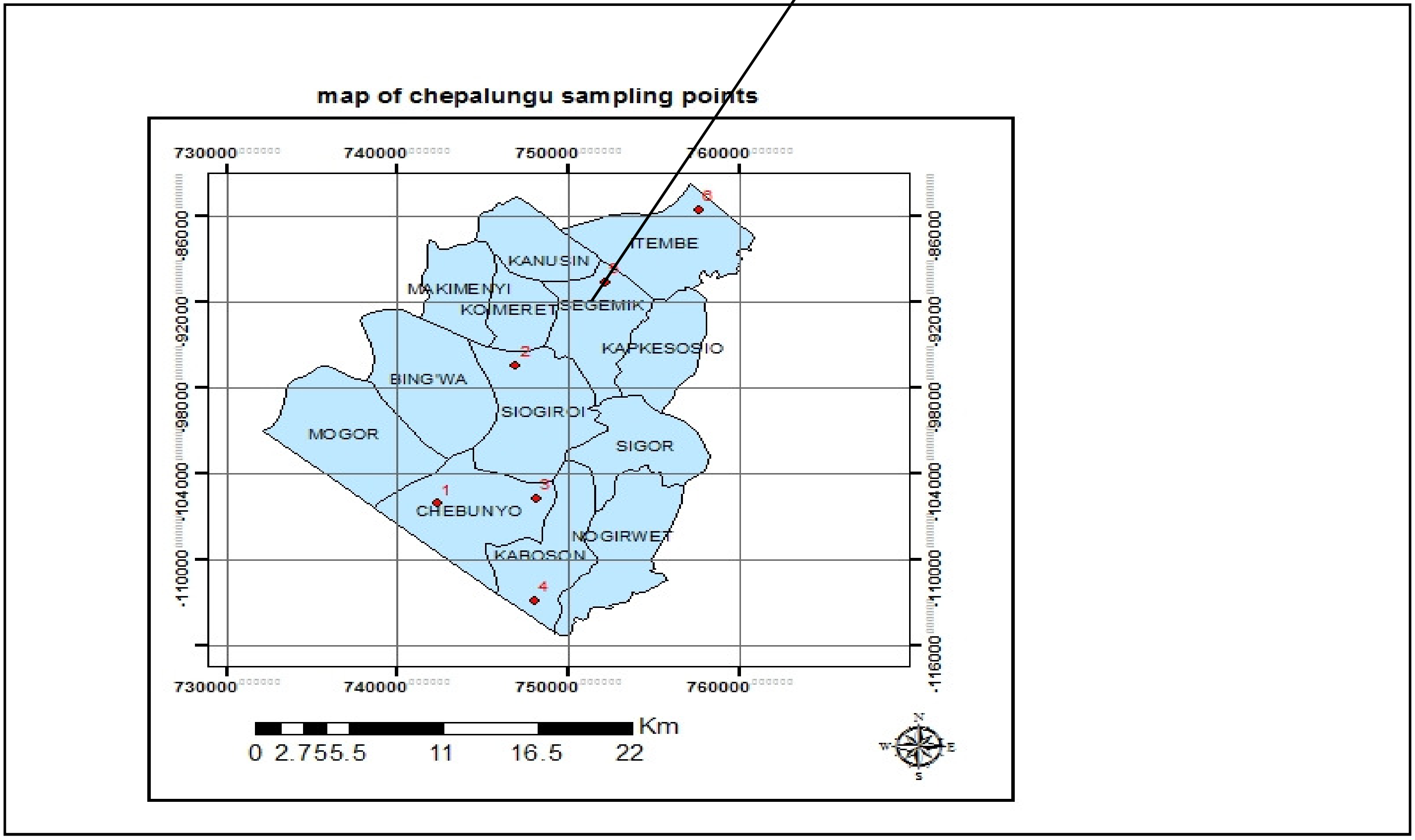

Figure 3: Map of Chepalungu Sub County showing the dam sampling sites

Site	Dam name	Abbriavation	alitude (m)	Cordinates (UTM)	Human activities around the sampling site
				Longitude Latitude	
1	Birir	BR	1826	0743399 9893461	Shopping center, Maize farming and Livestock keeping
2	Cheboloigo	CBG	1843	0743693 9909180	Maize farming and Livestock keeping
3	Kamogiboi	KBI	1818	0746078 9894968	Maize farming and Livestock keeping
4	Sogororbei	SGI	1773	0745110 9891162	Maize farming and Livestock keeping
5	Kaposur	KPR	1901	0753019 9913358	Maize farming and Livestock keeping
6	Kapewot	KPT	1927	0757069 9914064	Shopping center, Maize farming and Livestock keeping

Table 1: Sampling sites, coordinates and a description of the surrounding area

Figure 4: Kamogiboi Dam Site

2.2. Geology and Soils

On the geological map (Schoeman, 1949), most of the areas in Bomet are mapped as “phonolite with interbanded tuffs”, volcanic rocks of tertiary age. The hills are mapped as basement system quartzites (Braun H.M and Okwaro H.W, 1974). Phonolite rocks contain high amount of fluoride. This was according to studies carried out Colfax County, New Mexico (Carmichael I.S.E et al, 1970). The area covering Bomet, Kapkesosio, Segemik and Kapkwen has plateau soils which consist of dark grey clay loam top soil which shows brown mottles from 20cm downwards, overlying every dark grey or black clay starting 30 to 60cm depth. The dark color and the clay content would point to soils known as black cotton soils (Braun H.M and Okwaro H.W, 1974).

2.3. Site Selection and Sampling Plan

Field visits were made to the study area, Figure 3.3, the initial trip was for the sites selection, acquisition of topographical map and the selection of the dam sites, there was a general survey of the study area, familiarization with the county authority, the feasibility studies that involved the determination of resources requirements and schedule for sample collection. Actual sample collection was done in two different seasons in September 2016 (dry) and April 2017 (wet) seasons. Geographic Information System (GIS) data was obtained from the six selected dam sites during sample collection using the GPRS instrument; the sampling sites are shown in Table 3.1. Figures 3.1.4 and 3.1.5 show the pictorial views of Birir and Kamogiboi Dams respectively

2.4. Water Sample Collection and Preservation

Sampling was carried out during the dry season on 26th to 28th September, 2016 and during wet in April 2017. In quantitative analysis, only a small part of the sample material is generally used to provide the analytical signal from the concentration of the element of interest that is to be determined. This requires that specific precautions be taken to minimize in contamination and to provide a representative sample. All plastic (1L) containers were washed thoroughly with hot dilute aquaragia (mixture of nitric acid ($NHNO_3$) and hydrochloric acid (HCl) in the ratio of 1:3 respectively) and rinsed with large amounts of distilled deionized water and dried in the oven overnight prior to sample collection. The samples were collected in 1litre plastic containers from selected three different sampling points from the selected six dams, mix to form one composite sample from each dam; the samples were put in two separate 1litre plastic containers. In one of these containers, a few drops of concentrated nitric acid were added. This was used in the analysis of metals ions while the other sample was used in the determination of pH, total dissolved solids, suspended solids, fluorides, ammonia and nitrates. The samples were collected randomly from the three different selected sampling points from each dam. Each container was corked immediately to avoid contamination and labeled according to the dam from which the samples were collected, stored in polyurethane cool boxes in the field vehicle and transported to the Ministry of Mining and Geology analytical laboratory for chemical analysis.

2.5. Soil Samples Collection

For the determination of copper, zinc, cadmium, lead, chromium, and fluoride contents, soil samples were collected from the land adjacent to the sampling site of the dam where water samples were collected during each sampling period. A soil core was dug using hoe and scooped using a spade down to the depth of 15-30 cm from the three different points from the land adjacent to the water sampling site and 100 g of the scooped core taken. The core was thoroughly mixed to give a composite sample. Two replicate samples of approximately 150g were taken from the composite samples and labeled, and placed in plastic bag before transferring to a labeled self-sealing polythene bag and each placed in polyurethane cool-box prior to transportation to the laboratory for analysis.

2.6. Fertilizer Samples Collection

Fertilizers were bought from three different agro vets. Two types of fertilizers namely di-ammonium phosphate and calcium ammonium nitrate were bought from each agro vet. These fertilizers were packed in sampling bags and transferred to the laboratory for analysis.

2.7. Rain Water Sample Collection

Rain water samples were collected from the roofs of two different residential houses closely adjacent to Birir and Kapewot dams. About 10 liters of water was collected and was divided into two portions of 5liters each. One portion was treated with 3 drops of concentrated nitric acid. The portion treated with nitric acid was to be analyzed for metals while the other portion was for nitrates, pH, Ammonia, total dissolved solids, total suspended solids and phosphorous.

2.8. Sample Treatment and Storage in the Laboratory

The samples for nitrates and ammonia were decolorized using activated carbon followed by filtration using Whitman 541 filter papers (0.45nm). All samples were stored in the fridge at temperature of $4^{\circ}_{\circ}$ C.

2.9. Determination of PH

A Fischer model pH meter was first standardized with a buffer solution, of pH, 4.0, 7.0 and 10.0. The electrodes were rinsed, twice with distilled deionized water and the sample being analyzed. Each of the samples was then taken in a 100-ml beaker and electrodes immersed. After stabilization of the meter, the readings were recorded for each sample.

2.10. Determination of Total Dissolved Solids

The sample was first mixed thoroughly and filtered through a standard glass fiber filter and the filtrate was then evaporated to dryness in the oven at a temperature of 105°C and dried to a constant weight at 180°C. Total dissolved solids are represented by the increase in dish weight. The following procedure was carried out to obtain the total dissolved solids.

The disk with wrinkled side up was inserted into filtration apparatus. By applying vacuum, the disk was washed with 3 successive 20mls volume of reagent grade water and suctions were perform to remove all traces of water whereby washings were discarded. Sample volume were chosen to yield between 10 to 200mg dried residues. Samples were stirred with a magnetic stirrer, and then 10mls of each were pippeted into a glass fiber-filter with applied vacuum. The glass fiber filters were then washed each with three successive 10ml volume of each reagent grade-water allowing complete drainage between the washings. Then suction was continued on each for about 3 minutes after filtrations were complete. The total filtrates (with washings) were transferred to weighed evaporating dishes and evaporated to dryness on a steam bath. After complete evaporation, the dishes were dried for one hour in an oven at 180°C. The dishes were then cooled in a desiccator to balanced temperature. The process of drying and cooling cycles was repeated until constant weights were obtained. The calculation of the total dissolve solids was calculated using the formula

Amount of total dissolved solid /L= (A-B)*1000/sample volumes.

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

B= Weight of dish (mg).

2.11. Determination of Total Suspended Solids

Filtering apparatus containing filter fiber were assembled, samples were stirred with a magnetic stirrer then 10 ml of each were added to the filtering apparatus and filtered. Suction was then applied for about 3 minutes to complete the filtration. Filter fibers were then carefully removed from the filtration apparatus and transferred to an Aluminum planchette for support. They were then dried for at least 1 hour at $103\text{-}105^{\circ}$C in an oven and cooled in desiccators to balance temperatures and weighed. The cycle of drying was repeated until the weight changes were less than 4% of the previous weight (reference). The total suspended solids were calculated as follows:

Total suspended solids/L (mg) = (A-B) *1000/sample volumes.

Where;

A= weight of dried residue + filter (mg).

B= weight of filter alone (mg)

2.12. Determination of Nitrates

Nitrate together with organic matter absorbs at 220 nm while organic matrices alone absorbs at 275 nm. Both wavelengths are used for the determination of nitrates. This was done by subtracting two folds the absorbance at 275 from those at 220 nm. Stock nitrate standard solution was prepared by drying Potassium nitrate in an oven at a temperature of 105^{o}C for 24 hours and cooled in the desiccator. 0.7218 g was weighed accurately and dissolved in distilled deionized water and topped up to 1000 ml. This solution contains 100 ug NO_3 per ml. This was preserve with 2 ml $CHCl_3$/l to make it stable for one month. Working standards was prepared in the range of 0ppm to 3ppm using serial dilution formula of $C_1V_1=C_2V_2$. The working standards were treated using the same procedure as the samples.

Samples were filtered to remove interferences due to the suspended solids; 1 ml of 1N HCl was added to 50 ml of each filtered samples and mixed thoroughly. Absorbance of both the samples and the standards were measured against distilled deionized water which was adjusted to zero absorbance. Nitrate (NO_3) absorbance was obtained using a wavelength of 220 nm and the interference caused by dissolved organic matter was determined using a wavelength of 275 nm. To obtain absorbance due to nitrates, two times of the absorbance at 275 nm for samples and standards was subtracted from the reading at 220 nm. The UV/Vis spectrometer used was T80+ (Figure 3.2).

For soil and fertilizer samples, 5.000 g was weighed and transferred into a 100ml beaker, about 30 ml of distilled deionized water was added and 5ml of 1.0 N hydrochloric acid was added and digested in the hot plate for about 30 minutes. It was then cooled and filtered into 50ml volumetric flask and neutralized using 1molar sodium hydroxide (NaOH) and topped up to the mark using distilled deionized water. It was then analyzed using UV/Vis spectrometer T80+.

The actual concentration was obtained using the following formula

Actual concentration = (A-B)×Final volume ÷ weight taken

Where A= Sample reading, B= Blank reading.

2.13. Determination of Ammonia

2.13.1. Nessler's Reagent Preparation

Ammonia reacts with Nessler reagent to form a yellow colour which is determined at 425 nm. Ammonia can be determined calorimetrically using Nessler's reagents. An orange brown compound is formed from the reaction of Nessler's reagent with ammonia which is formed as are salt of the reaction between Nessler's reagents a dilute ammonium salt solution. The orange brown compound remains in colloidal solution and on low standing it flocculates. Measurements should be done before flocculation occurs. 70 g of potassium iodide and100 g of mercuric iodide was weighed accurately and dissolved in 100 ml of ammonia free water in one liter beaker and it was slowly added to a cooled solution of 160 g sodium hydroxide pellets (or 224 g of potassium hydroxide) in 700 ml of ammonia free water while stirring. The precipitate formed was allowed to settle or 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.

2.13.2. Ammonia Free Water Preparations

0.5 l of distilled water in a Pyrex apparatus was redistilled from a solution containing 1g of anhydrous sodium carbonate and 1g of potassium permanganate, the first 100 ml portion of the distillate was discarded and then about 300 ml was collected.

2.13.3. Preparation of Standard Ammonium Chloride Solution

3.141g of Analytical reagent (AR) ammonium chloride was dissolved and dried at 100 ˚C in ammonia free water and was diluted to a volume 1liter in a volumetric flask using the same water. This solution contains 1000ppm ammonium. From this 1000ppm a standard of 100ppm was prepared using serial dilution formula $C_1V_1=C_2V_2$ and from 100ppm working standard of 0.00ppm, 0.50ppm, 1.00ppm, 3.00ppm and 5.00ppm were prepared using the same formula. The ammonium standard calibration curve used in shown in Appendix A, Figure A.2

2.13.4. Colorimetric Method for Ammonia Determination in Water

50 mls of the sample was measured and 1ml of Nessler's reagent added. The absorbance was measured using ultraviolet/visible spectrophotometer at 420 nm (T80+). A series of standard ammonia solutions was prepared and treated likewise. From the absorbance values, the ammonia content in the sample was computed.

The actual concentration was obtained using the following formula

Actual concentration = (A-B)×Final volume ÷ volume taken

Where A= Sample reading
B= Blank reading

2.13.5. Colorimetric Method for Ammonia Determination in Soil Samples

For soil samples, 5.000 grams was weighed and transferred into a 100ml beaker, about 30ml of distilled deionized water was added and 5ml of aguaragia was added and digested in the hot plate for about 30 minutes. It was then cooled and filtered into 50ml volumetric flask and neutralized using 1molar sodium hydroxide (NaOH) and topped up to the mark using distilled deionized water. This was the transferred into 100ml water and 1ml of Nessler's reagent was added. The absorbance was measured using

ultraviolet/visible spectrophotometer at 420 nm (Figure 3.2). A series of standard ammonia solutions was prepared and treated likewise. From the absorbance values, the ammonia content in the sample was computed.
The actual concentration was obtained using the following formula
Actual concentration = (A-B)×Final volume ÷ weight taken
Where A= Sample reading
B= Blank reading

Figure 5: Ultraviolet visible Spectroscopy (T80+)

2.14. Determination of Fluorides in Water and Soil Samples

2.14.1. Electrode Method for Fluoride Determination in Water

Fluoride in water was determined using ion selective method. Apparatus used were Ion selective meter (Orion 290A) with combined fluoride electrode. Stock fluoride solution was prepared by dissolving 221.0 mg of anhydrous sodium fluoride (NaF) in distilled deionized water and diluted to 1000 ml; 1.0 ml = 100 mg F^-. Fluoride buffer was prepared by approximately added 500 ml distilled deionized water into a 1liter beaker, followed by 58 g NaCl, 57 ml acetic acid and 4.0 g 1,2 Cyclohexelenediaminetetraacetic acid (CDTA) the mixture was stirred to dissolve. The beaker was placed in a cold-water bath followed by adding 125ml of 6 N NaOH slowly while stirring until the pH was between 5.3 and 5.5 and was then transfer to a 1liter volumetric flask and topped up to the mark using distilled deionized water.

A series of standards (1ppm, 5ppm and 10ppm) were prepared from the stock solutions fluoride solution. To 100 ml beaker, 25 ml of standard solution was added by a volumetric pipette and an equal volume of buffer was also 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. 25ml of samples were measured and transferred into 100ml beaker and 25ml of buffer solution was added. The electrode was frequently calibrated between sample measurements by checking the potential of any of the prepared standards and adjusting the calibration control, until the meter read as before.
The actual concentration was obtained using the following formula
Actual concentration = (A-B)×Final volume ÷ weight taken
Where A= Sample reading
B= Blank reading

2.14.2. Electrode Method for Fluoride Determination in Soil Samples

For soil and fertilizer samples 5.000 grams was weighed and transferred into a 100ml beaker, about 30ml of distilled water was added and 5ml of aguaragia was added and digested in the hot plate for about 30 minutes. It was then cooled and filtered into 50ml volumetric flask and neutralized using 1molar sodium hydroxide and topped up to the mark using distilled deionized water. 25ml of this solution was then transferred to 100ml beaker and 25ml of fluoride buffer solution was added and analyzed using Ion selective meter (Figure 3.3). The actual concentration was obtained using the following formula
Actual concentration = (A-B)×Final volume ÷ weight taken
Where A= Sample reading, B= Blank reading

Figure 6: Ion selective meter (Orion 290A)

2.15. Determination of Total Phosphorus in Water and Soil Using Sulphuric Acid-nitric Acid Digestion Method

0.2197 g-ammonium metavanadate was dissolved in 400 ml of 1:1 HNO_3 and 50 g of ammonium molybdate was dissolved in 400 ml of distilled deionized water. The two solutions were thoroughly mixed and diluted to 1 liter with distilled water.

Phosphorus solution: 4.258 g of A.R. di-ammonium hydrogen phosphate was dissolved in distilled deionized water and was diluted to 1 liter to make 1000 ppm phosphorous stock standard solution from this stock solution a standard of 100ppm was prepared and from 100ppm a working standard of 0.00ppm, 1.00ppm, 2.50ppm, 5.00ppm and 10.00ppm were prepared using $C_1V_1=C_2V_2$ serial dilution formula. To 50 ml of water samples, 1 ml of concentrated H_2SO_4 and 5 ml concentrated HNO_3 were added and the volume reduced about 1ml by heating on the hot plate until the solution becomes colorless this removes HNO_3 from the samples. The sample was then cooled and approximately 20 ml distilled, 0.05 ml phenolphthalein indicator solution (one drop) was added and 1N NaOH solution until a faint tinge color was produced. It was then transferred to 100 ml volumetric flask and topped up to 100 ml mark using distilled deionized water. The standard solutions were treated using the same procedure as samples. 10 ml each of digested samples, blank and standard solutions were pippeted and transferred into 100 ml beakers and a volume of 10 ml molybdivanadate solution was added to each of the solution in beakers and 25 ml of distilled deionized water was added to each while mixing, allowed to stand for at least 5 minutes. Each solution was measured at a wavelength of 430 nm under a control of blank solution. This analysis was done using UV/VIS T80+.

The actual concentration was obtained using the following formula

Actual concentration = (A-B)×Final volume ÷ volume taken

Where A= Sample reading

B= Blank reading

For soil samples 5.000 grams was weighed and transferred into a 100ml beaker, about 30ml of distilled water was added and 5ml of nitric acid was added and digested in the hot plate for about 30 minutes. It was then cooled and filtered into 100ml volumetric flask and 0.05 ml phenolphthalein indicator solution (one drop) was added and 1N NaOH solution until a faint pink color was produced. It was then transferred to 100 ml volumetric flask and topped up to 100 ml mark using distilled water. The standard solutions were treated using the same procedure as sample. 10 ml each of digested samples, blank and standard solutions were pippeted and transferred into 100 ml beakers and a volume of 10 ml molybdivanadate solution was added to each of the solution in beakers and 25 ml of distilled water was added to each while mixing and was allowed stand for at least 5 minutes and finally analyzed using UV/VIS T80+.

The actual concentration was obtained using the following formula

Actual concentration=(A-B)×Final volume ÷ weight taken

Where A= Sample reading

B= Blank reading

2.16. Determination of Metals Ions Concentrations in Water, Soil and Fertilizer Samples

2.16.1. 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 taking 200 ml of distilled deionizes water into 500 ml beakers and adding 5 ml of nitric acid. The solution was then evaporated 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 transferred into volumetric flasks and topped up to 50 ml using distilled deionized water. The blanks were ready to be aspirated in an atomic absorption spectrometer and the concentration results obtained were used in the various calculations.

2.16.2. Preparation of Metal Ion Standards

2.16.3. Preparation of Copper Standard Calibration Curve

1.000 g of copper metal strip was accurately weighed and dissolved in 1:1 HNO_3 acid and then diluted using distilled water to a volume of 1000 ml to make 1000 ppm copper. The 1000 ppm solution was first diluted to 100 ppm followed by serial dilution to obtain the following working standards; 0.00 ppm,0.50 ppm,1.00 ppm,3.00 ppm and 5.00 ppm. The standard solutions were aspirated by atomic absorption spectrometer at wavelength (λ) value of 327.4 nm. The calibration curve for the copper metal standard is shown was used

2.16.4. Preparation of Cadmium Standard

1.000 g of cadmium metal strip was accurately weighed and dissolves in 1:1 HNO_3 nitric acid the solution was diluted using distilled deionized water to a volume of 1000 ml to make 1000 ppm cadmium. From 1000 ppm, dilution was made to give 100 ppm using the dilution formula C1V1=C2V2 where c and v are concentration and volume respectively. The following working standards were prepared by serial dilution; 0.00 ppm,0.50 ppm,1.00 ppm,1.50 ppm and 2.00 ppm cadmium. The standard solutions were aspirated by atomic absorption spectrometer at wavelength (λ) value of 228.8nm. The calibration curve for the cadmium metal standard is was used.

2.16.5. Preparation of Zinc Standard Calibration Curve

1.000 g of zinc metal strip was accurately weighed and dissolved in 1:1 HNO_3 acid and thereafter diluted using distilled water to a volume of 1000 ml, to make 1000 ppm zinc. The stock solution was diluted to 100 ppm and the following working standards were prepared by serial dilution; 0.00 ppm,0.50 ppm,1.00 ppm,3.00 ppm and 5.00 ppm. The standard solutions were aspirated by atomic absorption spectrometer at wavelength (λ) value of 213.9 nm. The calibration curve for the zinc metal standard were used

2.16.6. Lead Standard

1.000g of lead metal strip was accurately weighed and dissolved in 1:1 HNO3 acid then diluted using distilled deionized water to a volume of 1000 ml in 1000ml volumetric flask, to make 1000 ppm lead. From 1000 ppm, dilution was made to give 100 ppm using dilution formula C1V1=C2V2 where C and V are concentration and volume of the solution respectively. Serial dilution was done to obtain the working standards which were 0.00 ppm, 0.50 ppm, 1.00 ppm, 2.5 ppm, 5.00 ppm lead. The standard solutions were aspirated by atomic absorption spectrometer at wavelength (λ) value of 217.0nm. The calibration curve for the lead standard are is shown in Appendix B, Figure B.4

2.16.7. Preparation of Chromium Standard Calibration Curve

1.000 g of chromium metal was accurately weighed and dissolved in 1:1 hydrochloric acid with gentle heating and then cooled and diluted using distilled water to a volume of 1000 ml to make 1000ppm chromium. The 1000 ppm solution was first diluted to 100ppm followed by serial dilution to obtain the following working standards; 0.00 ppm, 1.00ppm, 2.50ppm, 5.0ppm and 10.00 ppm. The standard solutions were aspirated by atomic absorption spectrometer at wavelength (λ) value of Cr = 357.9 nm. The calibration curve for the chromium metal standard were used

2.16.8. Preparation of Water Samples for Metal Ion Analysis

The samples were first shaken well and a volume 200 cm^3 of each sample was measured using measuring cylinder and transferred to 500 ml beakers. 5 ml of concentrated nitric acid was measured using a measuring cylinder and added to each sample. It was then evaporated and digested to almost dryness on a hot plate and allowed to cool. The solutions were filtered into a volumetric flask using whatman filter paper No.541(0.45nm) and washed thoroughly using warm distilled deionized water and topped up to the mark. Finally, the samples were aspirated by Atomic Absorption Spectrometer (Figure 3.4) at the different wave length (ƛ) specific for each metal ion and under the control using water as the blank. (ƛ; Pb=217.0, Cd=228.8, Cu=327.4, Zn=213.9, Cr = 357.9nm).

The actual concentration was obtained using the following formula Actual concentration = (A-B)×Final volume ÷ volume taken, where A= Sample reading, B= Blank reading, ƛ= wave length

Figure 7: Atomic absorption spectrometer Spectra AA-10

2.17. Method Validation for Metal Analysis

The samples were first shaken well and a volume 200 cm^3 of each sample was measured using measuring cylinder and transferred to 500 ml beakers.5 ml of concentrated nitric acid was measured using a measuring cylinder and added to each sample. It was then evaporated and digested to almost dryness on a hot plate and allowed to cool. The solutions were filtered into a volumetric flask using whatman filter paper No.541(0.45nm) and washed thoroughly using warm distilled water and topped up to the mark. This was then analyzed using ICP-AES (ARCOS FHS 12). In this case only samples from two dams were analyzed.

3. Results

Parameter /Dam	**Birir**		**Cheboloigo**		**Kamogiboi**		**Sogororbei**		**Kaposur**		**Kapewot**	
	Dry	wet	Dry	wet	Dry	wet	Dry	wet	Dry	wet	Dry	wet
pH	8.41±0.1	7.49±0.03	7.57±0.1	7.57±0.01	8.11±0.010	7.44±0.02	8.23±0.031	7.36±0.04	7.50±0.010	7.48±0.08	7.42±0.027	7.49±0.01
TDS	112.2±1.44	95.1±3.97	184.9±1.03	154.5±3.42	110.7±1.33	103.7±4.02	99.4±0.80	95.9±1.03	108.7±0.64	87.9±2.9	132.0±0.72	99.3±4.31
TSS	11.6±1.11	90.7±7.89	21.3±3.08	71.6±3.4	8.91±0.64	16.6±4.44	25.6±2.46	120.2±9.63	36.2±1.40	175.9±4.91	13.3±1.33	26.1±3.61
Nitrates	7.26±0.002	5.45±0.23	4.79±0.010	4.11±0.12	4.44±0.016	2.71±0.03	5.68±0.009	3.35±0.20	5.51±0.013	5.42±0.06	11.50±0.017	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
fluorides	4.26±0.006	5.33±0.05	2.53±0.021	3.09±0.06	3.31±0.042	3.72±0.07	3.10±0.053	4.61±0.04	1.42±0.020	2.38±0.05	1.25±0.031	1.67±0.04
phosphorous	2.44±0.001	2.37±0.03	1.23±0.004	1.11±0.04	1.02±0.016	0.91±0.05	6.26±0.003	5.85±0.08	0.61±0.035	0.62±0.06	0.80±0.042	0.71±0.03
copper	0.29±0.01	0.14±0.02	0.46±0.020	BDL	0.23±0.070	0.22±0.03	0.17±0.023	BDL	0.25±0.031	BDL	0.89±0.031	BDL
cadmium	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
zinc	BDL	0.45±0.03	1.89±0.030	1.38±0.09	0.12±0.025	0.26±0.02	0.08±0.010	1.12±0.06	3.59±0.045	0.41±0.04	4.92±0.040	0.07±0.01
lead	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.87±0.042	BDL
Chromium	BDL	BDL	0.46±0.055	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.98±0.053	BDL

Table 2: Selected Physico-chemical parameters levels in water from six dams in Chepalungu sub county

	Maximum levels in drinking water		
Parameters	NEMA		WHO
pH	6.5-8.5		6.5-8.5
TDS	1200mg/L		NC
TSS	30 mg/L		NC
Nitrates	10 mg/L		50 mg/L
ammonia	0.5 mg/L		NC
fluorides	1.5 mg/L		1.5 mg/L
phosphorous	NC		NC
copper	0.05 mg/L		2 mg/L
cadmium	0.01 mg/L		0.003 mg/L
zinc	1.5 mg/L		3mg/L
Lead	NC		0.01mg/L (A,T)
Chromium	NC		0.05mg/L (P)

Table 3: WHO maximum allowed levels of selected physico-chemical parameters in drinking water

NC- Not classified
A- Provisional guideline value because calculated guideline value is below the achievable quantification level.
P- Provisional guideline value because of uncertainties in the health database.
T-provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection, etc.

Parameters/Site	**Birir**	**Cheboloigo**	**Kamogiboi**	**Sogororbei**	**Kaposur**	**Kapewot**
Fluorides	683±3.06	602±2.52	661±3.06	608±2.00	279±2.31	125±1.00
Copper	9.35±0.127	5.18±0.269	8.44±0.212	8.27±0.311	7.61±0.190	7.68±0.104
Cadmium	BDL	BDL	BDL	BDL	BDL	BDL
Zinc	23.5±0.624	12.83±0.252	32.60±0.200	25.40±0.819	27.50±0.625	15.23±0.404
Lead	45.87±0.833	43.93±0.907	39.43±0.971	19.10±1.082	54.93±0.643	61.30±1.05
Chromium	13.22±0.370	9.31±0.350	18.10±0.608	21.07±0.808	9.37±0.208	9.73±0.416

Table 4: Metal and fluoride ions concentration (µg/kg, dw) in soil samples
Average = Mean± S.D, BDL - Below Detection Limit

Parameters/Fertilizer	**DAP**	**CAN**
Fluoride	7.84±0.02	1.26±0.03
Copper	22.4±0.53	18.67±0.42
Cadmium	BDL	BDL
Zinc	7.83±0.21	1.00±0.02
Lead	7.77±0.12	5.36±0.42
Chromium	BDL	BDL

Table 5: Metal and fluoride ions concentration (µg/kg, dw) in fertilizer samples
DAP- Di-Ammonium Phosphate, CAN- Calcium Ammonium Nitrate, BDL- below detection limit

Parameters/Site	**A**	**B**
Flouride	0.26±0.03	0.16±0.03
Copper	BDL	BDL
Cadmium	BDL	BDL
Zinc	1.03±0.01	1.13±0.02
Lead	BDL	BDL
Chromium	BDL	BDL

Table 6: Metal and fluoride ions concentrations (µg/L) in the rain water samples

	Birir Dam			Kapewot Dam		
	1st results	2nd results	Standard deviation	1st results	2nd results	Standard deviation
pH	8.41	8.52	±0.08	7.42	7.54	±0.09
T.D.S	112.2	115.7	±2.47	132.0	131.0	±0.72
T.S.S	90.9	94.2	±2.33	82.3	79.7	±1.84
Nitrates	7.26	7.19	±0.05	11.50	11.37	±0.09
phosphorous	2.44	2.18	±0.18	0.80	0.91	±0.08
Fluoride	4.26	4.33	±0.05	1.25	1.15	±0.07
Ammonia	5.04	5.20	±0.11	0.63	0.69	±0.04
Copper	0.29	0.33	±0.03	0.89	0.96	±0.05
Cadmium	N.D	N.D	-	N.D	N.D	-
Zinc	0.14	0.18	±0.03	4.92	4.99	±0.05
Lead	N.D	N.D	-	0.87	0.84	±0.02
Chromium	N.D	N.D	-	1.98	2.12	±0.10

Table 7: Method validations during dry season; comparison of the average result during first and second analysis using different methods
NB: The units of all values are express in milligrams per liter (mg/L) except for pH.

4. Discussion

According to Table 4.1., the pH for Birir and Cheboloigo dams was within the recommended levels by WHO and NEMA while the levels of Total dissolved solids, nitrates, ammonium and zinc were above the maximum allowable value. Lead and cadmium were not both detected in water but Fluoride had higher concentration than maximum recommended value for domestic purpose in both dams. During dry season the levels of Total dissolved solids, Nitrates, Phosphorous and copper were higher than during wet season while the levels of Fluorides, Total suspended solids and Ammonia were higher during wet season than during dry season. The level of zinc was higher during dry season in Cheboloigo dam than during wet season but the same pollutant was vice versa in Birir dam.

The pH of Kamogiboi dam and Sogororbei dam were also within the recommended levels by WHO and NEMA while the levels of Total dissolved solids, Nitrates, Ammonium and zinc were below the maximum allowable value. Lead, Chromium and Cadmium was not detected in both dams but Fluoride had higher concentration than maximum recommended value for domestic purpose in both dams. During dry season the levels of Total dissolved solids, Nitrates, Ammonium, Phosphorous and copper were higher than during wet season while the levels of Fluorides, Total suspended solids and Zinc were higher during wet season than during dry season.

The PH of Kaposur dam and Kapewot dam were within the recommended levels by NEMA and WHO while the levels of Total dissolved solids were below the maximum recommended value. During dry season, the level of fluoride was below the maximum recommended value but during wet season the level was above the maximum recommended value in both dams. Lead, cadmium and chromium was not detected in both dams except during dry season for Kapewot dam. The levels of zinc and copper were above the maximum recommended value during dry season and vice versa during wet season. The level of ammonia for Kaposur dam was slightly higher than the maximum recommended value but for Kapewot dam, these levels were below the recommended value.

Table 4.3.1 shows that all the pollutants except cadmium are present in the entire soil sample. In these samples, fluorides had the highest concentration of between 125mg/L to 683mg/L, followed by lead with a range of between 19.10mg/L to 61.30mg/L, Zinc had a concentration between 12.83mg/L and 27.50mg/L while chromium had concentration between 9.37mg/L and 21.07mg/L. copper had a concentration between 5.18mg/L and 9.35mg/L.

Table 4.4.1 shows that the pollutants except cadmium and chromium are present in the fertilizers. The levels of fluoride were 7.84mg/Kg and 1.26mg/Kg, Zinc was 7.83mg/Kg and 1.00mg/Kg, copper was 22.4mg/Kg and 18.67mg/Kg while lead was 7.72mg/Kg and 5.36mg/Kg in DAP and CAN fertilizers respectively.

Table 4.5.1 shows that the levels of pollutants in rain water were below detection limits except zinc and fluoride which had concentration lower than the maximum recommended level by WHO and NEMA.

The standard deviation in table 4.6 ranges from ±0.02 to ±2.47 the lowest was that of lead and the highest was that of total dissolved solids. This clearly indicates that the method used was more reliable.

From the results, the pH level was within the recommended range by WHO and NEMA, Total dissolve solids were below the maximum recommended value with a range of between 87.9mg/L and 184.9mg/L, Total suspended solids ranged between 8.91mg/L and175.9mg/L which was higher than the maximum allowable level of 30mg/L, Nitrates ranged between 2.71mg/L and 11.50mg/L, Phosphorous ranged between 0.61mg/L and 6.26mg/L, Ammonium ranged between 0.13mg/L and 0.55mg/L, Copper ranged between nil and 0.96mg/L, Zinc ranged from 0.07mg/L to 4.99mg/L, while lead were not detected in all dams except Kapewot during dry season with a concentration of 0.87mg/L, Lead was detected during dry season in two dams only Cheboloigo and Kapewot with concentration of 0.46mg/L and 1.98mg/L respectively, Fluoride was higher than the recommended level of 1.5mg/L its ranged from 1.25mg/L to 5.33mg/L which indicates high fluorides in the area.

Generally, the levels of fluorides in all studied dams was higher than the maximum allowable value for domestic purpose and the concentration of fluorides during the wet season was higher than that of dry season.

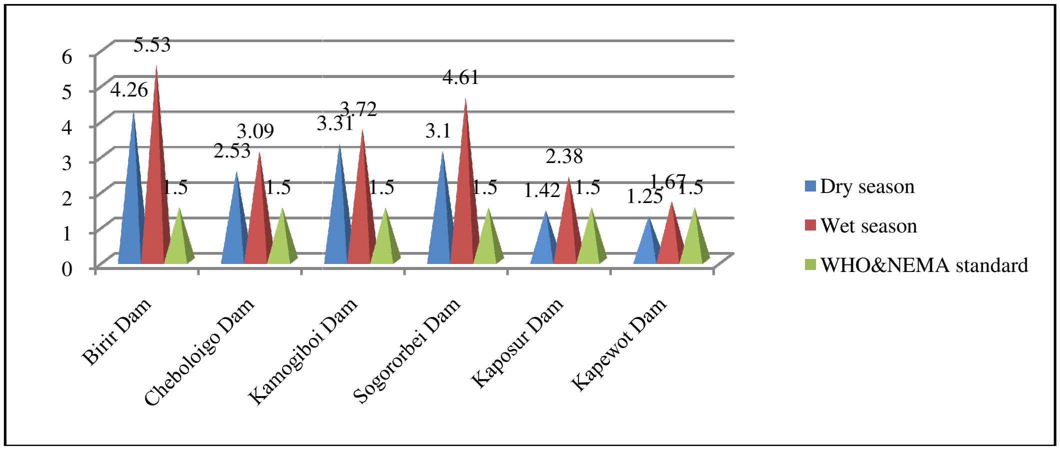

Figure 8: Comparison of the fluoride concentrations in dam water samples in dry and wet seasons with the WHO standard

5. Conclusion

From the results, it's clear that the source of fluorides in these dams is soil. During wet season, there is high level of fluorides which indicates that fluorides are washed to the dams but after some time it leached to the ground or form insoluble salts which settle to bottom of the dam. Rain water is contaminated with zinc but the concentration is within the recommended range and is likely to be originating from iron sheet which are coated by aluminum and zinc. The level of zinc in Kaposur and Kapewot dam is higher than the recommended value its likely to be originating from the soil and the fertilizers applied. Most of the pollutants are within the recommended levels. Di-ammonium Phosphate fertilizers contribute to the levels of fluorides and zinc. Rain water has low levels of this pollutant since it does not interact with soil. The PH of water from these dams is within the recommended range of 6.5 to 8.5. In conclusion, water from these dams is not suitable for use directly for domestic purpose before treatment.

6. Recommendation

Local population should be educated about the quality of water from these dams and provide treatment facilities for reducing fluoride and zinc concentration to avoid long term effect of high fluoride and zinc concentration.

Local population should be provided with subsidize water tank for collection of rain water which has low level of pollutant and hence can be used for cooking and drinking.

More studies should be carried out to determine if these pollutants are being transferred to food crops and domestic animals in this area.

Local population should consider filtering water from these dams since it has high levels of total suspended solids.

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Appendix A

- A.1: Preparation of the nitrates standard curve

The calibration standards were prepared and UV/Vis spectrometer T80+ was used for analysis of nitrates, ammonium, and phosphorous

The wavelength used was for nitrate detection was 220 nm, detection limit was 0.02ppm. The standard concentration are shown in Table A.1 and the calibration curve in Figure A.1

Standards	Concentration	Absorbance
1	0	0
2	0.2	0.05
3	0.5	0.126
4	1	0.255
5	3	0.765

Table A.1. 1: Nitrate standard for preparation on calibration curve

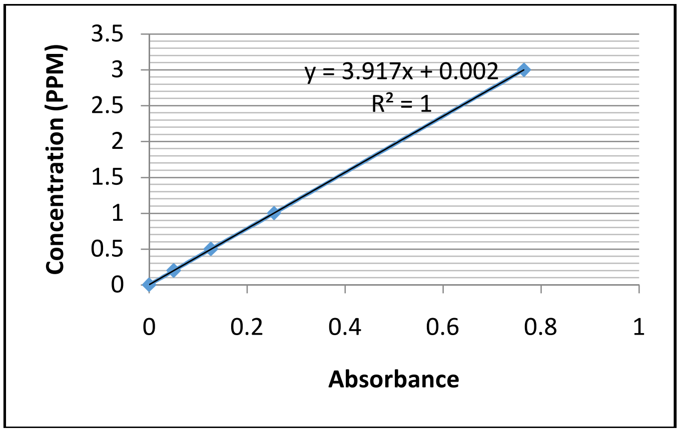

Figure A.1: Nitrate standard calibration curve

- A.2: Preparation of the ammonia standard curve

The wavelength used was 220 nm, detection limit was 0.02ppm. The standard concentrations are shown in Table A.1.2 and the calibration curve in Figure A.2

Standard	Concentration	Absorbance
1	0	0
2	0.5	0.079
3	1	0.152
4	3	0.451
5	5	0.758

Table A.1. 1: Ammonium standard solutions for the preparation of calibration curve

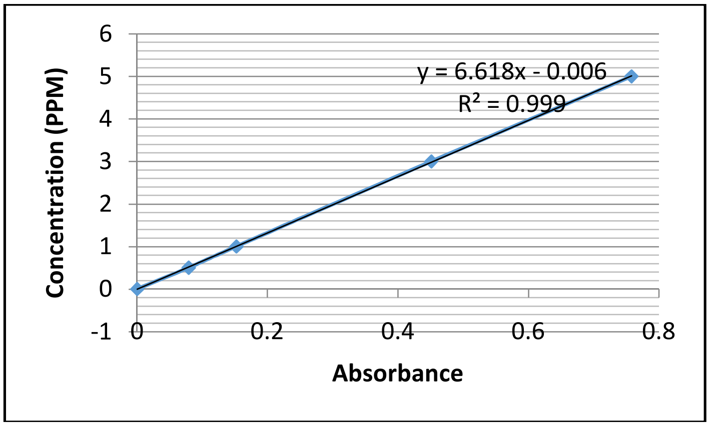

Figure A.2: Ammonium standard calibration curve

- A.4: Preparation of the phosphorous standard curve

The wavelength used was 430.nm, detection limit was 0.02ppm. The standard concentrations are shown in Table A.1.4 and the calibration curve in Figure A.4

Standard	Concentration	Absorbance
1	0	0
2	1	0.006
3	2.5	0.015
4	5	0.031
5	10	0.062

Table A.1. 4: Phosphorous standard solutions for the preparation of calibration curve

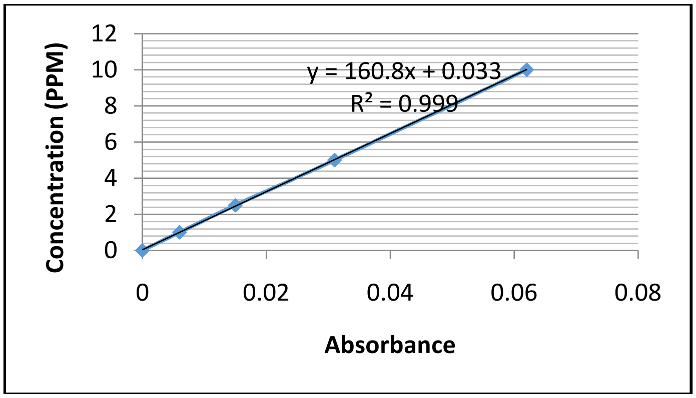

Figure A.4: Phosphorous standard calibration curve

Appendix B

- B.1: Preparation of the copper ion calibration standard

Atomic absorption spectrometer Spectra AA-10 instrument was used in the analysis of all the metal ion concentrations.

For copper analysis, the lamp current was 3mA, wavelength was 327 .4 nm, the slit with was 0.1 nm. The fuel used was acetylene and the oxidant is air, the detection limit was 0.003 ppm and sensitivity was 0.04 ppm

The calibration standard are given in Table B.1.1 and the calibration curve in Figure B.1

Standard	Concentration	Absorbance
1	0	0
2	0.5	0.032
3	1	0.066
4	3	0.199
5	5	0.331

Table B.1. 1: Copper standard solutions for the preparation of calibration curve

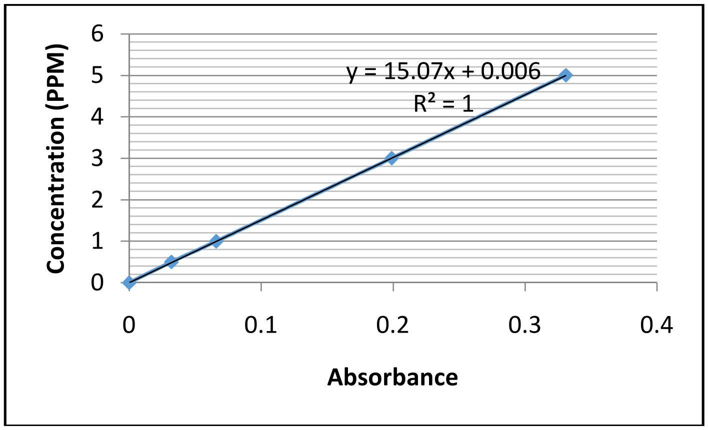

Figure B.1: Copper standard calibration curve

- B.2: Preparation of the copper ion calibration standard

For cadmium analysis, the lamp current was 8 mA, wavelength was 228.8 nm, and the slit width was 0.5 nm. 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 standard are given in Table B.1.2 and the calibration curve in Figure B.2

Standard	Concentration	Absorbance
1	0	0
2	0.5	0.05
3	1	0.098
4	1.5	0.147
5	2	0.196

Table B.1. 2: Cadmium standard solutions for the preparation of calibration curve

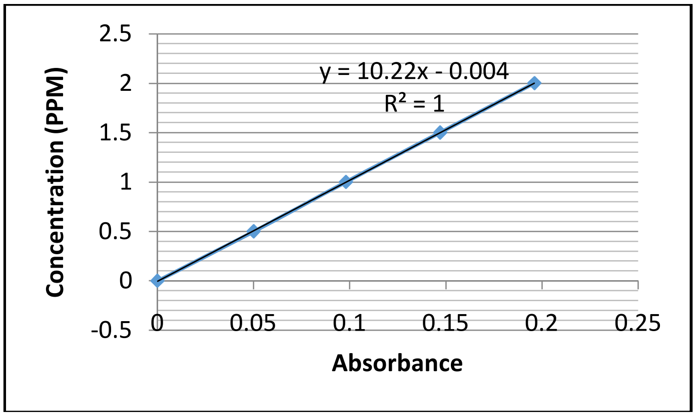

Figure B.2: Cadmium standard calibration curve

- B.3: Preparation of the zinc ion calibration standard

For zinc analysis, the lamp current was 3mA, wavelength was 213.9 nm, the slit with was 0.1 nm. The fuel used was acetylene and the oxidant is air, the detection limit was 0.002 ppm and sensitivity was 0.009ppm. The calibration standard are given in Table B.1.3 and the calibration curve in Figure B.3

Standard	Concentration	Absorbance
1	0	0
2	0.5	0.014
3	1	0.025
4	3	0.079
5	5	0.132

Table B.1.3: Zinc standard solutions for the preparation of calibration curve

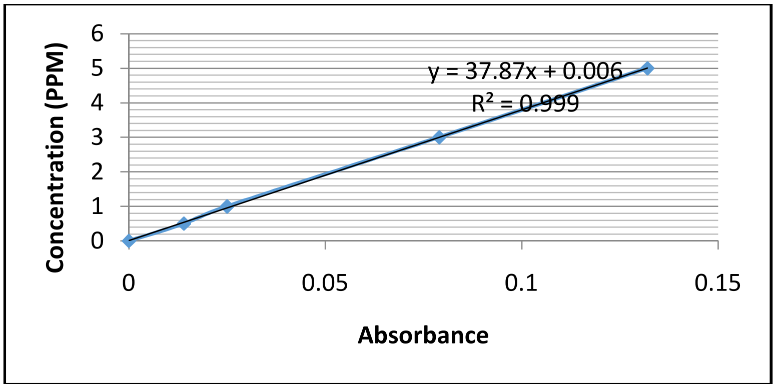

Figure B.3: Zinc standard calibration curve

- B.4: Preparation of the lead ion calibration curve

For the lead analysis, the lamp current was 5mA, wavelength was 217.0 nm, the slit with 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 standard are given in Table B.1.3 and the calibration curve in Figure B.4

Standard	Concentration	Absorbance
1	0	0
2	0.5	0.12
3	1	0.026
4	2.5	0.063
5	5	0.127

Table B.1.4: Lead standard solutions for the preparation of calibration curve

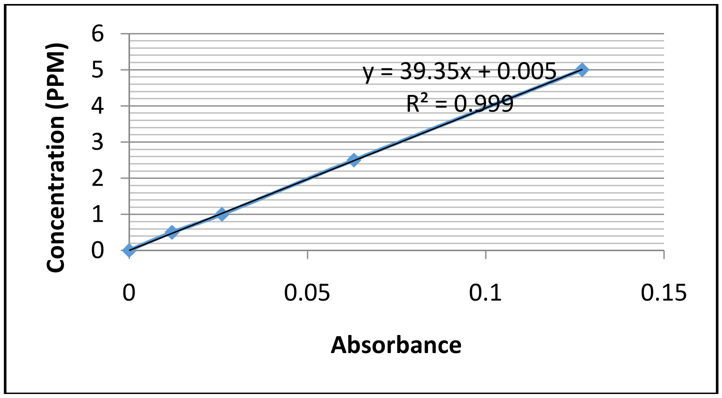

Figure B.4: Lead standard calibration curve

- B.5: Preparation of the lead ion calibration curve

For the Chromium analysis, the lamp current was 7 mA, wavelength was 357.9 nm, the slit with was 0.2 nm. The fuel used was acetylene and the oxidant is air, the detection limit was 0.005 ppm and sensitivity was 0.055 ppm. The calibration standards are given in Table B.1.5 and the calibration curve in Figure B.5

Standard	Concentration	Absorbance
1	0	0
2	1	0.075
3	2.5	0.181
4	5	0.352
5	10	0.709

Table B.1.5: Lead standard solutions for the preparation of calibration curve

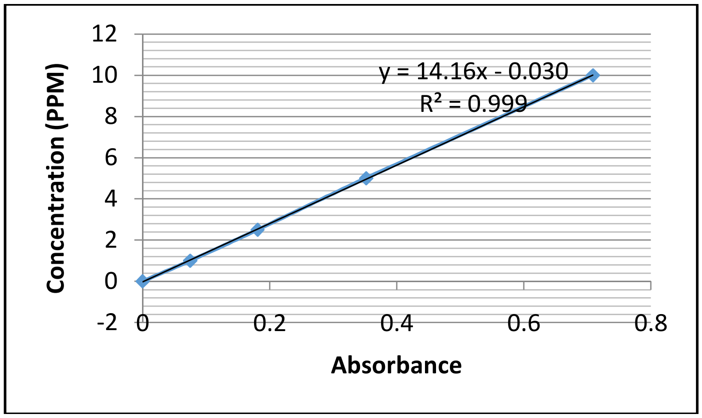

Figure B.5: Chromium standard calibration curve