DEFLUORIDATION WITH BONE CHAR

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DECLARATION AND RECOMMENDATION

Declaration

I Kariuki Samuel Mwangi, hereby declare that this thesis is my original work and has not been submitted for an award in any other institution of learning to the best of my knowledge.

Signed:.. Date. 22/02/2012

Kariuki S. M.

SM11/ 1502/05

Recommendation

We wish to confirm that this thesis was done under our supervision and has our approval to be presented for examination as per the Egerton University regulations.

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DEDICATION

This work is dedicated to my wife Terry and our children Kariuki and Kanyi for their encouragement and patience during my studies.

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ABSTRACT

Fluoride is an essential mineral that is present in trace amounts in the human tissue but is concentrated in bones and in teeth where it forms part of the bone and teeth crystalline structure. Ingestion of levels of fluoride greater than 1.5 mg/L during the period of tooth formation causes dental fluorosis while individuals depending on water supplies with fluoride levels greater than 3–6 mg/L or ingesting more than 10–20 mg of fluoride daily are likely to develop skeletal fluorosis after 10–20 years of exposure. Several defluoridation agents have been employed to remove fluoride from water. Bone char is the most widely used defluoridating agent in developing countries Kenya being one of them. Bone char is obtained by heating bones in a kiln at temperatures of 400–500°C in a controlled flow of air. The charred bones are packed in specially constructed defluoridating buckets. Apparently, due to the enormity of the fluoride problem, little attention seems to have been given to the effect the defluoridation agent may have on other essential mineral ions in water. Fluoride is believed to be removed from water by either the process of ion exchange with the hydroxyl ion of the bone hydroxyapatite or by adsorption. The metals which have long accumulated in the bone during the process of growth and metabolism could leach into water, or those in water could be captured just like fluoride during defluoridation. This study sought to find out whether when bone char is used as a defluoridating agent affects the concentration of some essential mineral ions in drinking water. Columns simulating defluoridation buckets were packed with bone char and water samples to be defluoridated collected after a resident time of 30 minutes. The water samples collected were analysed for changes in K^+, Na^+, Mg^{2+}, Fe^{2+}, Ca^{2+}, Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-} and PO_4^{3-} concentrations. Flame photometric method was used to determine the concentrations of K^+ and Na^+ while Mg^{2+}, Fe^{2+} and Ca^{2+} were analysed using an Atomic Absorption spectrophotometer. The concentrations of chlorides, carbonates and bicarbonates were determined titrimetrically while that of phosphates was done colorimetrically. The concentration of K^+, Na^+, Cl^-, CO_3^{2-}, HCO_3^-, Ca^{2+} and Fe^{2+} decreased on defluoridation. The concentration of Mg^{2+}, SO_4^{2-} and PO_4^{3-} increased on defluoridation but not above the WHO recommended levels. The pH also increased and in some cases above the WHO recommended range. However, defluoridation was not found to affect the quality of drinking water.

APPENDICES

INTRODUCTION

1.1 Background to the study

Fluorine, the 13th most abundant element in earth's crust (625mg /kg), often has a natural rock-derived origin in water (Koritnig, 1951). It occurs in minerals such as fluorspar, cryolite and flourapetite. The volcanic base rock in the African rift system is predominately alkali and rich in such minerals ions as sodium and fluoride. The soil produced by weathering of these rocks is similarly rich in fluoride (Bjorvatn, *et al.,* 1997). High fluoride concentrations occur often in areas of former volcanic activity. In Kenya and Tanzania in the old volcanic alkaline Rift Valley, fluoride is assumed to originate from dissolution of fluorite, evaporative concentration and hydrothermal activity (Griffoen, 1986). Since the hydro-chemistry of aquifers is strongly influenced by the surrounding lithology, the fluoride content of ground water of the rift valley is high, frequently to the extent that waters are rendered unfit for human consumption (Gaciri and Davies, 1993; Shenkut, 1997). During precipitation, rainwater leaches fluoride from the soils as well as from crystalline rock (Kilham and Hecky, 1973). The concentration of fluoride in ground water is dependent on the geology of the aquifer. Factors like the availability of fluoride containing minerals, the weathering and age of the rocks and the total history of the water from precipitation till it emerges in a spring determine the fluoride concentration (Griffoen, 1986).

Fluoride is an essential trace mineral that is present in trace amounts in every human tissue but becomes concentrated in bones and teeth (Williams and Caliende, 1984). Fluoride in foods and water is easily observed by way of portal system. From the amount ingested, about half is retained in bones and teeth and the rest is excreted in urine (Williams and Caliende, 1984; WHO, 1970). A study carried out to determine the levels of fluoride in foods indicate that food categories with the highest mean fluoride levels were; fish (2.118 mg/L), beverages (1.148 mg/L) and soups (0.606 mg/L). Individual samples with highest fluoride levels were; tea (4.97 mg/L), canned fish (4.57 mg/L), shellfish (3.36 mg/L), cooked veal (1.23 mg/L) and cooked wheat cereal (1.02 mg/L) (Agency for Toxic Substances and Disease Registry, 2001).

The use of fluoridated salt is becoming increasingly widespread across the globe. Thus this source of fluoride exposure is becoming increasingly important and insidious. Fluoridated salt usually contains about 250 mg/L fluoride which would result in daily intake of 2.5 mg of programmes include; Austria, Bolivia, Colombia, Costa Rica, Dominican Republic, France, Germany, Honduras, Nicaragua, Panama, Switzerland and Venezuela (Marthaler, 2006).

Ingestion of fluoride during the period of tooth development causes dental fluorosis (Fantaye *et al*, 1997). Studies by Bårdsen and Bjorvatn (1997) indicate that the first year of life is the most important period for the development of dental fluorosis in the maxillary permanent central incisors. Infact, severity of dental fluorosis increases during this period (Fejerskov *et al.*, 1988). An inverse relationship seems to exist between the severity of dental fluorosis and the age at which exposure took place (Fantaye *et al.*, 1997). Individuals depending on water supplies with fluoride levels greater than 3-6 mg/L or ingesting more than 10-20 mg of fluoride daily are likely to develop skeletal fluorosis after 10-20 years of exposure (WHO, 1984). Mild form of dental fluorosis is characterized by opaque white lines, which fuse to form opaque white patched mottled enamel. It may be stained yellow to dark brown by uptake of pigments from food and drinks after the teeth have erupted (van Palestein Helderman *et al.,* 1995). In more severe cases discrete pits occur on the enamel. Early skeletal fluorosis is not clinically obvious even though radiological changes are discernible in the skeleton at early stages (Jolly *et al.*, 1969). In advanced stages, it is manifested with restriction of movement of the spine and of the joints of the limbs and with neurological complications (Siddiqui, 1955).

Besides food and water, the other important source of fluoride is *magadi*. *Magadi* is the local name for trona, $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$ an evaporite mineral which can be found at alkaline lakes (crystalline) or as an efflorescent crust (scooped) on the earth's surface in the Rift Valley of East Africa (Nielsen and Dahi, 1995). Trona is often contaminated with fluoride which is caused by high fluoride content of the volcanic rocks enriched in alkalis in the Rift Zone (Gerasimovsky and Savinova, 1969). In trona, fluoride occurs as villiamite, NaF, and as kogarkite $Na_2SO_4.NaF$ (Darragi *et al.*, 1983) and the fluoride concentration in magadi varies between 0.2 and 14.9 mg/g (Baker 1958; Nanyaro *et al.*, 1984; Mungure, 1987; Mabelya *et al.,* 1992). Communities in the central region of Tanzania who use water of fluoride content as low as 0.4 mg/L are still affected by severe dental fluorosis. This has been attributed to use of *Magadi* (van Palestein Helderman *et al.*, 1995). Some communities in East, Central and West Africa use *Magadi* as; a tenderizer to speed-up the cooking process for food such as beans, maize and meat, a flavoring agent and a *al*., 1992; Makanjuola and Beetlestone, 1975; Malentlema, 1982; Mungure 1987; Sodipo 1993; Uzogora *et al.,* 1990; WHO 1984; Baker, 1958). In some cases the fluoride uptake from *Magadi* may be higher than that from water (Mabelya *et al.,* 1992).

Generally fresh water is low in fluoride concentration. It has been said that more than 95% of fresh water sources in the world contain less than 1.5 mg/L fluoride (Phantumvanit *et al*., 1988). The problem arises in the remaining 5% of the water sources which is distributed all over the world with dominance in the developing countries. Overviews of the fluoride concentrations in drinking water sources have been reported in the form of tables with the highest and the lowest concentrations in different countries (Cholak, 1959; Moller, 1965). A general or average fluoride concentration in a country or area is not justifiable because concentrations may vary even between adjacent sources. Normally, an area is said to have a high fluoride concentration if its ground water has a fluoride concentration higher than 1.5 mg/L (WHO 1984). The most intensive mapping of fluoride concentration in drinking water has been done in USA. High and extreme high concentrations are generally found in the states bordering Mexico and around the vertical center line of the country (Cholak, 1959; Moller, 1965; JRB, 1984). Concentrations of more than 8 mg/L in some water supply systems have been reported (JRB 1984). In the rest of America, Argentina has been cited to have high concentrations of fluoride (Troiani *et al*., 1987; Moller, 1965). In Africa, countries along the Rift Valley for example Ethiopia, Kenya and Tanzania are probably facing the most severe problems with fluoride in drinking water. In the north eastern provinces of Tanzania and Southern and Central Kenya concentrations of more than 8 mg/L are commonly consumed (Bardecki, 1974; Nair *et al.,* 1984). In the Ethiopian Rift Valley several villages are supplied with drinking water containing more than 30 mg/L (Haimanot *et al.,* 1987). In Asia most attention has been drawn to the fluoride problem in India. A large number of people in various parts of India are hit by high concentrations of fluoride which, however, rarely exceed 10 mg/L (Handa, 1975; Bulusu *et al.,* 1979). China, where it is reported that some 100 million people are affected (He *et al*., 1995), Thailand and Japan are also facing the same problem but they are generally seen to be scattered (Moller, 1965; Cholak, 1959; Gao *et al*., 1994). The problem is normally overcome by utilization of alternative water sources. A study in the Njoro Division of Nakuru District, Kenya showed that 48.3% of children had the problem. (Moturi *et al.*, 2002).

Several defluoridating agents have been employed with different degrees of success. Use of bone char , prepared by heating bones in a special kiln at 400–500C in a controlled oxygen atmosphere for 10–14 days, is the commonest agent used in Kenya. Bone char is packed and sold in special domestic defluoridation units by the Catholic Diocese of Nakuru(CDN). Large community defluoridation units have also been constructed among communities severely affected by the fluoride problem to provide them with safe water for domestic consumption.

1.2 Statement of the problem

The preparation of bone char involves subjecting the bones to high temperatures (400–500 ^{o} C) for 10–14 days. This could leave some of the mineral ions long accumulated in bones during the process of growth and metabolism loosely held due to the breaking down of the bone matrix. These metals could leach into the water and on the other hand, just like fluoride, other ions could be captured by the bone by ion – exchange or adsorption processes. Although bone char has been demonstrated to be efficient in water defluoridation, no studies have been done to find out if it affects the quality of the effluent in terms of mineral content. It is necessary to find out if apart from removing fluoride, the bone char changes the composition of water in any way. Preliminary reports show that there could be leaching of some metals into water and removal of others during defluoridation.

1.3 Objectives

1.3.1 General Objective

To find out whether the mineral ions in bone char leach into water and whether some common ions in drinking water are exchanged or adsorbed during defluoridation.

1.3.2 Specific Objectives

1. To determine the concentration of mineral ions expected in high concentrations in bones, that is; K^+, Na^+, Mg^{2+}, Fe^{2+}, Ca^{2+}, CO_3^{2-}, HCO_3^- and PO_4^{3-} in samples of bone char before it has been washed and after it has been washed, dried and packaged for use.

2. [illegible] water samples obtained from fluorotic areas of Lanet and Njoro before and after defluoridation using bone char.
3. To determine whether any mineral ions leach from the bone char during defluoridation
4. To determine the pH of water before and after defluoridation and find out whether it conforms to the WHO standards.
5. To ascertain that the mechanism of the process in defluoridation is only by exchange with the OH^-.

1.4 Hypotheses

1. The concentrations of K^+, Na^+, Mg^{2+}, Fe^{2+}, Ca^{2+},CO_3^{2-}. HCO_3^- and PO_4^{3-} in bone char decrease on washing.
2. Defluoridation reduces the concentrations of mineral ions in water.
3. Mineral ions leach into water during defluoridation.
4. pH of water decreases on deflouridation.
5. The mechanism of defluoridation is not by exchange with the OH^- ion.

1.5 Justification of the study

Bone char remains the most common defluoridation agent for water with high levels of flouride in Eastern Africa. World Health Organization (WHO) has provided guidelines for permissible levels for some mineral ions important to the human body. It is important to evaluate whether or how defluoridation affects the quality of drinking water.

1.6 Definition of Terms.

Dental fluorosis: A condition caused by ingestion of excess fluoride and manifested by browning and chipping of teeth.

Skeletal fluorosis: A crippling condition of the limbs caused by ingestion of excessive fluoride.

Fluorotic region: A region whose groundwater has a fluoride concentration greater than 1.5 mg/L and hence a high prevalence of fluorosis.

Defluoridation: Removal of fluoride from water contaminated with fluoride.

1.7 Expected outputs

1. Data that will be shared with stakeholders, especially Catholic Diocese of Nakuru, in the use of bone char as defluoridation agent for onward transmission to the communities in fluorotic regions in the country.
2. Point out gaps for further investigation in this area of research.
3. Publish the results of the study in refereed journals.

LITERATURE REVIEW

2.1 Defluoridation techniques

In the past decade, a wide range of defluoridation materials and methods have been investigated and analyzed, mainly on a laboratory scale. Insufficient removal efficiency, complicated maintenance and/or unaffordable costs, particularly for rural populations, are the main reasons why these methods have been rarely implemented in developing countries, except in some areas. The most common defluoridation methods used include activated alumina, Nalgonda technique, tricalcium phosphate, magnesite, activated clay, bone char, and contact precipitation.

2.1.1 Activated Alumina

Activated alumina (γ-AlO_3) often used as a filter media to remove fluoride, is especially widespread in industrialized nations. However, in India UNICEF is financing defluoridation projects using activated alumina for household water treatment, and supporting more than 25,500 households with defluoridation units (Müller *et al*., 2006). In East Africa, only two communities (in the central parts of Ethiopia) treat fluoride-rich groundwater with activated alumina. Special plants have been constructed for this purpose. These alumina plants have been in operation for more than 40 years without major upgrading. Their removal efficiency is relatively low (60 %) on account of maintenance and age problems (Müller *et al* 2006). Another drawback of this method in Ethiopia is the high cost of activated alumina, a chemical that has to be imported from overseas.

2.1.2 Nalgonda technique

On adding alum ($AlK(SO_4)_2.12H_2O$) and lime ($Ca(OH)_2$) to the raw water, insoluble aluminum hydroxide floccules are formed, sediment to the bottom and co-precipitate fluoride. This method, commonly known as the Nalgonda Technique, was named after the Indian village where it was developed. The method is most popular in India; however, it has also been applied in Ethiopia on household and community level. Nalgonda defluoridation units can reduce fluoride concentration from ~10 mg/L to ~2.5 mg/L; none of the evaluated plants in East Africa meets the WHO international guideline value of 1.5 mg/l (Müller *et al*., 2006). Moreover any deviation from pH 7 leads to an increase in residual aluminium concentration, which is also highly dependent on the amount of suspended aluminium hydroxide flocs. Aluminium seems to be toxic

Technique is rather work-intensive, as chemicals have to be added daily and manual stirring for 15 minutes is required.

2.1.3 Tricalcium Phosphate

Tricalcium phosphate (TCP) has been used to remove fluoride from drinking water since 1930's. Studies by He *et al*., (1995) has shown that there is a negative correlation between the defluoridation efficiency of TCP and the pH levels of raw water, and a positive correlation between the defluoridation efficiency and the temperature as well as contact time.

2.1.4 Magnesite

Magnesite is a mineral form of magnesium carbonate. In Eastern Africa it is available and being exploited at the Chambogo mines in the northern part of Tanzania (Singano, 1991). Studies by Singano *et* a*l*., (1995) have shown that magnesite calcined into magnesia (MgO) has an optimum fluoride removal capacity at pH levels between 10.0 and 11.0. For drinking water purposes it is recommended that the pH be adjusted after treatment.

2.1.5 Clay

Clay consists of minute mineral particles which have precipitated under water. The main components of clay are oxygen, silicon, and aluminium. Smaller amounts of iron, potassium, calcium, magnesium and other elements are also present. Ndegwa (1980) reported a fluoride binding capacity of 80 mg/kg; while Zewge and Moges (1990) found that pot chips were able to bind as much as 560 mg/kg. Hendrickson and Vik (1984) however, concluded that fluoride uptake in clayware is slow and of limited capacity. Later work by Hauge *et al*., (1994) has concluded that firing clay at temperatures between 500 and 700^{o}C produced clayware with optimal binding properties, while the fluoride binding processes were greatly reduced by firing above 800^{o}C. Bårsden and Bjorvatn (1995) reported good results by use of laterite clay from Balang, Northern Cameroon calcined at 570^{o}C for three hours. Here the fluoride concentration was reduced from 5.47 to 0.48 mg/L in two hours, from 12.2 to 0.26 mg/L in twelve hours and from 31.2 to 0.76 mg/L in twelve hours.

Charred bone has been proposed as an agent for defluoridation of water since 1935 (Smith and Davey, 1939) and has been used as such in water works in the USA (Horowitz, *et al.*, 1972). It was later replaced by activated alumina and reintroduced in Thailand in the late 1980s. It is now one of the most promising defluoridating agents for use in the developing countries (Phantumvanit *et al.*, 1988). It can be produced locally by charring animal bones at approximately 450^{0}C in a low oxygen atmosphere (Dahi, 2000). After charring, the bones are washed and subsequently used as a filter material. Over 1,000 household and 40 community filters, equipped with bone char as a filter medium, have been implemented so far in Kenya and Tanzania (Müller *et al.*, 2006). Mavura *et al.*, (2004) have attempted to construct a cartridge filter packed with bone char and whose length, flow rate of water; compactness and particle size have been optimized for removal of fluoride when it is connected to a domestic faucet. A major drawback of this method is its restricted acceptance, for instance among some Hindu communities, which refused it on account of the cattle bones used in this method. The efficiency of locally manufactured filters has been evaluated by Mavura and Bailey (2002).

2.1.7 Contact Precipitation

Contact precipitation, a recently developed method, was first tested in a pilot plant in Tanzania (Dahi, 2000). Addition of calcium and phosphate to the raw water leads to a precipitation of fluoride when it comes into contact with bone char. The Catholic Diocese of Nakuru (CDN), a non-profit organization in Kenya, has supplemented its bone char filter units with specially developed pellets releasing calcium and phosphate to the raw water since 2006 (Müller *et al.*, 2008).

Coetzee *et* al (2003) found bauxite clays to have the best overall potential for fluoride adsorbents. Other clay types could have their adsorption capacity enhanced by chemical activation using 1% Na_2CO_3 solutions and dilute HCl.

2.2 Bone structure

Mature bone is about 60% mineral and 40% collagen. The mineral portion of the bone consists of poorly crystallized, CO_3^{2-} containing, Ca-deficient hydroxyapatite analog (Posner, 1985). The special nature of bone mineral surface from *in vitro* and *in vivo* ion exchange studies has been ions are taken up from solution and bound on bone mineral surfaces.

Hydroxyapatite can remove certain ions from solution in the sense of physical adsorption, while it can also exchange solution ions for crystal surface ions. Large chemical groups, such as tetramethylammonium ions are physically absorbed. Certain ions comparable to Ca^{2+} in size and charge (Sn^{2+}, Na^{+}) and other ions not necessarily able to substitute Ca^{2+} in the apatite structure (Ba^{2+}, Ra^{2+}, Mg^{2+}, Li^{+}, K^{+}) will exchange readily from solution for surface Ca^{2+} (Posner, 1985). The exchange of solution anions, such as PO_4^{3-} and F^-, for surface ions has been described extensively. The fluoride reaction is of interest because it is not reversible, since the substitution of F^- for OH^- on the surface results in a more stable compound.

2.2.1 Preparation of Bone Char

The preparation of bone char is crucial for its properties as a defluoridation agent and water purifier. Unless carried out properly, the bone charring process may result to a product of low defluoridation capacity and/or deterioration of water quality (Dahi, 2000). Bone char is obtained by bones being calcined between 400 and 500℃ for 10−14 days (CDN and Müller, 2007). During the process the organic materials in the bone crack to low molecule, volatile compounds which evaporate. The residual organic carbon mineralizes to graphite. The graphite remains in the porous apatite structure (Jacobsen and Dahi, 1997).

Locally, charring of bones is done at Catholic Diocese of Nakuru (CDN) water programme centre. Bones are delivered to CDN from local cattle and camel butcheries. A full kiln load takes about one week for the charring process to be complete. It is believed that the total heat required and the duration for complete charring depend to a large extent on the batch size and the packing rather than the type or nature of the bone (Dahi and Bregnhoj, 1995).

When the charring process is complete, the bone char is cooled and then sorted. Any uncharred bones are set aside to be returned to the kiln. Good bone char is grey to black brittle material that is then ground to small particles ranging from 0.2 mm to 4.0 mm diameter. The different particle sizes are separated using sieves and those between 0.63 and 2 mm are packed in beds which are then washed with a spray of water from above until no color is observed in the effluent. The clean material is then air dried and packed in buckets fitted with faucets and sold to users.

Bone char has specific ability to take up fluoride from water. This is believed to be due to its chemical composition, mainly hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$, where one or both the hydroxyl groups can be replaced by fluoride.

The chemical equation for the principal reaction is:-

$$Ca_{10}(PO_4)_6(OH)_2 + 2F^- \rightleftharpoons Ca_{10}(PO_4)_6F_2 + 2OH^- \dots\dots\dots\dots\dots\dots\dots.. (1)$$

When analyzed for major components, the bone char shows the content of calcium phosphate, 57−80%, calcium carbonate, 6−10%, and activated carbon, 7−10% (Dahi, 2000). There is apparently no reported work to investigate what absorption effect the bone char would have on any of the mineral ions in drinking water.

2.4 Previous work on effect on quality of water by defluoridation agents

Bårdsen and Bjorvatn (1997) have demonstrated defluoridation of water by the use of laterite red clay from Balang, Northern Cameroon. The elemental composition of the clay was analysed by the use of a Philips SEM 515 scanning electron microscope combined with an EDAX PV 9900 energy dispersive X-ray analyzer KV = 20.0. The elemental composition is given in table 1 below;

Table 1: Composition of laterite clay from Balang, Cameroon.

Element	Na	Mg	Al	Si	P	K	Ca	Ti	Fe	Ni	Cu
% Weight	0.10	0.60	30.50	25.13	0.15	0.29	0.18	6.10	36.83	0.07	0.15

Adapted from: Bårdsen and Bjorvatn (1997)

The chemical profile of water before and after defluoridation is given in Table 2;

from Balang, Cameroon.

Element	Before µg/g	After µg/g	Element	Before µg/g	After µg/g
F	7.76000	0.15000	Pr	0.00000	0.00004
Li	0.00111	0.00077	Nd	0.00000	0.00012
B	0.00643	0.00226	Sm	0.00000	0.00001
Na	18.0000	15.0000	Eu	0.00001	0.00002
Mg	0.88550	0.90000	Gd	0.00000	0.00002
Al	0.01328	0.03773	Ni	0.00000	0.00154
Si	1.34100	1.00200	Cu	0.00513	0.07573
Ca	9.70000	2.30000	Zn	0.00000	0.00987
Sc	0.00110	0.00075	Ga	0.00019	0.00005
Ti	0.00962	0.00451	As	0.00011	0.00019
V	0.00011	0.00526	Se	0.00086	0.00395
Cr	0.00500	3.50000	Br	0.10750	1.31100
Mn	0.00024	0.01681	Rb	0.00189	0.00078
Fe	0.00632	0.02452	Sr	0.20000	0.20000
Co	0.00001	0.00046	Y	0.00001	0.00005
Rh	0.00003	0.00004	Zr	0.00001	0.00016
Pd	0.00001	0.00000	Nb	0.00000	0.00004
Cd	0.00029	0.00745	Mo	0.00848	0.00518
Sn	0.00000	0.00004	W	0.00290	0.00004
Sb	0.00000	0.00003	Os	0.00000	0.00003
I	0.00049	0.00127	Au	0.00000	0.00003
Cs	0.00007	0.00002	Th	0.00000	0.00002
Ba	0.06042	0.10630	U	0.00029	0.00001
Ce	0.00002	0.00019	–	–	–

Adapted from: Bårdsen and Bjorvatn (1997) laterite caused a relatively great decrease in the calcium concentration and a similar increase in the concentration of chromium. The increase in chromium is unwanted. However apart from chromium, all elemental concentrations in defluoridated water were safely within the limits accepted for drinking water quality (De Zuane, 1990).

Table 3: Impact on bicarbonate, sulphate and silica on drinking water samples defluoridated using alumina

Origin of data	Before treatment HCO_3^- mg/l	After treatment HCO_3^- mg/l	Before treatment SO_4^{2-} mg/l	After treatment SO_4^{2-} mg/l	Before treatment SiO_2 mg/l	After treatment SiO_2 mg/l	Before treatment Ca^{2+} mg/l	After treatment Ca^{2+} mg/l
Mineral water A	292	292	699	714	-	-	244	246
Mineral water B	299	295	305	312	-	-	168	165
Mineral water C	1452	1435	8	9	-	-	168	173
Mineral water D	4343	4307	179	176	16 SiO_3^{2-}	15.4 SiO_3^{2-}	80	80
Mineral water type 1	241	244	69	72	25.6 H_2SIO_3	23.9 H_2SIO_3	59.0	60,8
Mineral water type2	1650	1610	482	492	122 H_2SiO_3	111 H_2SiO_3	345	336
Mineral water type 3	798	786	—	2270	15.3 SiO_2	15.8 SiO_2	557	552
Spring A	280	300	63	58	-	-	3.0	3.0
Spring B	289	295	583	571	-	-	217.0	207.0
Spring C	326	329	295	337	21.0 SiO_2	19.0 SiO_2	162	168
Spring E	162	162	425	431	10.9 SiO_2	4.0 SiO_2	200	207
Spring F	322	322	44	44	-	-	-	-
Spring G	1452	1397	9	9	-	-	168	161

Adapted from: European Commission report of the ad-hoc working group on technological assessment of natural mineral water treatment (2006)

The adsorption effect for bicarbonate remains negligible even at very high contents (over 4 g/l). However, no substantial change in the sulphate content is observed after passing through the adsorber even for water with the highest sulphate concentration.

A study by Chen *et al* (2008) showed that bone char removed arsenic (V) from water by a complex mechanism of co-precipitation and ion exchange, and was strongly dependant on pH and dosage of adsorbent. Brunson and Sabatini (2009) have also shown that fish bone can remove fluoride and arsenic simultaneously with minimal competition albeit fluoride is removed more effectively than arsenic.

Garmes *et al* (2002) applied a hybrid process that combined the adsorption on conventional solid adsorbents such as aluminium and zirconium oxide along with a specific Donnan dialysis procedure to treat ground water with excessive fluoride. The cation composition remained unchanged whereas anions, except chloride, were partially eliminated and substituted by chloride ions, giving a fluoride concentration below the acceptable values

2.5 WHO and EU drinking water standards

WHO has provided guidelines for quality of drinking water since 1984 which have been reviewed over the years, the latest being in 1993. The EU has also come-up with their own standards which are more recent (1998), complete and more strict than the WHO standards. Below is a comparative table for the mineral ions for both WHO and EU standards.

Parameter	WHO standards (1993)	EU standards (1998)
pH	no guideline[(1)]	not mentioned
Conductivity	250 microS/cm	250 microS/cm
Cations (positive ions)		
Cadmium (Cd)	0.003 mg/L	0.005 mg/L
Copper (Cu)	2 mg/L	2.0 mg/L
Iron (Fe)	No guideline[(2)]	0.2 mg/L
Lead (Pb)	0.01 mg/L	0.01 mg/L
Manganese (Mn)	0.5 mg/L	0.05 mg/L
Sodium (Na)	200 mg/L	200 mg/L
Zinc (Zn)	3 mg/L	not mentioned
Anions (negative ions)		
Chloride (Cl^-)	250 mg/L	250 mg/L
Fluoride (F^-)	1.5 mg/L	1.5 mg/L
Sulfate (SO_4^-)	500 mg/L	250 mg/L
Nitrate (NO_3^-)	50 mg/L total nitrogen	50 mg/L
Nitrite (NO_2^-)	0.5 mg/L total nitrogen	0.50 mg/L

(1) Desirable: 6.5-8.5

(2) Desirable: 0.3 mg/L

Adapted from: (http://www.lenntech.com/WHO-EU-water-standards.htm, 2006)

MATERIALS AND METHODS

3.1 Bone char

Two bone char samples of particle size 0.63 – 2 mm were obtained from CDN water quality; one processed and ready for the packing of the domestic defluoridation units and the other in process (milled but not washed or air-dried).

3.2 Collection of water samples

Water samples were obtained from bore holes in Lanet, Egerton University and its environs. Water from two natural springs and one artificial well was also sampled. These are areas known to be fluorotic from earlier studies.The bore holes whose water was sampled were; Lanet New Creation Church old borehole (Labeled Lanet BH1), Lanet New Creation Church new borehole (Labeled Lanet BH2), Egerton University bore hole No.2 and No.12 (Labeled Egerton BH2 and Egerton BH12 respectively), Ng'ondu borehole and St. Joseph's Kihingo Catholic church borehole. The two natural springs in the environs of Egerton University were Maji moto and Njugu-ini spring, and the artificial well is a 15 metres dug-out well in Belbur. The samples were collected in new polyethene bottles previously washed with liquid detergent and hot water and then rinsed with distilled water. They were then filtered using a Whatman No.4 filter paper to remove any suspended material and stored in a refrigerator.

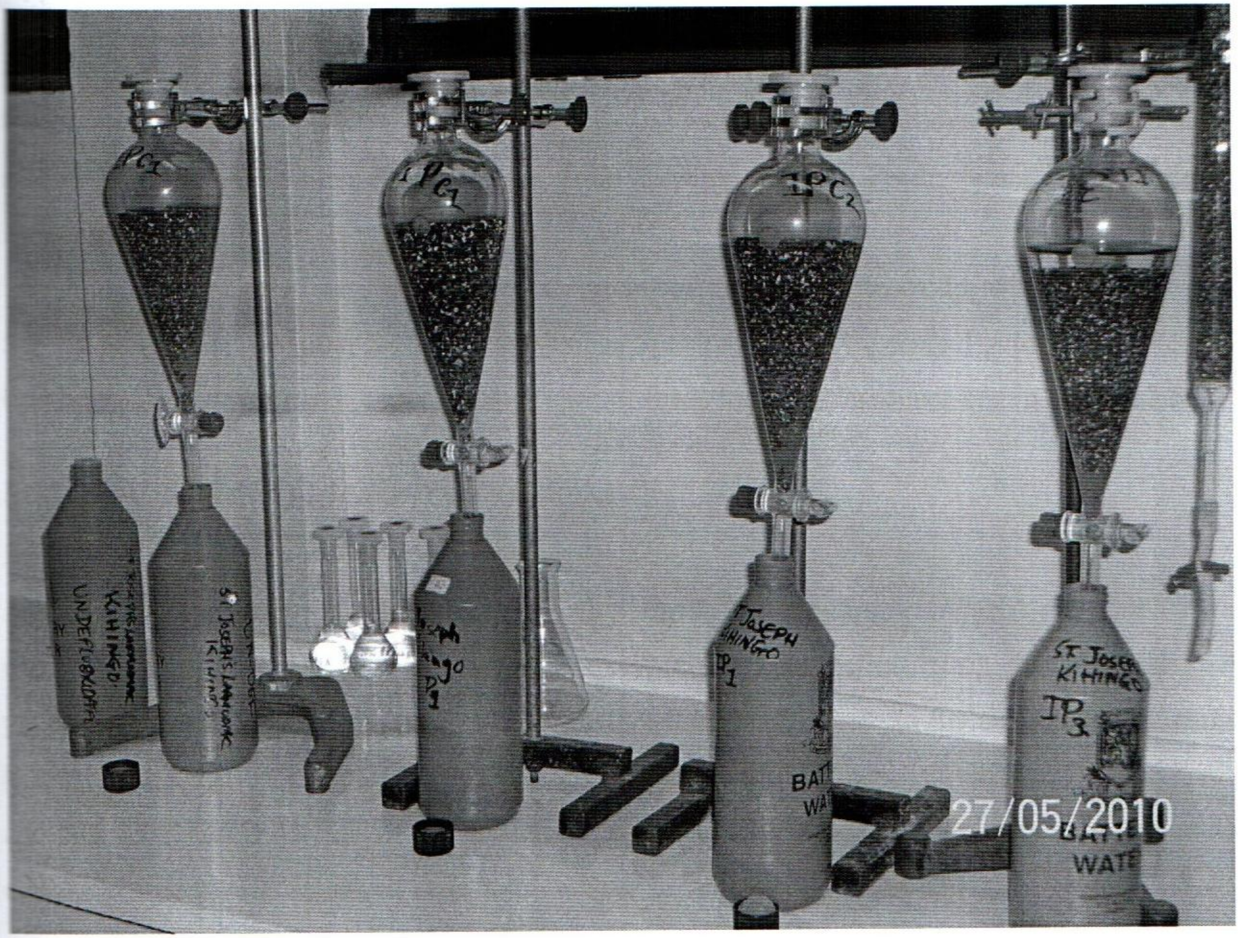
3.3 Washing of Glassware

All glassware were washed with warn water and liquid detergent, rinsed several times with tap water before being soaked overnight in chromic acid solution. They were then rinsed with distilled water followed by 1 in 15 parts dilute HNO_3 and then several portions of distilled water.

3.4 Setting up of defluoridation units

Defluoridation units were set up to simulate the domestic one manufactured by CDN.

Separating funnels of 500 mL volume were plugged with cotton wool and 300 mL bed volume of bone char added. The set up was done in triplicate for both samples of bone char. They were labeled; P1, P2, P3, for the processed bone char, and IP1, IP2, IP3, for the in-process ones. Enough distilled water was added to completely soak the bone char and left for 30 minutes before being drained off completely.



3.4.1 Defluoridation of the Water Samples

Enough of each sample to cover the bone char was added to each of the six units. They were then left to stand for 30 minutes before all the water was drained off into plastic sample bottles previously washed as in 3.2 above.

The procedure was repeated until 500 mL of the defluoridated sample was collected from each of the units.

3.5 Analyses of samples

3.5.1 Determination of Mineral Concentration of Bone Char

Two grams of each sample were weighed accurately in triplicate into an Erlenmeyer flask and 50 mL of 1:1 aqueous solution of hydrochloric acid added. The content of the flask was gently boiled to dissolve the minerals. This was then filtered into a 100 mL volumetric flask using Whatman No.4 filter paper and made to the mark with de-ionised water. A reagent blank was with de-ionised water. The concentration of Ca^{2+}, Mg^{2+} and Fe^{2+} in these preparations was analysed using a Atomic Absorption Spectrophotometer model S11 from Thermo Jarell Ash Cooperation of Waltham, MA, USA. Potassium and sodium concentrations were analysed using a Model 410 Corning Flame Photometer, from Corning Science Products of Halstead, Essex, England.

The concentration of F^- was determined using an Ion Selective Electrode, while for PO_4^{3-} and SO^{4-} a Novaspec II Model 80-2088-64 Visible Spectrophotometer from Pharmacia Biotech of Cambridge, U.K. was used. The details of each of these methods are described in section 3.5.2.

3.5.2 Analysis of defluoridated water samples

3.5.2.1 Determination of pH of water samples

A Model pH 211 Microprocessor-based bench pH/mV/^{0}C meter from HANNA instruments was used to measure the pH of the water samples before and after defloridation. A Whatman 0-14 pH paper was used to do a rough check on whether the samples were in the acidic or basic range. Buffers of pH 4.01 and 7.01 were used to calibrate the meter where samples were in the acidic and pH 7.01 and 9.18 for those in the basic range. The procedure described in the meter operation manual was followed and the pH values for the samples recorded.

3.5.2.2 Determination of potassium

Calibration standard solution of 2, 4, 6, 8 and 10 mg/L K were prepared by making serial dilutions of a 1000mg/l solution , prepared by dissolving 1.9353g analytical grade KCl from Merck UK in water and making up to 1 L with water.

A blank solution containing only distilled water was used to zero the instrument reading. The highest concentration standard 10 mg/L K was aspirated and after obtaining a stable reading the instrument controls were adjust to give a convenient reading of 10.0 emission readings. The standard solutions were removed and after waiting for 10 seconds, distilled water was aspirated for 20 seconds before readjusting the "blank" control for a 0.0 reading.

After 10 seconds the 10 ppm K standard solution was aspirated and the above procedure repeated until a blank reading of 0.0 was obtained and the 10 mg/L K standard gave a reading of 10.0 emission units.

between measurements. The value of each standard was noted and the results plotted against standard concentrations.

3.5.2.3 Determination of sodium

The procedure in 3.5.2.2 above was repeated for sodium using standard solutions of 5, 10, 15, 20, 25 and 30 mg/ L Na. The standard solutions were made by making serial dilutions of a 1000 mg/L solution prepared by dissolving 2.5285g dried NaCl, obtained from Fluka of Germany, in 1 litre of water

3.5.2.4 Determination of calcium, magnesium and iron

The instrument parameters were set as per the manufacturer's operation manual recommendations for each metal. However, the burner height and fuel (acetylene) flow rate were optimised to obtain a maximum absorbance reading with the middle standard for each of the metals. Standards solutions of 1, 3, 5, 10, 15 and 20 mg/L for Ca, 0.1, 0.2, 0.3 and 0.4 mg/L for Mg, and 1, 2, 3, 4 and 5 mg/L for Ca were used to get a calibration curves. A reagent blank of distilled water was used to zero the instrument readings. A reagent blank of distilled water/ HCl described in section 3.5.1 was used for the digested bone-char samples.

Absorbance readings were taken at 422.7 nm for Ca, 285.2 nm for Mg and 248.3 nm for Fe. The concentrations of the three metals in every sample were read off from the calibration curves.

3.5.2.5 Determination of the concentration of fluoride in water

Fluoride content in water was determined using the procedure described in the instruction manual for the Thermo Orion model fluoride combination electrode from Orion Research Incorporation, Beverly, Massachusetts USA (1999). The fluoride combination electrode was used together with an Electrothermal Analyser, Model 3405 from Jenway of Fested, Dunmow, U.K.

3.5.2.6 Determination of Carbonates and Bicarbonates.

The official method 920.94 of the Association of Official Analytical Chemists (AOAC), 1995 edition, was used for these determinations.

3.5.2.7 Determination of chloride

Reagents:

0.0200 mol/ litre $AgNO_3$

0.1 mol/ litre K_2CrO_4

1 mol/ litre CH_3CO_2H

1 mol/litre Na_2CO_3

0.0100 mol/ litre $MgCl_2.6H_2O$

Standardisation of $AgNO_3$ solution

Ten millilitres of the magnesium chloride solution was transffered into a conical flask. The pH of the solution was measured using a pH meter. The ideal pH for this test is 8. Using the ethanoic acid and the sodium carbonate solutions above added drop wise, the pH was adjusted to 8. To this, 3 mL of the K_2CrO_4 solution were added and titrated with the $AgNO_3$ solution until a permanent tinge of orange/brown colour. The procedure was repeated until two concordant titres were obtained. The titre volumes were used to calculate the concentration of the $AgNO_3$ solution in mol/ litre.

Analysis of chloride in water samples

Using a pH meter the pH of a sample of the water to be analysed was measured to ascertain that it was approximately 8. If not, it was adjusted as in section 3.5.2.7. A 50 mL portion was placed in a conical flask and 3 mL of the K_2CrO_4 solution added. This was titrated with the $AgNO_3$ solution whose concentration had been determined above. The titrations were done in duplicate. Using the titration data, the concentration of Cl^- in the water samples was calculated in moles/litre and then in mg/litre.

3.5.2.8 Determination of Sulphate

Reagents:

(a) Conditioning reagent.
Fifty millilitres of glycerol were mixed with 30 mL of hydrochloric acid, 100 mL of propan-2-ol and 75 g of sodium chloride.

(b) Barium chloride.
A 0.3 mL plastic spoon was used to dispense the salt.

(c) Sulphate standard solution.

were prepared by dissolving accurately weighed respective amounts of the salt, dissolving them in distilled water and making them up to 1 litre.

Sample preparation.

The water samples were filtered through Whatman No.4 filter to remove any suspended matter that would cause interference. Five millilitres of the conditioning solution was added to 100 mL of sample in an Erlenmeyer flask and the content mixed using a magnetic stirrer. While stirring a spoonful of barium chloride was added and the process continued at constant speed for exactly 1 minute. Some solution was immediately transferred into a sample cell of a Visible Spectrophotometer Model Novaspec II from Pharmacia Biotech of Cambridge, UK. The transmittance of the solution was measured at 420 nm at 30 seconds intervals for 4 minutes and the maximum reading recorded. A reagent blank determination was conducted with distilled water but omitting barium chloride. The sample reading was corrected with the blank and its SO_4^{2-} concentration in mg/L read from a standard calibration curve.

Standard calibration curve.

Standards solutions of 5, 10, 15, 20,25 and 30 mg SO_4^{2-}/L were prepared in the same way as above, their transmittance measured, and a calibration curve plotted. Standards were introduced for every 4 samples.

3.5.2.9 Determination of Phosphates

Reagents

(a) 5 N H_2SO_4 was prepared by diluting 70 mL of concentrated H_2SO_4 to 500 mL with distilled water.

(b) Potassium antimonyl tartrate solution was prepared by weighing 1.3715 g $K(SbO)C_4H_4O_6O \cdot 5H_2O$, dissolving it in 400 mL distilled water and then diluting to 500 mL. This reagent was stored in a dark stoppered glass bottle in a refrigerator.

(c) Ammonium molybdate solution was prepared by dissolving 20 g $(NH4)_6Mo_7O_{24}.4H_2O$ in 500 mL distilled water and stored in a plastic bottle in a refrigerator.

(d) 0.1 M Ascorbic acid was repared by dissolving 1.76 g ascorbic acid in 100 mL of distilled water and stored in the refrigerator.

then adding with mixing, in the order; 50 mL 5 N H_2SO_4 , 5 mL potassium antimonyl tartarate solution and 15 mL ammonium molybdate. When turbidity formed, the mixture was shaken and left to stand for a few minutes before proceeding.

(f) Hydrolysing acid solution was prepared by slowly adding 310 mL H_2SO_4 to 600 mL distilled water, cooling the solution and diluting to 1 litre.

(g) Phosphorus standard solutions

1. The stock solution was prepared by dissolving 0.2197 g KH_2PO_4 previously dried at 105° C, and making up to 1 litre with distilled water.
2. The intermediate solution was prepared by diluting 10 mL of the stock solution to 1 litre.
3. The working solutions was prepared by diluting 0, 1.0., 3.0, 5.0, 10.0, 20.0, 30.0, and 40.0 mL intermediate solution in 50 mL. These solutions contained 0.00, 0.01, 0.03, 0.05, 0.10, 0.20, 0.30 and, 0.40 mg PO_4^{3-}/ L.

Procedure:

The samples had previously been preserved from the day of collection with 40mg $HgCl_2$/L and stored in a refrigerator as it was not possible analyse immediately. A drop of phenolphthalein was added to 50.0 mL sample and if a red colouration developed, the hydrolyzing acid solution was added dropwise until it was discharged. Eight millilitres of combined reagent was added and mixed thoroughly. After 20 minutes absorbances were taken at 880 nm against a reagent blank as the reference.

3.5.3 Analysis of data

The data collected was analysed using paired *t* –test to compare concentrations of mineral ions in water samples before and after defluoridation to determine whether there was any significant difference between the two. In the tests ;

$H_o: \mu_1 = \mu_2$

$H_1: \mu_1 \neq \mu_2$

Where μ_1 and μ_2 are mean concentrations in mg/L before and after defluoridation respectively.

The tests were carried out at α=0.05 where α is the level of significance.

RESULTS AND DISCUSSION

4.1 Results of Analyses

The results of the analyses of the various mineral ions were recorded in tables and displayed in the graphs below for ease of comparisons.

Table 5: The pH of water samples before and after defluoridation

Sample	Before	After
Egerton BH2	8.11	8.63
Egerton tap	8.00	8.21
Maji moto	7.46	8.48
Belbur	7.12	8.47
Njugu-ini	6.83	8.41
Lanet BH1	7.48	8.70
Lanet BH2	7.00	8.61
Ng'ondu	8.12	8.63
St Josephs Kihingo	6.36	8.65
Egerton BH12	8.14	8.52

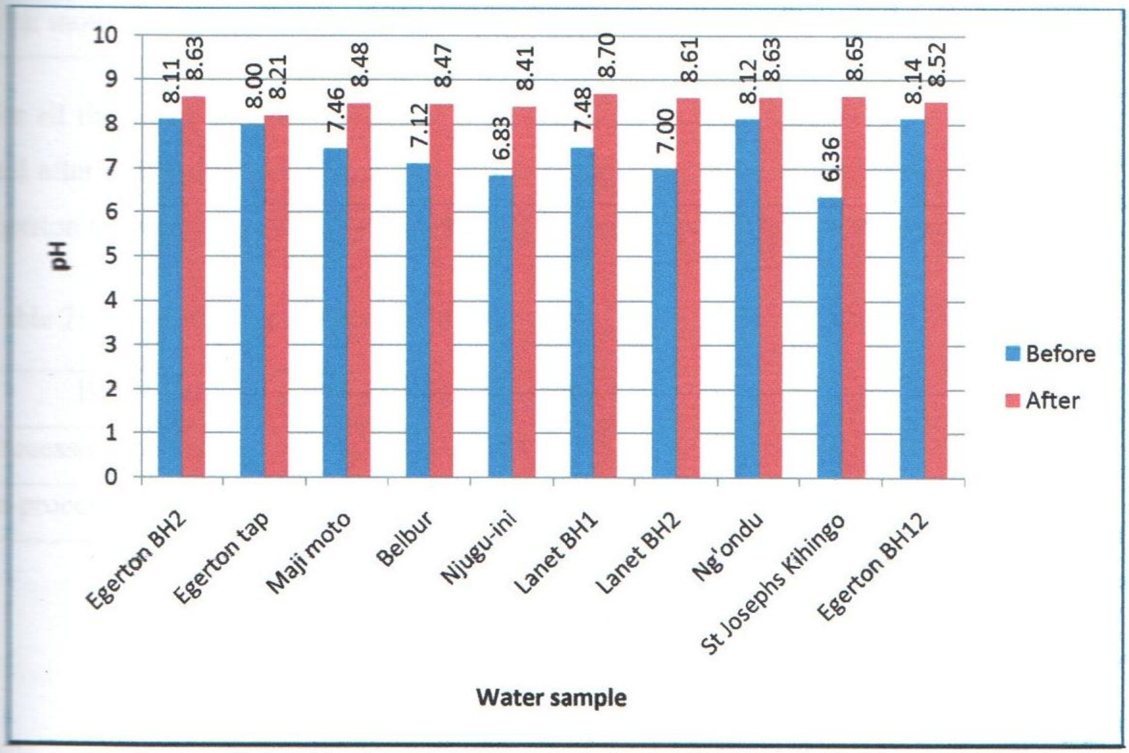


Figure 2: pH of water samples before and after defluoridation.

Variable / Sample	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	8.1200	8.6267	0.0000	0.0513	-24.22	0.000	-0.5602,-0.4529
Belbur	7.1200	8.4683	0.0000	0.354	-93.17	0.000	-1.3855,-1.3111
St Josephs Kihingo	6.3600	8.6483	0.0000	0.0854	-65.62	0.000	-2.3780,-2.1987
Egerton tap	8.0000	8.1267	0.0000	0.1432	-2.17	0.082	-0.2769,0.0236
Lanet BH1	7.4800	8.7033	0.0000	0.1986	-15.09	0.000	-1.4317,-1.0150
Lanet BH2	7.0000	8.6133	0.0000	0.1864	21.20	0.000	-1.8090,-1.4177
Egerton BH12	8.1400	8.5233	0.0000	0.1622	-5.79	0.002	-0.5535,-0.2131
Egerton BH2	8.11000	8.63000	0.00000	0.2366	-53.83	0.000	-0.54483,-0.49517
Njugu-ini	6.8300	8.4083	0.0000	0.0960	-40.27	0.000	-1.6791,-1.4776
Maji moto	7.4600	8.4833	0.0000	0.0589	-42.57	0.000	-1.0851,-0.9615

For all the water samples there was significant difference (increase) between the pH's before and after defluoridation, since the p-values were less than $\alpha = 0.05$. However the p-value for Egerton tap water was slightly above $\alpha = 0.05$, hence the difference was not significant.

Table 7: Concentration of fluoride in bone char

Bone char	Average conc., mg/L
Processed bone char	31.64
In-process bone char	32.58

Sample	Before	After
Ng'ondu	5.89	0.1633
Belbur	1.58	0.1967
St Josephs Kihingo	3.12	0.1800
Egerton tap	4.19	0.1700
Lanet BH1	4.49	0.2067
Lanet BH2	3.12	0.1717
Egerton BH12	4.79	0.1483
Egerton BH2	5.12	0.1667
Njugu-ini	2.96	0.1700
Maji moto	5.12	0.1650

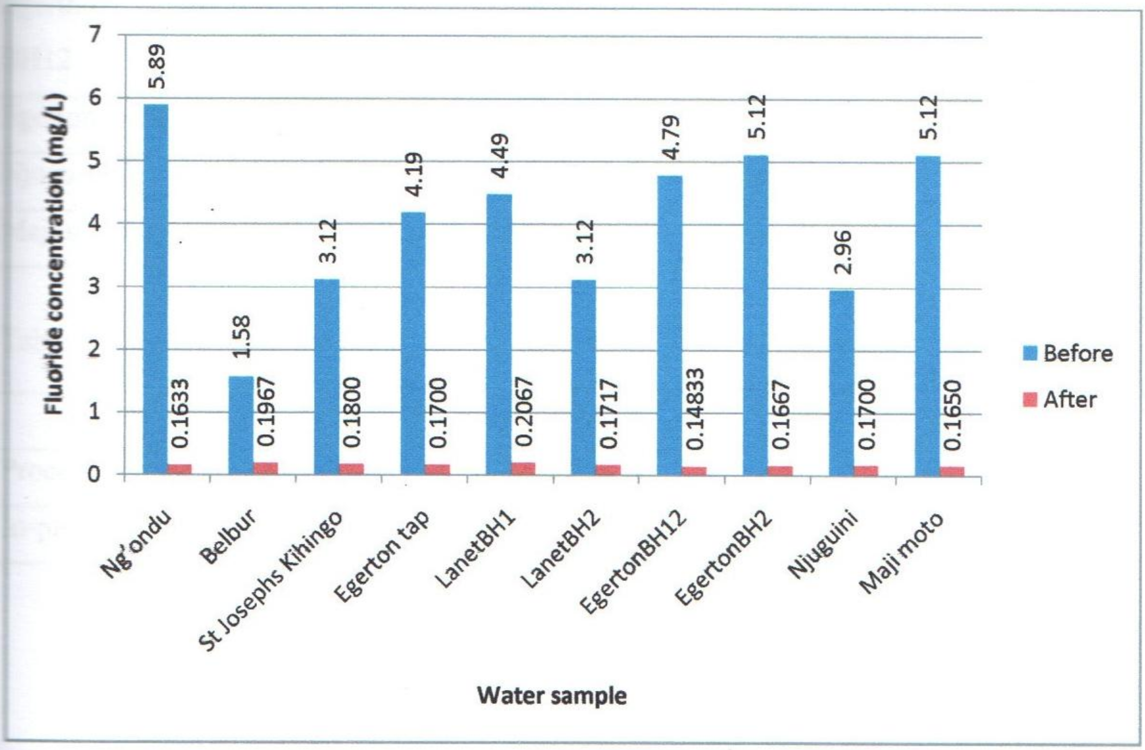


Figure 3: Fluoride concentration in water samples before and after defluoridation.

For all the water samples there was significant difference (decrease) between the concentrations before and after defluoridation, since the p-values were less than $\alpha = 0.05$

Sample \ Variable	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	5.8900	0.1633	0.0000	0.0258	543.28	0.000	5.6996, 5.7538
Belbur	1.5800	0.1967	0.0000	0.0388	87.30	0.000	1.3426, 1.4241
St Josephs Kihingo	3.1200	0.1800	0.0000	0.0261	276.16	0.000	2.9126, 2.9674
Egerton tap	4.1900	0.1700	0.0000	0.0452	218.02	0.000	3.9726, 4.0674
Lanet BH1	4.4900	0.2067	0.0000	0.0301	348.44	0.000	4.2517, 4.3148
Lanet BH2	3.1200	0.17170	0.0000	0.0534	135.12	0.000	2.8922, 3.0044
Egerton BH12	4.79000	0.14833	0.00000	0.1472	772.42	0.000	4.62622, 4.65711
Egerton BH2	5.1200	0.1667	0.0000	0.0280	432.59	0.000	4.9239, 4.9828
Njugu-ini	2.9600	0.1700	0.0000	0.0261	262.07	0.000	2.7626, 2.8174
Maji moto	5.1200	0.1650	0.0000	0.0274	443.19	0.000	4.9262, 4.9837

Table 10: Concentration of sodium in bone char

Bone char	Average conc., mg/L
Processed bone char	114.00
In-process bone char	32.58

Sample	Before	After
Ng'ondu	104	81.33
Belbur	115	59.50
St Josephs Kihingo	125	51.00
Egerton tap	110	44.67
Lanet BH1	84	58.50
Lanet BH2	90	65.83
Egerton BH12	108	79.00
Egerton BH2	104	82.00
Njugu-ini	79	93.67
Maji moto	135	54.00

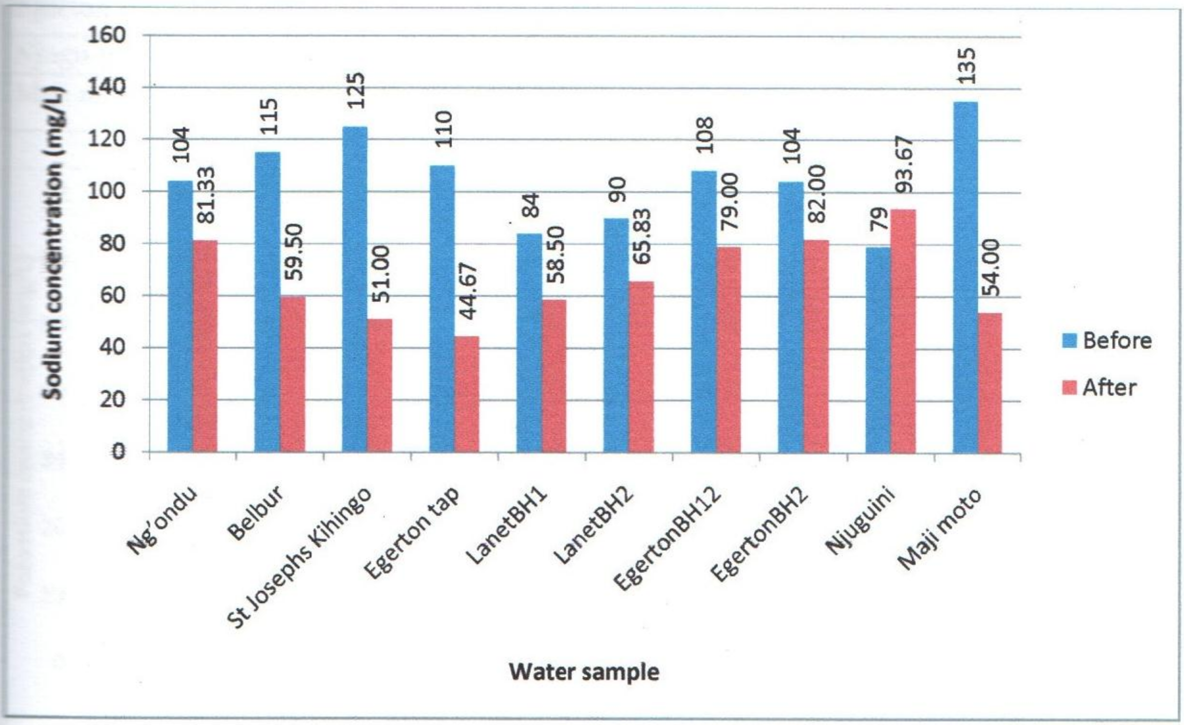


Figure 4: Sodium concentration in water samples before and after defluoridation.

For all the water samples there was significant difference (decrease) between the concentrations before and after defluoridation, since the p-values were less than $\alpha = 0.05$

Bone char	Average conc., mg/L
Processed bone char	4
In-process bone char	11

Table 13: Potassium concentration in water samples before and after defluoridation

Sample	Before	After
Ng'ondu	9	7.500
Belbur	63	25.500
St Josephs Kihingo	14	9.667
Egerton tap	22	14.333
Lanet BH1	22	15.830
Lanet BH2	18	12.167
Egerton BH12	17	11.000
Egerton BH2	13	8.667
Njugu-ini	20	14.833
Maji moto	22	15.000

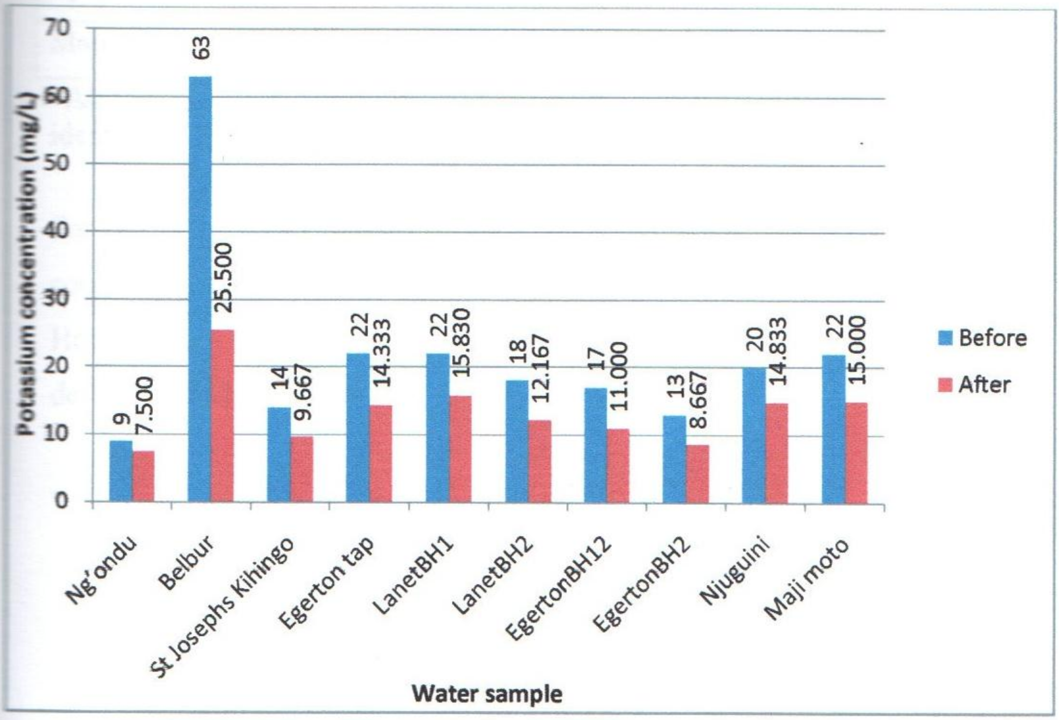


Figure 5: Potassium concentration in water samples before and after defluoridation.

Variable / Sample	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	9.000	7.500	0.000	0.837	4.39	0.007	0.622, 2.378
Belbur	63.000	25.500	0.000	0.837	109.79	0.000	36.622, 38.378
St Josephs Kihingo	14.000	9.667	0.000	0.516	20.55	0.000	3.791, 4.875
Egerton tap	22.000	14.333	0.000	0.516	36.37	0.000	7.125, 8.209
Lanet BH1	22.00	15.83	0.00	5.31	2.85	0.036	0.60, 11.74
Lanet BH2	18.000	12.167	0.000	2.041	7.00	0.001	3.691, 7.975
Egerton BH12	17.0000	11.0000	0.0000	0.0000	*	*	6.00000, 6.0000
Egerton BH2	13.000	8.667	0.000	0.516	20.55	0.000	3.791, 4.875
Njugu-ini	20.000	14.833	0.000	1.329	9.52	0.000	3.772, 6.562
Maji moto	22.000	15.000	0.000	1.414	12.12	0.000	5.516, 8.484

*All values obtained for the tests (See results for Egerton BH12 in Appendix 2) were identical

For all the water samples there was significant difference (decrease) between the concentrations before and after defluoridation, since the p-values were less than $\alpha = 0.05$. However no p-value was obtained for Egerton BH12 since all the concentrations after defluoridation were identical.

Bone char	Average conc., mg/L
Processed bone char	85.23
In-process bone char	56.82

Table 16: Magnesium concentration in water before and after defluoridation

Sample	Before	After
Ng'ondu	0	0.38
Belbur	0.27	0.3867
St Josephs Kihingo	0.89	5.967
Egerton tap	0.05	4.83
Lanet BH1	0.26	0.565
Lanet BH2	0.95	2.272
Egerton BH12	0.02	0.31167
Egerton BH2	0.01	0.3867
Njugu-ini	0.08	6.252
Maji moto	0.07	5.683

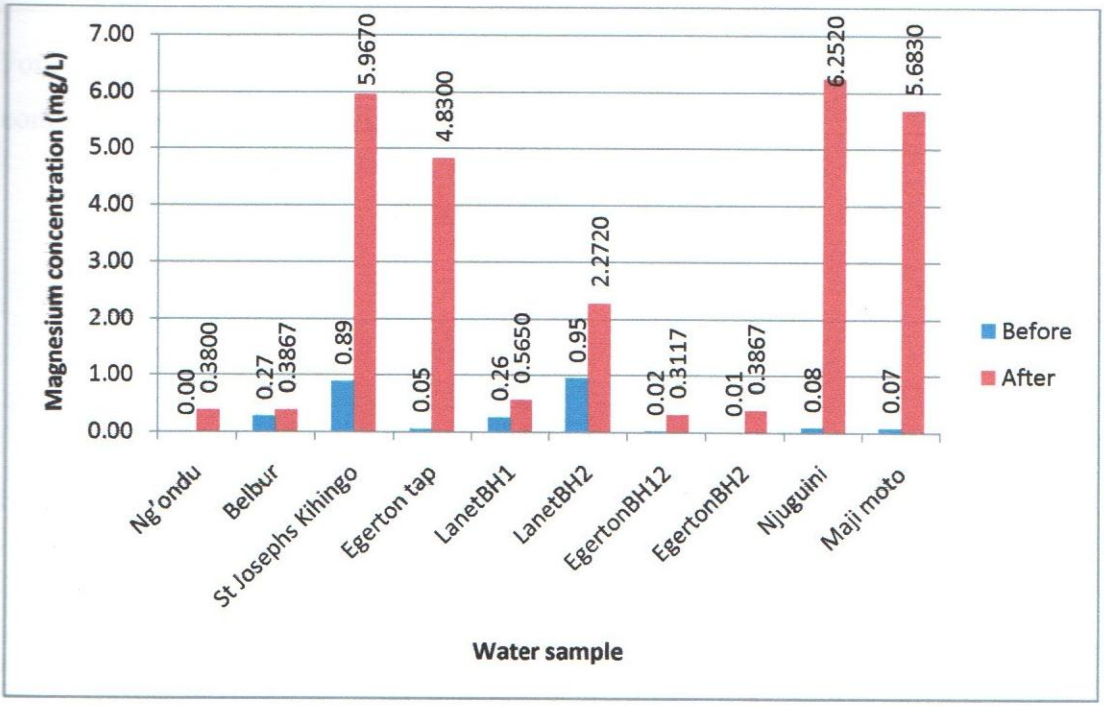


Figure 6: Magnesium concentration in water samples before and after defluoridation.

Sample \ Variable	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	0.0000	0.3800	0.0000	0.0559	-16.66	0.000	-0.4386,-0.3214
Belbur	0.2700	0.3867	0.0000	0.0814	-3.51	0.017	-0.2021,-0.0321
St Josephs Kihingo	0.890	5.967	0.000	1.180	-10.54	0.000	-6.315,-3.839
Egerton tap	0.050	4.830	0.000	0.593	-19.74	0.000	-5.402,-4.158
Lanet BH1	0.2600	0.5650	0.0000	0.0266	-28.04	0.000	-0.330,-0.2770
Lanet BH2	0.950	2.272	0.000	0.880	-3.68	0.014	-2.246,0.398
Egerton BH12	0.0200	0.31167	0.0000	0.01835	-38.94	0.000	-0.31092,-0.27241
Egerton BH2	0.0100	0.3867	0.0000	0.0497	-18.58	0.000	-0.4288,-0.3245
Njugu-ini	0.080	6.252	0.000	1.898	-7.96	0.001	-8.164,-4.180
Maji moto	0.070	5.683	0.000	1.525	-9.02	0.000	-7.214,-4.013

For all the water samples there was significant difference (increase) between the concentrations before and after defluoridation, since the p-values were less than α =0.05.

Bone char	Average conc., mg/L
Processed bone char	93.80
In-process bone char	95.46

Table 19: Phosphates concentration in water samples before and after defluoridation

Sample	Before	After
Ng'ondu	4.14	91.52
Belbur	0.00	29.24
St Josephs Kihingo	87.86	60.86
Egerton tap	2.14	59.81
Lanet BH1	1.70	84.20
Lanet BH2	1.40	69.20
Egerton BH12	13.14	71.93
Egerton BH2	0.43	49.74
Njugu-ini	0.00	47.97
Maji moto	0.00	48.64

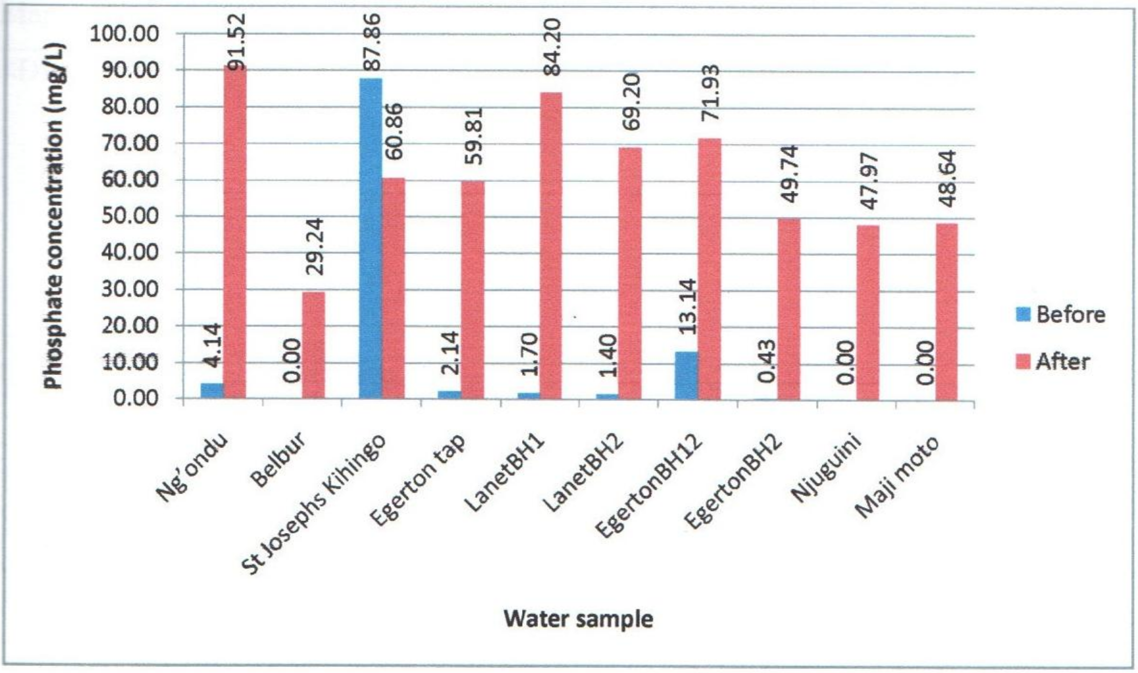


Figure 7: Phosphates concentration in water samples before and after defluoridation.

For all the water samples there was significant difference (increase) between the concentrations before and after defluoridation, since the p-values were less than $\alpha = 0.05$

Sample \ Variable	$\bar{X}_1$	$\bar{X}_2$	$S_{\bar{X}_1}$	$S_{\bar{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	4.14	91.52	0.00	18.17	-11.78	0.000	-106.45,-68.32
Belbur	<DL	29.24	0.00	10.36	-6.92	0.001	-40.11,-18.37
St Josephs Kihingo	87.86	60.86	0.00	8.48	7.80	0.001	18.10,35.90
Egerton tap	2.14	59.81	0.00	19.56	-7.22	0.001	-78.20,-37.14
Lanet BH1	1.7	84.2	0.0	41.3	-4.90	0.004	-125.8,-39.2
Lanet BH2	1.4	69.2	0.0	37.2	-4.46	0.007	-106.8,-28.7
Egerton BH12	13.14	71.93	0.00	16.15	-8.91	0.000	-75.74,-41.84
Egerton BH2	0.43	49.74	0.00	7.41	-22.92	0.000	-77.08,-61.54
Njugu-ini	<DL	47.97	0.00	19.31	-6.09	0.002	-68.24,-27.71
Maji moto	<DL	48.64	0.00	18.20	-6.55	0.001	-67.74,-29.54

<DL means below detection limits

Sample	Before	After
Ng'ondu	166	131.67
Belbur	2024	1598.33
St Josephs Kihingo	266	207.67
Egerton tap	139	134.33
Lanet BH1	140	97.20
Lanet BH2	213	193.67
Egerton BH12	171	144.50
Egerton BH2	147	108.17
Njugu-ini	282	241.33
Maji moto	302	277.33

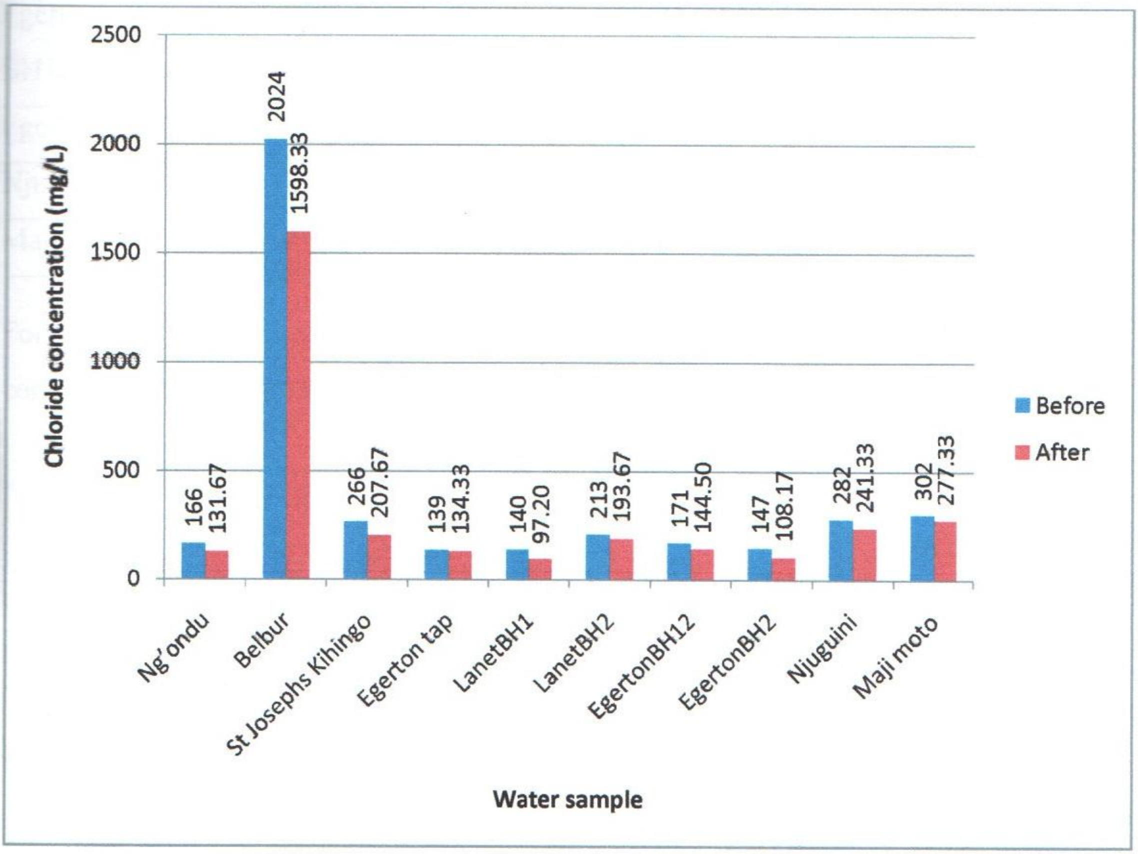


Figure 8: Chloride concentration in water samples before and after defluoridation.

Variable / Sample	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	166.00	131.67	0.00	10.78	7.80	0.001	23.02,45.65
Belbur	2024.00	1598.33	0.00	16.67	62.55	0.000	408.17,443.16
St Josephs Kihingo	266.00	207.67	0.00	8.57	16.67	0.000	49.34,67.33
Egerton tap	139.00	134.33	0.00	2.88	3.98	0.011	1.65,7.68
Lanet BH1	140.0	97.2	0.0	31.0	3.39	0.019	10.3,75.3
Lanet BH2	213.00	193.67	0.00	7.39	6.41	0.001	11.57,27.09
Egerton BH12	171.00	144.50	0.00	6.28	10.33	0.000	19.90,33.10
Egerton BH2	147.00	108.17	0.00	14.72	6.46	0.001	23.39,54.28
Njugu-ini	282.00	241.33	0.00	5.32	18.74	0.000	35.09,46.25
Maji moto	302.00	277.33	0.00	15.71	3.85	0.012	8.18,41.15

For all the water samples there was significant difference (decrease) between the concentrations before and after defluoridation, since the p-values were less than $\alpha = 0.05$

Bone char	Average conc., mg/L
Processed bone char	8.00
In-process bone char	43.33

Table 24: Iron concentration in water samples before and after defluoridation

Sample	Before	After
Ng'ondu	4.33	1.9980
Belbur	0.33	0.3300
St Josephs Kihingo	4.00	1.1680
Egerton tap	0.30	0.2867
Lanet BH1	0.33	0.3300
Lanet BH2	0.33	0.3300
Egerton BH12	0.67	0.3300
Egerton BH2	1.00	0.3300
Njugu-ini	1.00	0.7800
Maji moto	0.67	0.6700
Spiked sample	5.40	0.7330

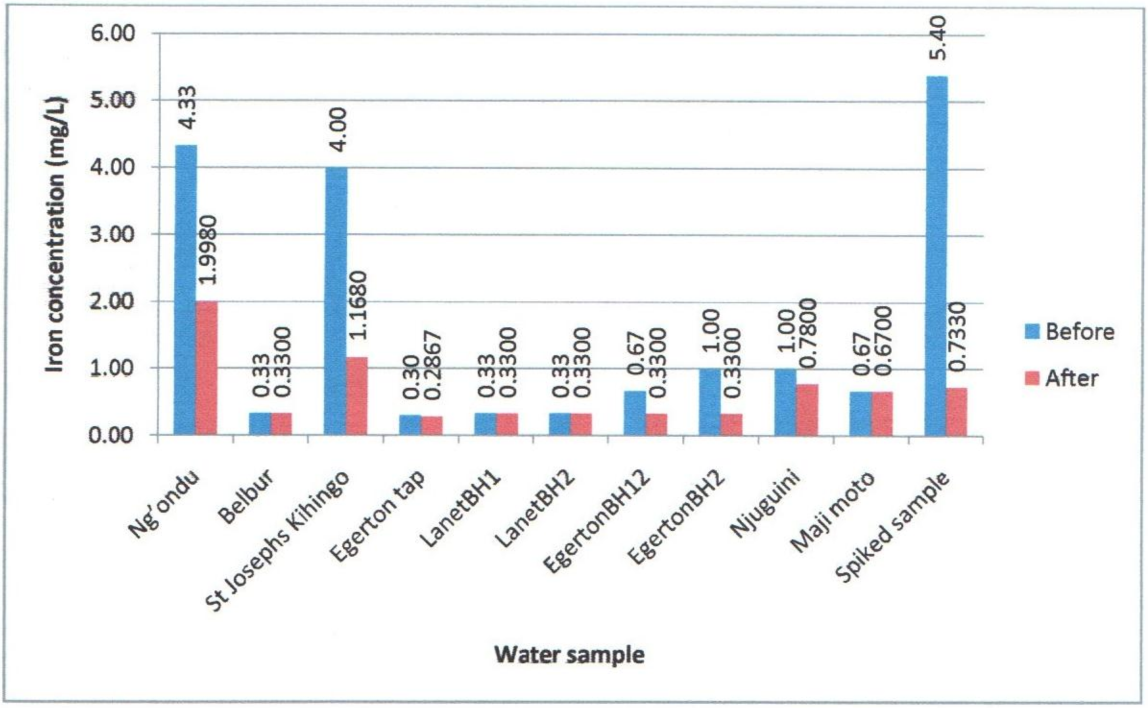


Figure 9: Iron concentration in water samples before and after defluoridation.

difference (decrease) in the concentration of iron before and after defluoridation since the p-values were less than $\alpha = 0.05$. The sample from Egerton tap had a p-value greater than α=0.05. The p-values for those from Lanet BH1, Lanet BH2, Egerton BH12, Egerton BH2 and Maji moto could not be obtained since the concentrations after defluoridation were identical. A confirmatory check with a spiked sample confirmed that there is a significant decrease in concentration on defluoridation

Table 25: Summary of paired t-test for iron determination results

Variable / Sample	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	4.330	1.998	0.000	0.664	8.60	0.000	1.635,3.028
Belbur	0.3300	0.3300	0.0000	0.0000	*	*	0.0000,0.0000
St Josephs Kihingo	4.000	1.168	0.000	0.459	15.10	0.000	2.350,3.314
Egerton tap	0.300	0.2867	0.000	0.0671	1.58	0.175	-0.0271,0.1138
Lanet BH1	0.3300	0.3300	0.0000	0.0000	*	*	0.0000,0.0000
Lanet BH2	0.3300	0.3300	0.0000	0.0000	*	*	0.0000,0.0000
Egerton BH12	0.6700	0.3300	0.0000	0.0000	*	*	0.3400,0.3400
Egerton BH2	1.0000	0.3300	0.0000	0.0000	*	*	0.6700,0.6700
Njugu-ini	1.00	0.7800	0.0000	0.1704	3.16	0.025	0.0412,0.3988
Maji moto	0.6700	0.6700	0.0000	0.0000	*	*	0.0000,0.0000
Spiked sample	5.400	0.733	0.000	0.1033	110.68	0.000	4.5583, 4.7551

*All values obtained for the tests (See Appendix 7) were identical.

Bone char	Average conc., mg/L
Processed bone char	9.11
In-process bone char	16.04

Table 27: Sulphates concentration in water samples before and after defluoridation

Sample	Before	After
Ng'ondu	11.54	15.193
Belbur	56.55	25.260
St Josephs Kihingo	4.57	7.242
Egerton tap	16.11	18.865
Lanet BH1	12.89	37.560
Lanet BH2	15.28	19.130
Egerton BH12	16.74	19.542
Egerton BH2	11.33	15.055
Njugu-ini	2.49	14.290
Maji moto	19.96	27.392

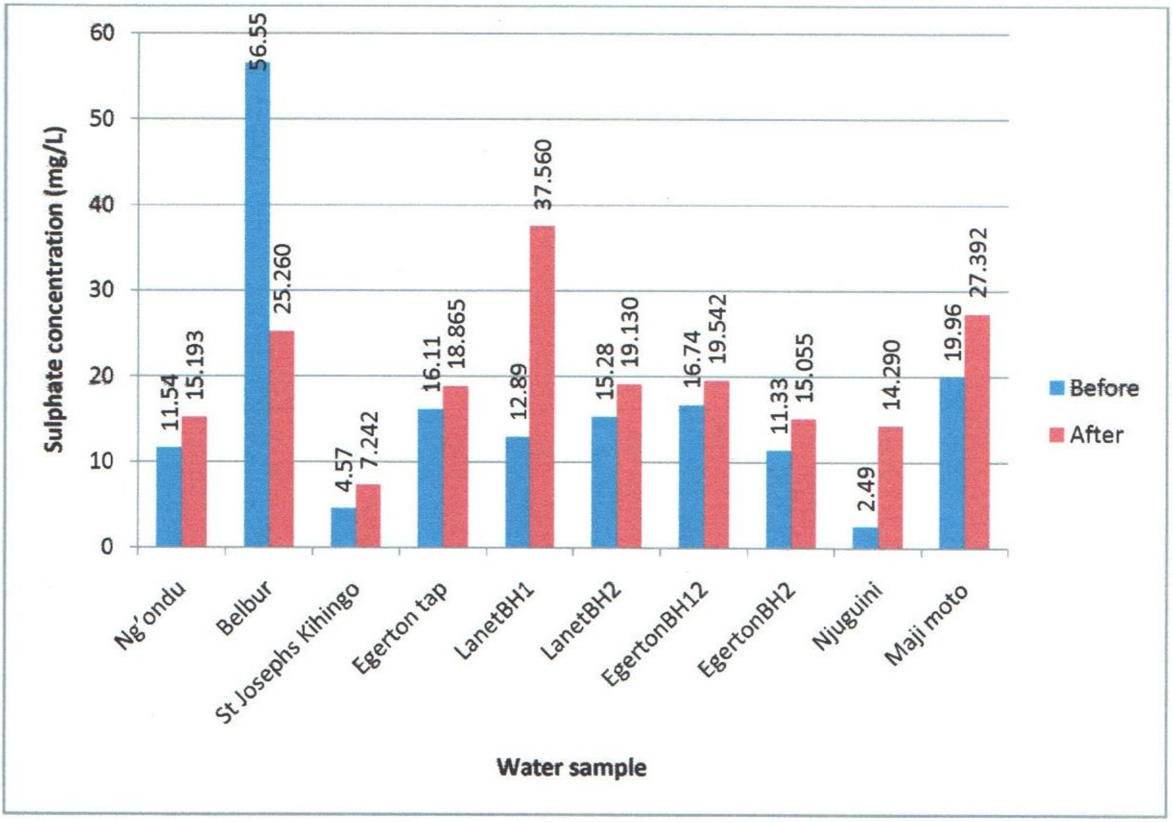


Figure 10: Sulphates concentration in water samples before and after defluoridation.

Variable / Sample	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean diff (lower, upper)
Ng'ondu	11.540	15.193	0.000	2.270	-3.94	0.011	-6.036,-1.271
Belbur	56.55	25.26	0.00	4.13	18.54	0.000	26.95,35.63
St Josephs Kihingo	4.570	7.242	0.000	2.346	-2.79	0.038	-5.133,-0.210
Egerton tap	16.110	18.865	0.000	1.536	-4.39	0.007	-4.367,-1.143
Lanet BH1	12.89	37.56	0.00	7.92	-7.63	0.001	-32.99,-16.36
Lanet BH2	15.28	19.13	0.00	4.63	-2.03	0.098	-8.70,1.01
Egerton BH12	16.740	19.542	0.000	1.122	-6.11	0.002	-3.980,-1.624
Egerton BH2	11.330	15.055	0.000	1.533	-5.95	0.002	-5.333,-2.117
Njugu-ini	2.49	14.29	0.00	2.69	-10.67	0.000	-14.32,-8.98
Maji moto	19.960	27.392	0.000	1.129	-9.44	0.000	-9.426,-5.408

Sample	Before	After
Ng'ondu	11	9.000
Belbur	7	7.833
St Josephs Kihingo	5	11.000
Egerton tap	12	11.833
Lanet BH1	12	11.330
Lanet BH2	4	8.000
Egerton BH12	4	7.670
Egerton BH2	14	9.500
Njugu-ini	17	10.000
Maji moto	14	13.833

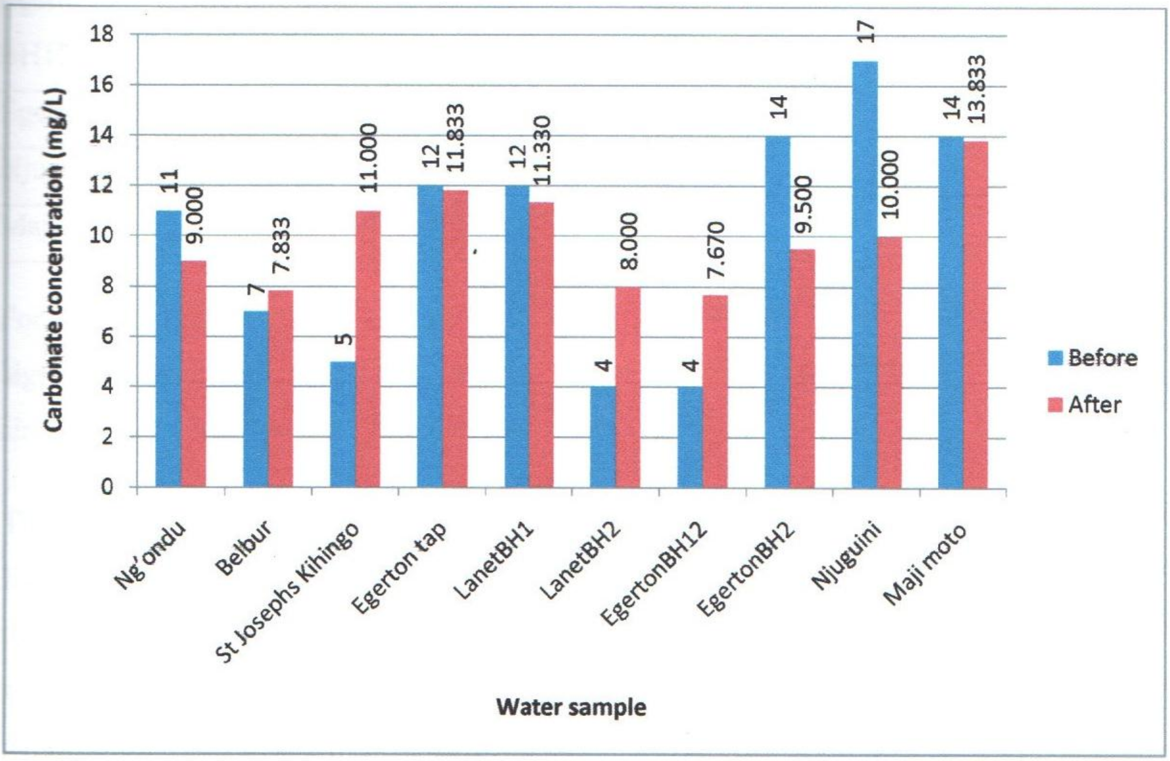


Figure 11: Carbonates concentration in water samples before and after defluoridation.

Variable / Sample	$\bar{X}_1$	$\bar{X}_2$	$S_{\bar{X}_1}$	$S_{\bar{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	11.00	9.00	0.00	2.45	2.00	0.102	-0.57,4.57
Belbur	7.000	7.833	0.000	2.317	-0.888	0.419	-3.267,1.598
St Josephs Kihingo	5.00	11.00	0.00	2.53	-5.81	0.002	-8.65,-3.35
Egerton tap	12.000	11.833	0.000	1.602	0.25	0.809	-1.515,1.848
Lanet BH1	12.00	11.33	0.00	3.72	0.44	0.679	-3.24,4.57
Lanet BH2	4.000	8.000	0.000	1.095	-8.94	0.000	-5.150,-2.850
Egerton BH12	4.00	7.67	0.00	3.78	-2.38	0.063	-7.63,0.30
Egerton BH2	14.000	9.500	0.000	1.225	9.00	0.000	3.215,5.785
Njugu-ini	17.000	10.000	0.000	1.549	11.07	0.000	5.374,8.626
Maji moto	14.000	13.833	0.000	1.835	0.22	0.833	-1.759,2.092

For water samples from St Josephs Kihingo, Egerton BH2 and Njugu-ini there was a significant difference (decrease) between the concentration before and after defluoridation, since the p-values were less than $\alpha = 0.05$.

There was a decrease in the concentration of carbonates in water samples from Ng'ondu, Egerton tap, Lanet BH1 and Maji moto. However these changes were not significant since the p values were greater than $\alpha=0.05$. Samples from Belbur and Egerton BH12 showed some insignificant increases in concentration after defluoridation, while that from Lanet BH2 actually showed a significant increase.

Sample	Before	After
Ng'ondu	265	229.83
Belbur	382	161.17
St Josephs Kihingo	280	246.33
Egerton tap	274	218.83
Lanet BH1	375	278.00
Lanet BH2	303	220.80
Egerton BH12	280	231.30
Egerton BH2	252	219.17
Njugu-ini	268	210.20
Maji moto	257	222.83

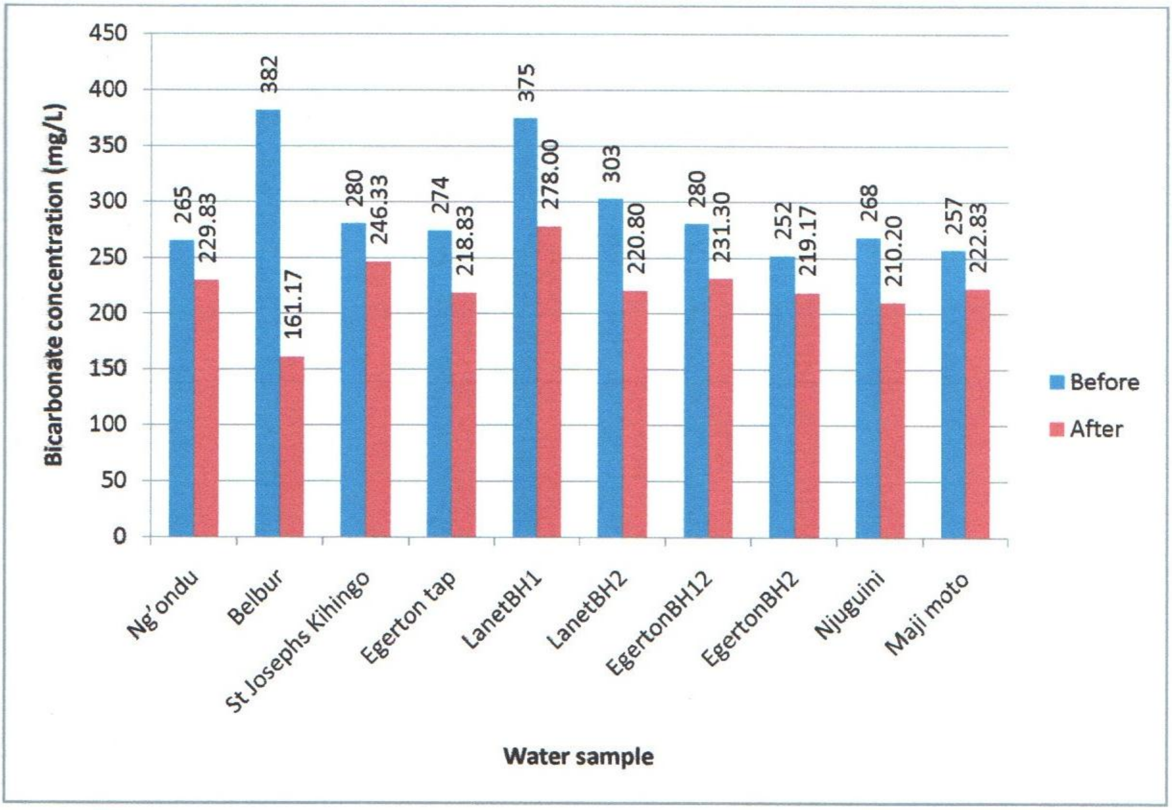


Figure 12: Bicarbonates concentration in water samples before and after defluoridation.

Sample \ Variable	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	265.00	229.83	0.00	18.55	4.64	0.006	15.70, 54.64
Belbur	382.00	161.17	0.00	15.96	33.90	0.000	204.09 ,237.58
St Josephs Kihingo	280.00	246.33	0.00	15.47	5.33	0.003	17.43,49.91
Egerton tap	274.00	218.83	0.00	23.47	5.76	0.002	30.53,79.80
Lanet BH1	375.00	278.00	0.00	71.8	3.31	0.021	21.7,172.3
Lanet BH2	303.00	220.80	0.00	45.1	4.46	0.007	34.8,129.5
Egerton BH12	280.00	231.30	0.00	25.6	4.66	0.006	21.8,75.5
Egerton BH2	252.00	219.17	0.00	23.11	3.48	0.018	8.58,57.09
Njugu-ini	268.00	210.2	0.00	37.1	3.82	0.012	18.9,96.7
Maji moto	257.00	222.83	0.00	18.67	4.48	0.007	14.57,53.76

For all the water samples there was significant difference (decrease) between the concentrations before and after defluoridation, since the p-values were less than $\alpha = 0.05$.

Bone char	Average conc., mg/L
Processed bone char	2000
In-process bone char	1500

Table 34: Calcium concentration in water samples before and after defluoridation

Sample	Before	After
Ng'ondu	0	0.4667
Belbur	0	0
St Josephs Kihingo	0	0
Egerton tap	0	0
Lanet BH1	0	0
Lanet BH2	0	0
Egerton BH12	0.3	0.6
Egerton BH2	0	0.4667
Njugu-ini	0	0
Maji moto	0	0
Spiked Sample	10.7	0.733

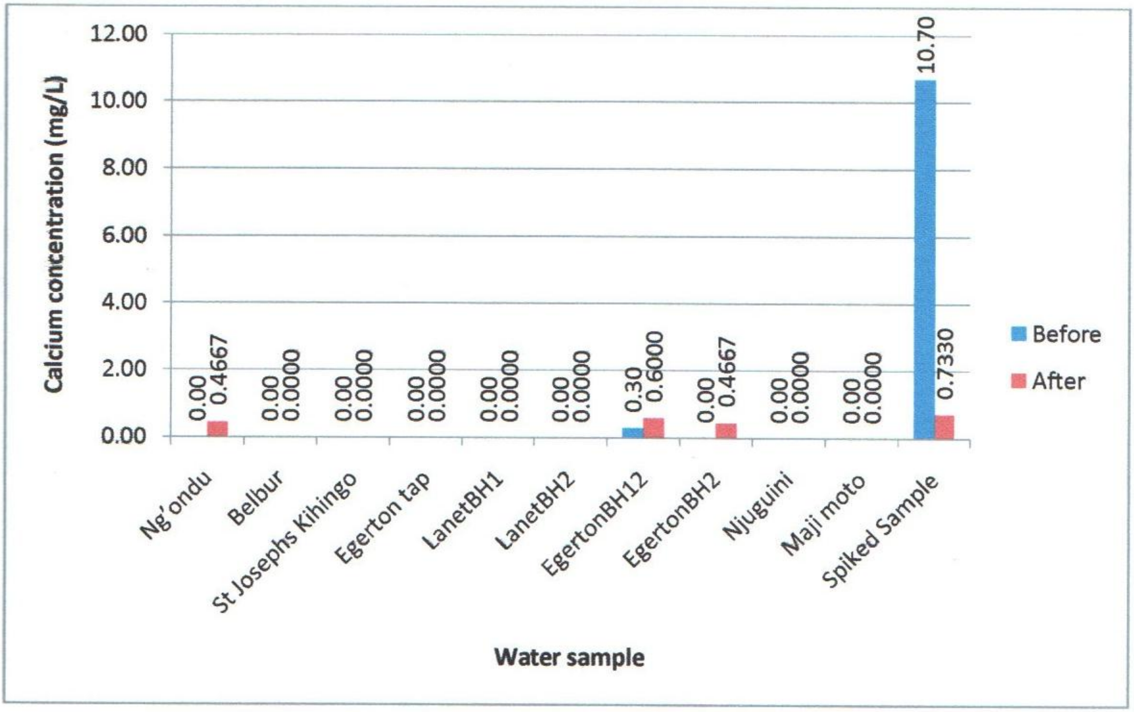


Figure 13: Calcium concentration in water samples before and after defluoridation.

Sample \ Variable	$\overline{X}_1$	$\overline{X}_2$	$S_{\overline{X}_1}$	$S_{\overline{X}_2}$	T-value	P-value	95% CI for mean difference (lower, upper)
Ng'ondu	0.000	0.4667	0.000	0.0816	-14.00	0.000	-0.5554, -0.3810
Belbur	*	*	*	*	*	*	*
St Josephs Kihingo	*	*	*	*	*	*	*
Egerton tap	*	*	*	*	*	*	*
Lanet BH1	*	*	*	*	*	*	*
Lanet BH2	*	*	*	*	*	*	*
Egerton BH12	0.3000	0.6000	0.000	0.1095	- 6.71	0.001	-0.4150, -0.1850
Egerton BH2	0.000	0.4667	0.000	0.0816	-14.00	0.000	-0.5554, -0.3810
Njugu-ini	*	*	*	*	*	*	*
Maji moto	*	*	*	*	*	*	*
Spiked Sample	10.700	0.733	0.000	0.280	87.04	0.000	9.672, 10.261

Water samples from Ng'ondu, Egerton BH12 and Egerton BH2 showed significant difference (decrease) between the concentrations before and after defluoridation, since the p-values were less than α =0.05. The rest of the samples had concentrations below levels detectable by the instrument used. A distilled water sample spiked with a known concentration of calcium was used to confirm the results.

4.2.1 Carbonates, Bicarbonates, Chlorides, Iron, Sodium and Potassium

The significant decrease in carbonates, bicarbonates, chlorides, iron, sodium and potassium concentrations in water after defluoridation, could be due to their adsorption by bone char. However the fact that there was some increase in the concentrations of carbonates in a few samples may be due to the presence of other ions in water influencing their adsorption. This however needs further investigation. Bårdsen and Bjorvatn (1997) who used fired laterite clay from Balang, Nothern Cameroon reported a decrease in the concentration of iron in defluoridated water. This was despite the fact that laterite clay is rich in iron. Similar studies commissioned by European Commission on natural mineral water (2006) using alumina as a defluoridating agent, showed a decrease in the concentrations of bicarbonates and calcium.

4.2.2 Magnesium, Phosphates and Sulphates

The significant increase in the concentrations of magnesium, phosphates and suphates after defluoridation. This is an indication that these ions leach from the bone char into the water during defluoridation. Similar results were obtained from the study commissioned by European Commission (2006) for sul[phates. The study by Bårdsen and Bjorvatn (1997) also gave similar results for chromium which leached from iron rich fired laterite clay. It should be noted that the concentration of sulphates in the water from Belbur , a shallow well, actually dropped on defluoridation and that the concentration of chlorides was high. Whether this two observations are related or not, needs to be investigated.

4.2.3 Defluoridation Process and pH

Comparing the amount of the F^- from the water samples during defluoridation in moles/litre, with the increase in OH^- concentration in moles per litre, there is a difference in concentration as shown in table 36.

	Change in fluoride conc. (moles/L)	Change in OH conc. (moles/L)	Difference (moles/L)
	Egerton tap		
P1	0.000208947	7.38E-07	2.08E-04
P2	0.000208947	6.98E-07	2.08E-04
P3	0.000210526	9.50E-07	2.10E-04
IP1	0.000213684	9.65E-08	2.14E-04
IP2	0.000213684	2.33E-08	2.14E-04
IP3	0.000213684	-1.09E-07	2.14E-04
	Maji moto		
P1	0.000261632	3.06E-06	2.59E-04
P2	0.000261105	2.38E-06	2.59E-04
P3	0.000258474	2.81E-06	2.56E-04
IP1	0.000261105	2.18E-06	2.59E-04
IP2	0.000261105	1.94E-06	2.59E-04
IP3	0.000258474	2.59E-06	2.56E-04
	Belbur		
P1	7.00E-05	2.96E-06	6.71E-05
P2	7.11E-05	2.75E-06	6.83E-05
P3	7.21E-05	3.26E-06	6.89E-05
IP1	7.48E-05	2.62E-06	7.22E-05
IP2	7.43E-05	2.69E-06	7.16E-05
IP3	7.48E-05	2.62E-06	7.22E-05
	Njugu-ini		
P1	0.000145474	2.28E-06	1.43E-04
P2	0.000146	3.24E-06	1.43E-04
P3	0.000146	3.40E-06	1.43E-04
IP1	0.000148632	2.22E-06	1.46E-04

IP3	0.000148105	2.02E-06	1.46E-04
	Lanet BH1		
P1	0.000223368	3.25E-06	2.20E-04
P2	0.000223368	7.64E-06	2.16E-04
P3	0.000224421	7.64E-06	2.17E-04
IP1	0.000226526	2.93E-06	2.24E-04
IP2	0.000226526	2.93E-06	2.24E-04
IP3	0.000226526	3.25E-06	2.23E-04
	Lanet BH2		
P1	0.000151895	5.15E-06	1.47E-04
P2	0.000152421	7.31E-06	1.45E-04
PC3	0.000152947	5.27E-06	1.48E-04
IP1	0.000157684	2.99E-06	1.55E-04
IP2	0.000157158	2.35E-06	1.55E-04
IP3	0.000157684	2.99E-06	1.55E-04
	N'gondu		
P1	0.000298947	3.69E-06	2.95E-04
P2	0.000301053	3.15E-06	2.98E-04
P3	0.000301579	2.31E-06	2.99E-04
IP1	0.000301579	1.92E-06	3.00E-04
IP2	0.000302632	2.85E-06	3.00E-04
IP3	0.000302632	3.15E-06	2.99E-04
	St. Joseph's Kihingo		
P1	0.000153474	3.00E-06	1.50E-04
P2	0.000152947	4.87E-06	1.48E-04
P3	0.000153474	5.23E-06	1.48E-04
IP1	0.000155579	4.55E-06	1.51E-04
IP2	0.000155579	4.55E-06	1.51E-04
IP3	0.000156105	4.55E-06	1.52E-04

	Egerton BH1		
P1	0.000243053	3.28E-06	2.40E-04
P2	0.000241474	2.88E-06	2.39E-04
P3	0.000244632	3.18E-06	2.41E-04
IP1	0.000244105	2.79E-06	2.41E-04
IP2	0.000244632	3.08E-06	2.42E-04
IP3	0.000245158	2.69E-06	2.42E-04
	Egerton BH2		
P1	0.000258474	7.58E-07	2.58E-04
P2	0.000260053	6.15E-07	2.59E-04
P3	0.000258474	2.89E-06	2.56E-04
IP1	0.000261632	2.79E-06	2.59E-04
IP2	0.000261105	3.09E-06	2.58E-04
IP3	0.000261632	2.69E-06	2.59E-04

Equationl above indicates that defluoridation is an ion-exchange process where 1 mole of F^- replaces 1 mole of OH^- in the hydroxyapatite. However from the calculations reported in Table 36 above, the number of moles of F^- removed from water in each case is more than the number of moles of OH^- released into the water. This implies that there is more fluoride removed than that exchanged with the hydroxyapatite. It is therefore possible that there is a certain amount of fluoride also removed by adsorption to the bone char. Similar studies, using commissioned by European Commission on natural mineral water (2006) reported no changes in pH during deluoridation using activated alumina..

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The concentrations of Na^+, K^+, PO_4^{3-}, SO_4^{2-}, Fe^{2+} and F^- were more in the in-process bone char than in the processed one. This, for all the mineral ions except F^-, could be attributed to the fact that most of the bones delivered to CDN still have some muscle tissue which on burning leaves behind the mineral ions. The concentrations of CO_3^{2-}, HCO_3^-, Na^+, K^+, Cl^-, Fe^{2+} and Ca^{2+} in water decrease on defluoridation.

In contrast, the concentrations of Mg^{2+}, PO_4^{3-} and SO_4^{2-}, increase on defluoridation. This implies that Mg^{2+}, PO_4^{3-} and SO_4^{2-}, leach from the bone char during defluoridation. Though this is so, none of them are above the WHO recommended levels. The pH of water also increases due to the exchange of the OH^- in the hydroxyapatite with the F^- in water. For water samples with pHs of more than 6 and high F^-, the pH after defluoridation will be outside the WHO desirable pH range (6.5 – 8.5).

The results of this study supports the theory that the mechanism of the process of defluoridation could be by ion exchange.

5.2 Recommendation

This study has shown that though some mineral ions leach into the water and others are removed during the process of defluoridation with bone char, the water remains within the recommended WHO guidelines for drinking water for the parameters analysed. Therefore consumers of ground water in fluorotic areas are recommended to use it as an effective defluoridation agent.

Further studies on whether there is preference of absorption of ions during the process of defluoridation should be carried out. Studies should also be carried out to investigate why some ions leach from the bone char during defluoridation while others are adsorbed and whether the pH of the water has an effect on their adsorption.

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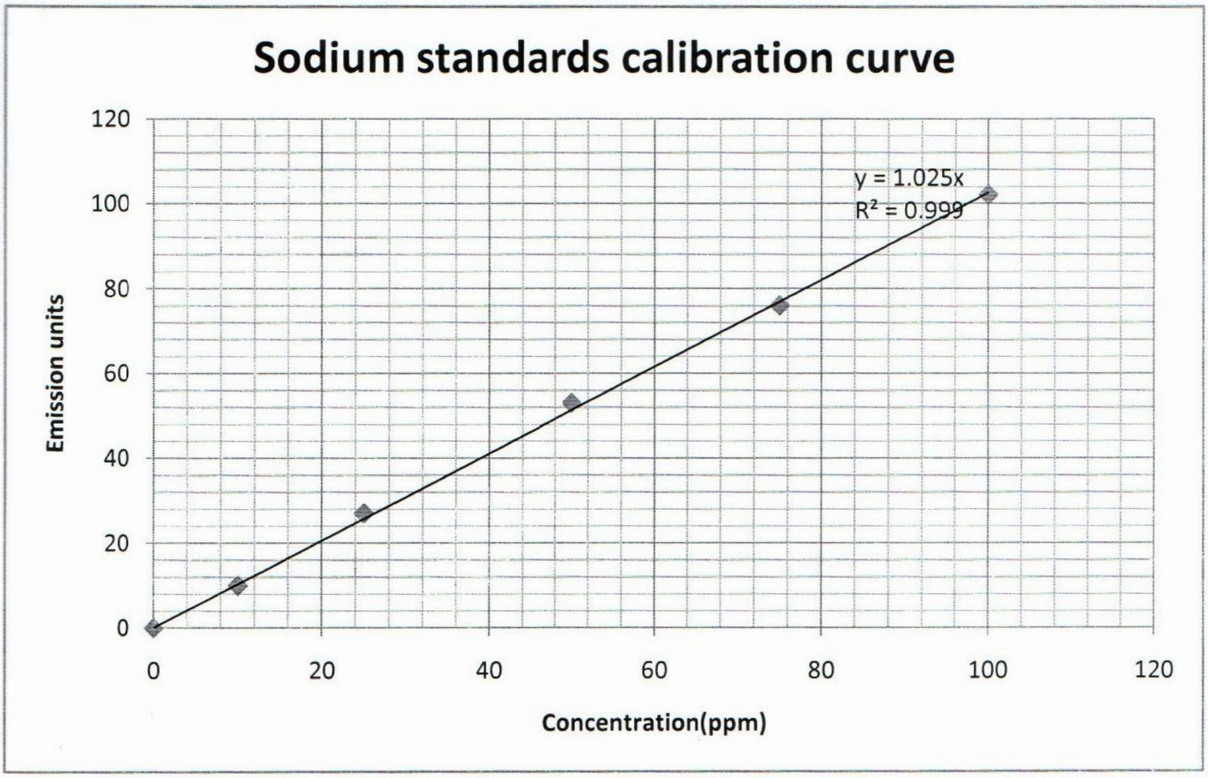
APPENDICES

APPENDIX 1: CALCULATION OF CONCENTRATION OF SODIUM FROM ITS STANDARDS CALIBRATION CURVE

Standards	
Conc.	Emission units
0	0
10	10
25	27
50	53
75	76
100	102



Sample	Emission units	Conc.	Conc.*df
P1	57	56	111
P2	57	56	111
P3	61	60	119
IP1	67	65	131
IP2	75	73	146
IP3	73	71	142

Egerton university tap			
Sample	Emission units	Conc.	Conc.*df
P1	45	44	44
P2	50	49	49
P3	50	49	49
IP1	39	38	38
IP2	44	43	43
IP3	46	45	45
UD	56	55	110

Njugu-ini			
Sample	Emission units	Conc.	Conc.*df
P1	53	52	103
P2	51	50	100
P3	60	59	117
IP1	83	81	81
IP2	85	83	83
IP3	80	78	78
UD	81	79	79

Maji moto			
Sample	Emission units	Conc.	Conc.*df
P1	59	58	58
P2	59	58	58
P3	59	58	58
IP1	50	49	49
IP2	49	48	48
IP3	54	53	53
UD	69	67	135

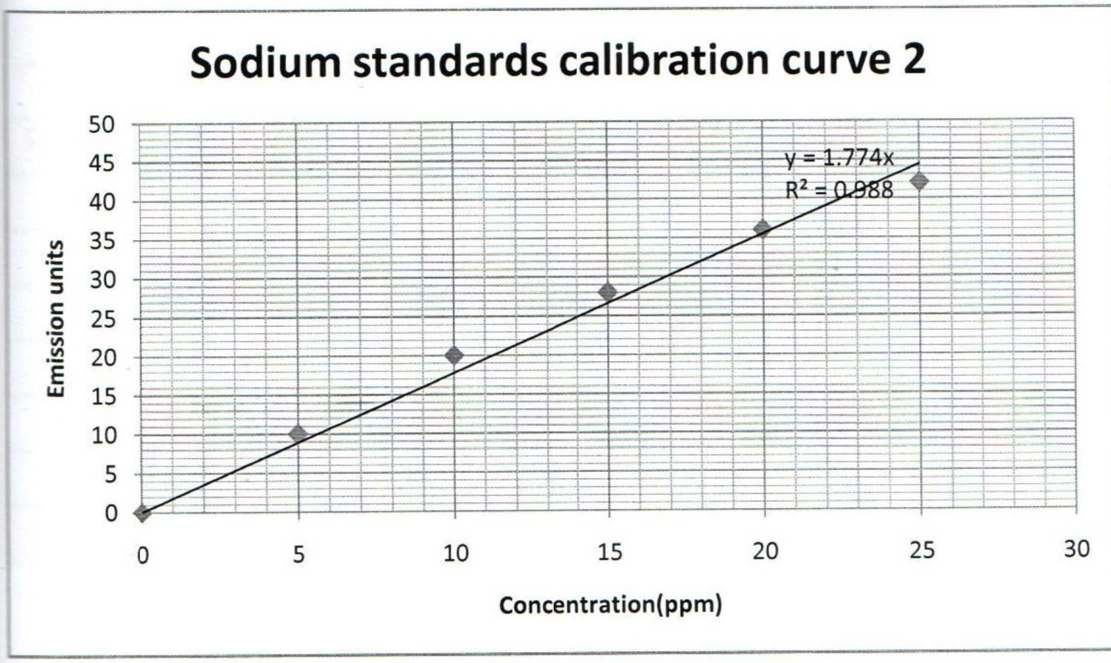
Belbur			
Sample	Emission units	Conc.	Conc.*df
P1	69	67	67
P2	66	64	64
P3	73	71	71
IP1	53	52	52
IP2	53	52	52
IP3	52	51	51
UD	59	58	115

Lanet BH2			
Sample	Emission units	Conc.	Conc.*df
P1	52	51	51
P2	55	54	54
P3	59	58	58
IP1	77	75	75
IP2	81	79	79
IP3	80	78	78
UD	46	45	90

Lanet BH1			
Sample	Emission units	Conc.	Conc.*df
P1	73	71	71
P2	73	71	71
P3	75	73	73
IP1	48	47	47
IP2	46	45	45
IP3	44	43	43
UD	43	42	84

St. Joseph's Kihingo			
Sample	Emission units	Conc.	Conc.*df
P1	53	52	52
P2	50	49	49
P3	57	56	56
IP1	50	49	49
IP2	49	48	48
IP3	53	52	52
UD	64	62	125

Standards	
Conc.	Emission units
0	0
5	10
10	20
15	28
20	36
25	42



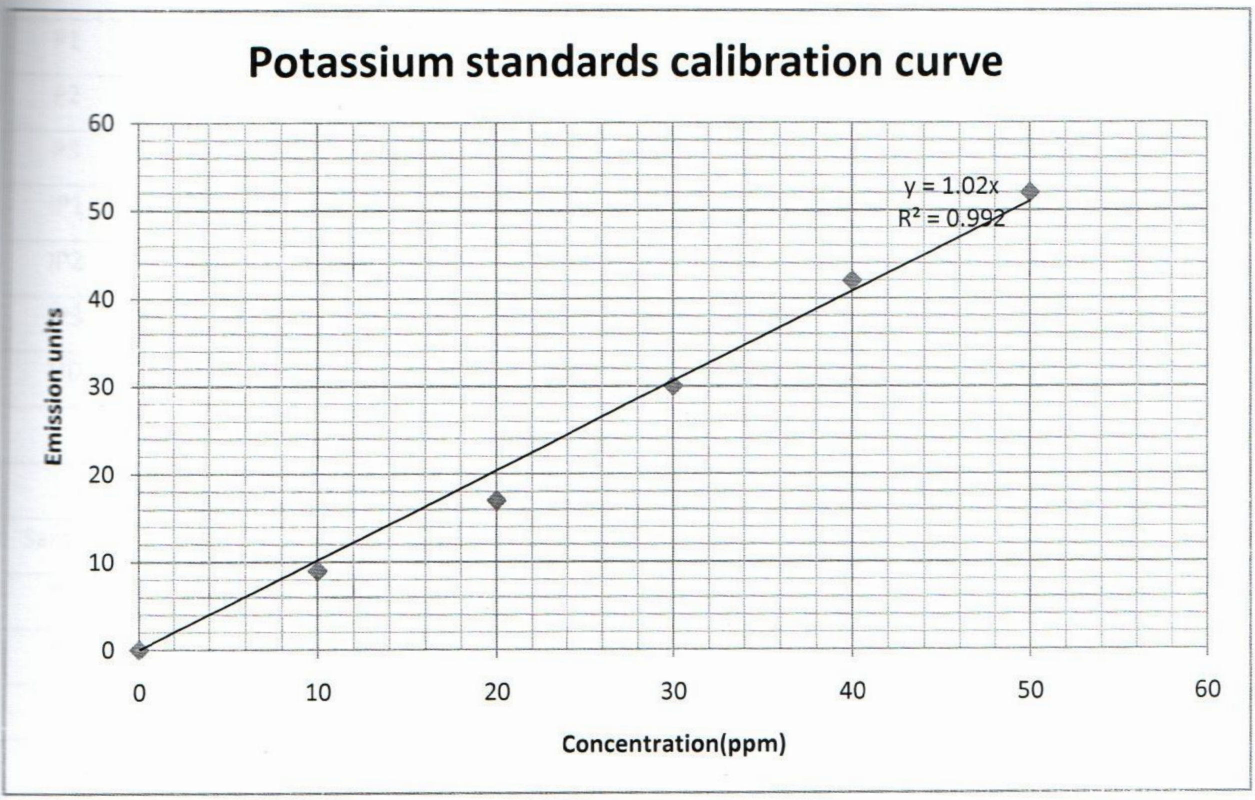
Egerton BH2			
Sample	Emission units	Conc.	Conc.*df
P1	20	11.27	90.19
P2	19	10.71	85.68
P3	17	9.58	76.66
IP1	19	10.71	85.68
IP2	16	9.02	72.15
IP3	18	10.15	81.17
UD	23	12.97	103.72

Egerton BH12			
Sample	Emission units	Conc.	Conc.*df
P1	18	10.15	81.17
P2	21	11.84	94.70
P3	17	9.58	76.66
IP1	17	9.58	76.66
IP2	16	9.02	72.15
IP3	16	9.02	72.15
UD	24	13.53	108.23

Ng'ondu			
Sample	Emission units	Conc.	Conc.*df
P1	17	9.58	76.66
P2	20	11.27	90.19
P3	19	10.71	85.68
IP1	15	8.46	67.64
IP2	17	9.58	76.66
IP3	20	11.27	90.19
UD	23	12.97	103.72

APPENDIX 2. CALCULATION OF CONCENTRATION OF POTASSIUM FROM ITS STANDARDS CALIBRATION CURVE

Standards	
Conc.	Emission units
0	0
10	9
20	17
30	30
40	42
50	52



Sample	Emission units	Conc.	Conc.*df
P1	15	15	15
P2	14	14	14
P3	15	15	15
IP1	14	14	14
IP2	14	14	14
IP3	14	14	14
UD	22	22	22

Njugu-ini			
Sample	Emission units	Conc.	Conc.*df
P1	16	16	16
P2	16	16	16
P3	16	16	16
IP1	14	14	14
IP2	14	14	14
IP3	13	13	13
UD	20	20	20

Maji-moto			
Sample	Emission units	Conc.	Conc.*df
P1	17	17	17
P2	15	15	15
P3	15	15	15
IP1	13	13	13
IP2	14	14	14
IP3	16	16	16
UD	22	22	22

Sample	Emission units	Conc.	Conc.*df
P1	24	24	24
P2	26	25	25
P3	27	26	26
IP1	27	26	26
IP2	27	26	26
IP3	27	26	26
UD	32	31	63

Lanet BH2			
Sample	Emission units	Conc.	Conc.*df
P1	14	14	14
P2	14	14	14
P3	14	14	14
IP1	10	10	10
IP2	11	11	11
IP3	10	10	10
UD	18	18	18

Lanet BH1			
Sample	Emission units	Conc.	Conc.*df
P1	21	21	21
P2	21	21	21
P3	20	20	20
IP1	11	11	11
IP2	11	11	11
IP3	11	11	11
UD	22	22	22

St. Joseph's Kiningo			
Sample	Emission units	Conc.	Conc.*df
P1	9	9	9
P2	10	10	10
P3	10	10	10
IP1	9	9	9
IP2	10	10	10
IP3	10	10	10
UD	14	14	14

Ng'ondu			
Sample	Emission units	Conc.	Conc.*df
P1	7	7	7
P2	8	8	8
P3	8	8	8
IP1	6	6	6
IP2	8	8	8
IP3	8	8	8
UD	9	9	9

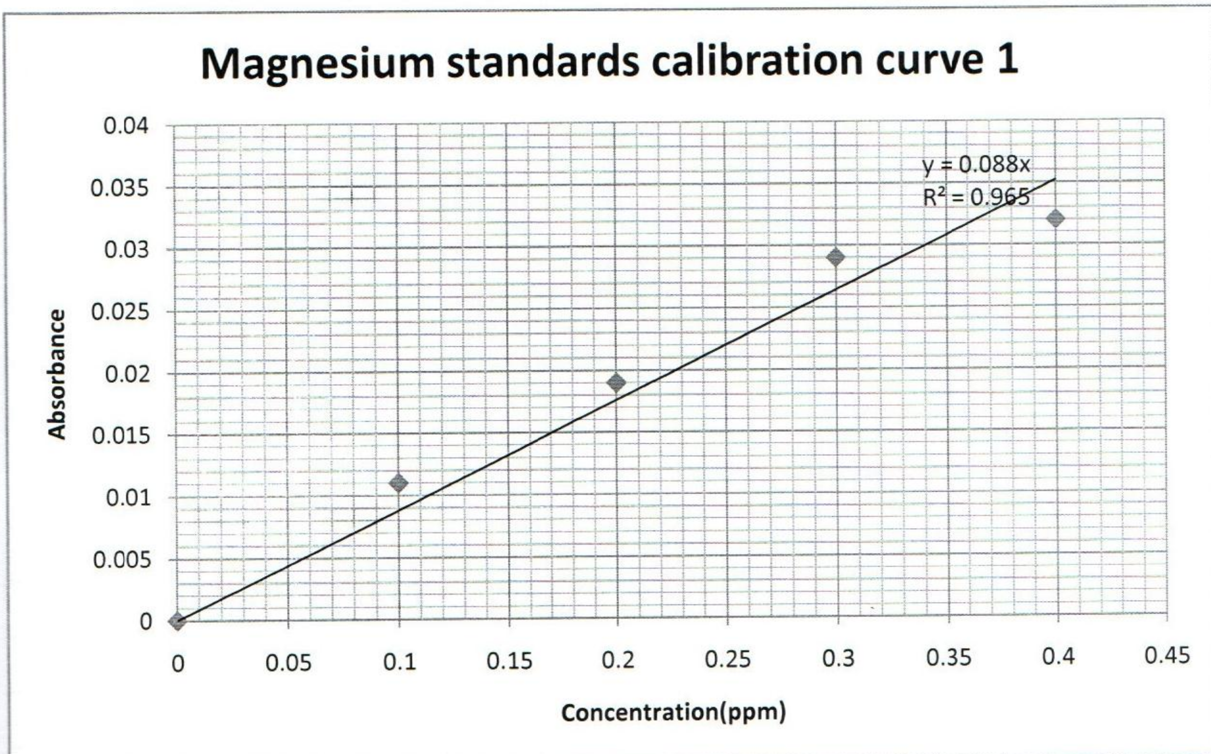
Egerton BH2			
Sample	Emission units	Conc.	Conc.*df
P1	9	9	9
P2	9	9	9
P3	9	9	9
IP1	8	8	8
IP2	9	9	9
IP3	8	8	8
UD	13	13	13

Egerton DALL			
Sample	Emission units	Conc.	Conc.*df
P1	11	11	11
P2	11	11	11
P3	11	11	11
IP1	11	11	11
IP2	11	11	11
IP3	11	11	11
UD	17	17	17

Bone char			
Sample	Emission units	Conc.	Conc.*df
P1	4	4	4
P2	4	4	4
P3	4	4	4
P AVERAGE			4
IP1	6	6	12
IP2	6	6	12
IP3	5	5	10
IP AVERAGE			11

STANDARDS CALIBRATION CURVE

Standards	
Conc.	Absorbance
0	0
0.1	0.011
0.2	0.019
0.3	0.029
0.4	0.032



Bone char			
Sample	Absorbance	Conc.	Conc.*df
P	0.015	0.17	85.23
IP	0.01	0.11	56.82

Egerton university tap			
Sample	Absorbance	Conc.	Conc.*df
P1	0.007	0.08	3.98
P2	0.008	0.09	4.55
P3	0.008	0.09	4.55
IP1	0.01	0.11	5.68
IP2	0.009	0.10	5.11
IP3	0.009	0.10	5.11
UD	0.004	0.05	0.05

Njugu-ini			
Sample	Absorbance	Conc.	Conc.*df
P1	0.008	0.09	4.55
P2	0.008	0.09	4.55
P3	0.008	0.09	4.55
IP1	0.013	0.15	7.39
IP2	0.014	0.16	7.95
IP3	0.015	0.17	8.52
UD	0.007	0.08	0.08

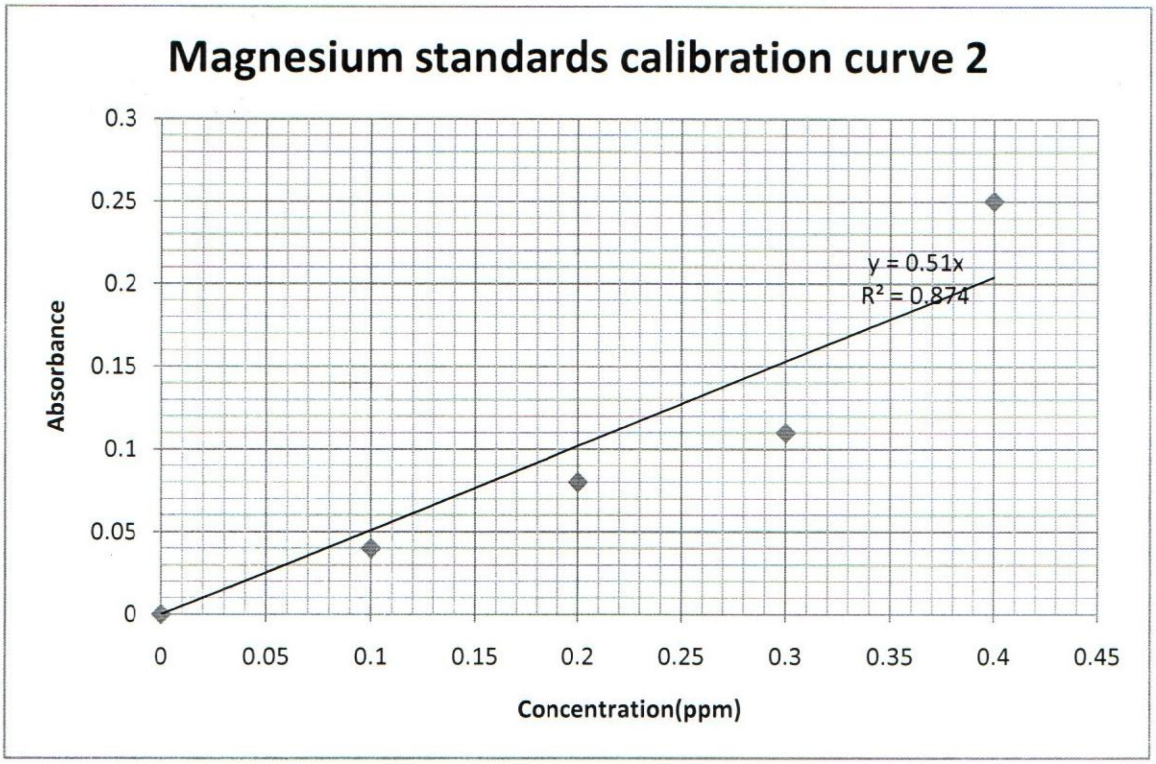
Maji-moto			
Sample	Absorbance	Conc.	Conc.*df
P1	0.007	0.08	3.98
P2	0.007	0.08	3.98
P3	0.009	0.10	5.11
IP1	0.013	0.15	7.39
IP2	0.012	0.14	6.82
IP3	0.012	0.14	6.82
UD	0.006	0.07	0.07

Lanet BH2			
Sample	Absorbance	Conc.	Conc.*df
P1	0.003	0.03	1.70
P2	0.003	0.03	1.70
P3	0.002	0.02	1.14
IP1	0.005	0.06	2.84
IP2	0.005	0.06	2.84
IP3	0.006	0.07	3.41
UD	0.021	0.24	0.95

Lanet BH1			
Sample	Absorbance	Conc.	Conc.*df
P1	0.025	0.28	0.57
P2	0.026	0.30	0.59
P3	0.023	0.26	0.52
IP1	0.024	0.27	0.55
IP2	0.025	0.28	0.57
IP3	0.026	0.30	0.59
UD	0.023	0.26	0.26

St. Joseph's Kihingo			
Sample	Absorbance	Conc.	Conc.*df
P1	0.009	0.10	5.11
P2	0.009	0.10	5.11
P3	0.008	0.09	4.55
IP1	0.012	0.14	6.82
IP2	0.012	0.14	6.82
IP3	0.013	0.15	7.39
UD	0.026	0.30	0.89

Standards	
Conc.	Absorbance
0	0
0.1	0.04
0.2	0.08
0.3	0.11
0.4	0.25



Belbur			
Sample	Absorbance	Conc.	Conc.*df
P1			
P2	0.014	0.03	0.41
P3	0.01	0.02	0.29
IP1			
IP2	0.012	0.02	0.47
IP3	0.01	0.02	0.39
UD	0.007	0.01	0.27

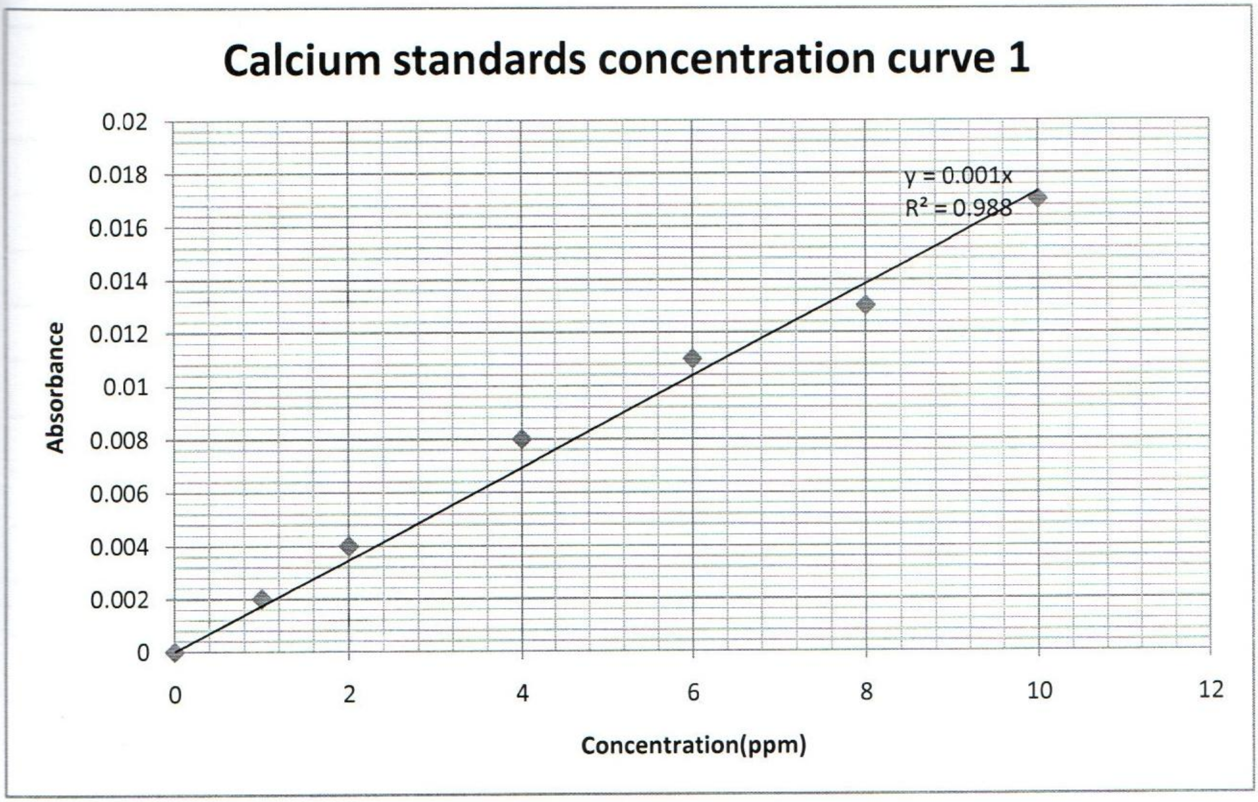
Sample	Absorbance	Conc.	Conc.*df
P1	0.017	0.03	0.40
P2	0.015	0.03	0.35
P3	0.015	0.03	0.35
IP1	0.013	0.03	0.31
IP2	0.017	0.03	0.40
IP3	0.02	0.04	0.47
UD	0.002	0.00	0.00

Egerton BH2			
Sample	Absorbance	Conc.	Conc.*df
P1	0.017	0.03	0.33
P2	0.022	0.04	0.43
P3	0.019	0.04	0.37
IP1	0.017	0.03	0.33
IP2	0.022	0.04	0.43
IP3	0.022	0.04	0.43
UD	0.004	0.01	0.01

Egerton BH12			
Sample	Absorbance	Conc.	Conc.*df
P1			
P2	0.014	0.03	0.33
P3	0.013	0.03	0.31
IP1	0.012	0.02	0.28
IP2	0.014	0.03	0.33
IP3	0.013	0.03	0.31
UD	0.009	0.02	0.02

STANDARDS CALIBRATION CURVE

Standards	
Conc.	Absorbance
0	0
1	0.002
2	0.004
4	0.008
6	0.011
8	0.013
10	0.017



Bone char			
Sample	Absorbance	Conc.	Conc.*df
P	0.02	20	2000
IP	0.015	15	1500

Egerton university tap		
Sample	Absorbance	Conc.
P1	<0.002	<1ppm
P2	<0.002	<1ppm
P3	<0.002	<1ppm
IP1	<0.002	<1ppm
IP2	<0.002	<1ppm
IP3	<0.002	<1ppm
UD	<0.002	<1ppm

Njugu-ini		
Sample	Absorbance	Conc.
P1	<0.002	<1ppm
P2	<0.002	<1ppm
P3	<0.002	<1ppm
IP1	<0.002	<1ppm
IP2	<0.002	<1ppm
IP3	<0.002	<1ppm
UD	0.002	2

Maji-moto		
Sample	Absorbance	Conc.
P1	<0.002	<1ppm
P2	<0.002	<1ppm
P3	<0.002	<1ppm
IP1	<0.002	<1ppm
IP2	<0.002	<1ppm
IP3	<0.002	<1ppm
UD	<0.002	<1ppm

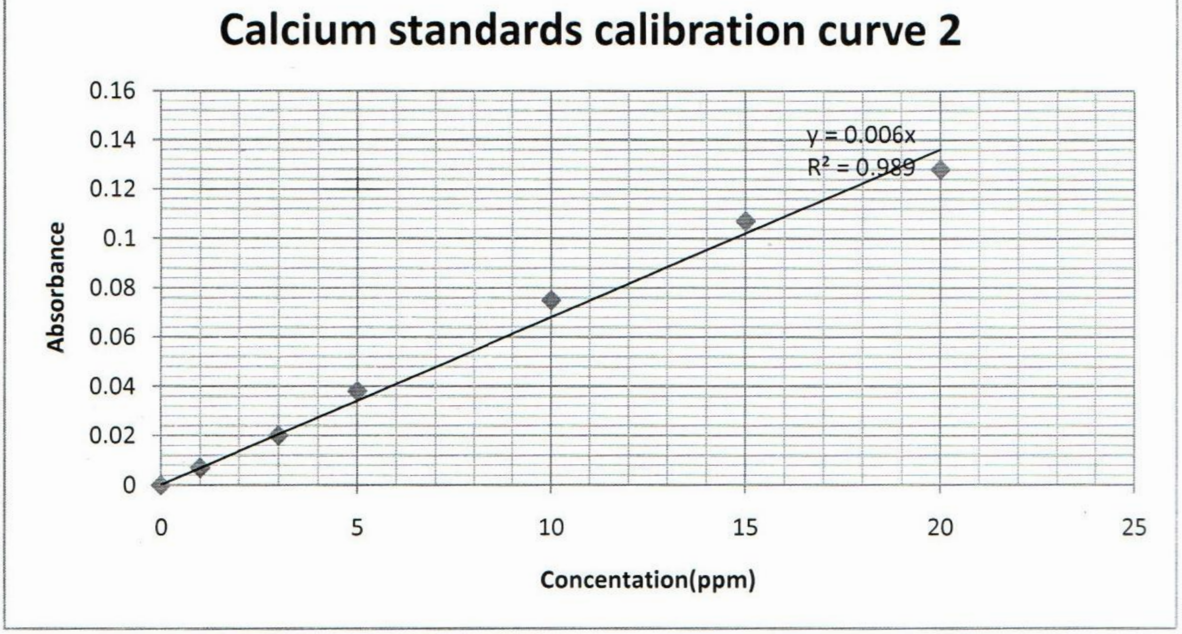
Belbur		
Sample	Absorbance	Conc.
P1	<0.002	<1ppm
P2	<0.002	<1ppm
P3	<0.002	<1ppm
IP1	<0.002	<1ppm
IP2	<0.002	<1ppm
IP3	<0.002	<1ppm
UD	0.008	8

Lanet BH2		
Sample	Absorbance	Conc.
P1	<0.002	<1ppm
P2	<0.002	<1ppm
P3	<0.002	<1ppm
IP1	<0.002	<1ppm
IP2	<0.002	<1ppm
IP3	<0.002	<1ppm
UD	0.001	1

Sample	Absorbance	Conc.
P1	<0.002	<1ppm
P2	<0.002	<1ppm
P3	<0.002	<1ppm
IP1	<0.002	<1ppm
IP2	<0.002	<1ppm
IP3	<0.002	<1ppm
UD	<0.002	<1ppm

St. Joseph's Kihingo		
Sample	Absorbance	Conc.
P1	<0.002	<1ppm
P2	<0.002	<1ppm
P3	<0.002	<1ppm
IP1	<0.002	<1ppm
IP2	<0.002	<1ppm
IP3	<0.002	<1ppm
UD	<0.002	<1ppm

Standards	
Conc.	Absorbance
0	0
1	0.007
3	0.02
5	0.038
10	0.075
15	0.107
20	0.128



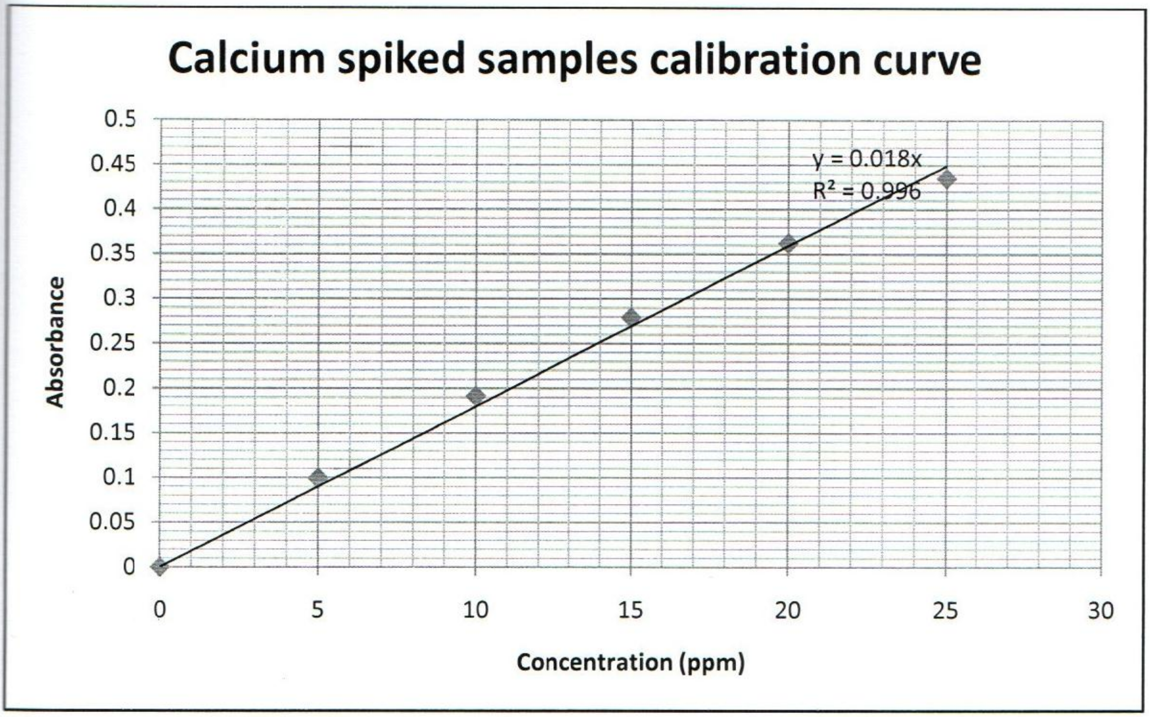
Ng'ondu		
Sample	Absorbance	Conc.
P1	0.003	0.5
P2	0.003	0.5
P3	0.003	0.5
IP1	0.002	0.3
IP2	0.002	0.3
IP3	0.003	0.5
UD	<0.007	<1ppm

Egerton BH2		
Sample	Absorbance	Conc.
P1	0.003	0.5
P2	0.003	0.5
P3	0.002	0.3
IP1	0.003	0.5
IP2	0.003	0.5
IP3	0.003	0.5
UD	<0.007	<1ppm

Sample	Absorbance	Conc.
P1	0.004	0.7
P2	0.004	0.7
P3	0.003	0.5
IP1	0.003	0.5
IP2	0.003	0.5
IP3	0.004	0.7
UD	0.002	0.3

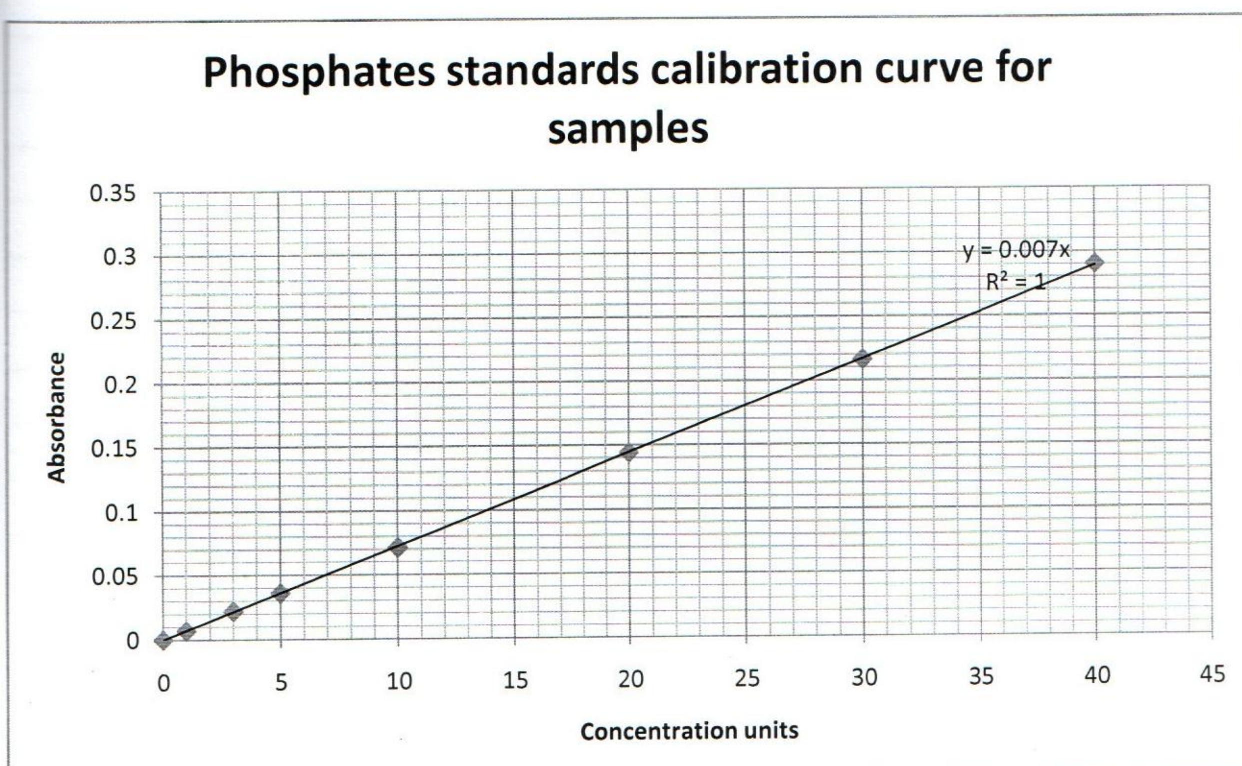
Standards for spiked sample	
Conc.	Absorbance
0	0
5	0.099
10	0.191
15	0.279
20	0.362

Spiked samples		
Sample	Absorbance	Conc.
UD	0.193	10.7
PI	0.015	0.8
P2	0.016	0.9
P3	0.007	0.4
IP1	0.015	0.8
IP2	0.02	1.1
IP3	0.007	0.4



APPENDIX 5: CALCULATION OF CONCENTRATION OF PHOSPHATES FROM ITS STANDARDS CALIBRATION CURVE

Standards	
Conc.	Absorbance
0	0
1	0.007
3	0.022
5	0.036
10	0.071
20	0.144
30	0.216
40	0.29



Sample	Absorbance	Conc.	Conc.*df
P1	0.127	18.14	72.57
P2	0.138	19.71	78.86
P3	0.129	18.43	73.71
IP1	0.049	7.00	28.00
IP2	0.104	14.86	59.43
IP3	0.081	11.57	46.29
UD	0.015	2.14	2.14

Njugu-ini			
Sample	Absorbance	Conc.	Conc.*df
P1	0.155	22.14	66.43
P2	0.166	23.71	71.14
P3	0.135	19.29	57.86
IP1	0.225	32.14	32.14
IP2	0.218	31.14	31.14
IP3	0.204	29.14	29.14
UD	<0.007	<1ppm	<1ppm

Maji-moto			
Sample	Absorbance	Conc.	Conc.*df
P1	0.145	20.71	62.14
P2	0.152	21.71	65.14
P3	0.159	22.71	68.14
IP1	0.212	30.29	30.29
IP2	0.233	33.29	33.29
IP3	0.23	32.86	32.86
UD	<0.007	<1ppm	<1ppm

Sample	Absorbance	Conc.	Conc.*df
P1	0.09	12.86	38.57
P2	0.084	12.00	36.00
P3	0.096	13.71	41.14
IP1	0.143	20.43	20.43
IP2	0.139	19.86	19.86
IP3	0.136	19.43	19.43
UD	<0.007	<1ppm	<1ppm

Lanet BH2			
Sample	Absorbance	Conc.	Conc.*df
P1	0.143	20.43	102.14
P2	0.141	20.14	100.71
P3	0.149	21.29	106.43
IP1	0.122	17.43	34.86
IP2	0.125	17.86	35.71
IP3	0.123	17.57	35.14
UD	0.01	1.43	1.43

Lanet BH1			
Sample	Absorbance	Conc.	Conc.*df
P1	0.236	33.71	134.86
P2	0.141	20.14	80.57
P3	0.238	34.00	136.00
IP1	0.121	17.29	51.86
IP2	0.117	16.71	50.14
IP3	0.121	17.29	51.86
UD	0.012	1.71	1.71

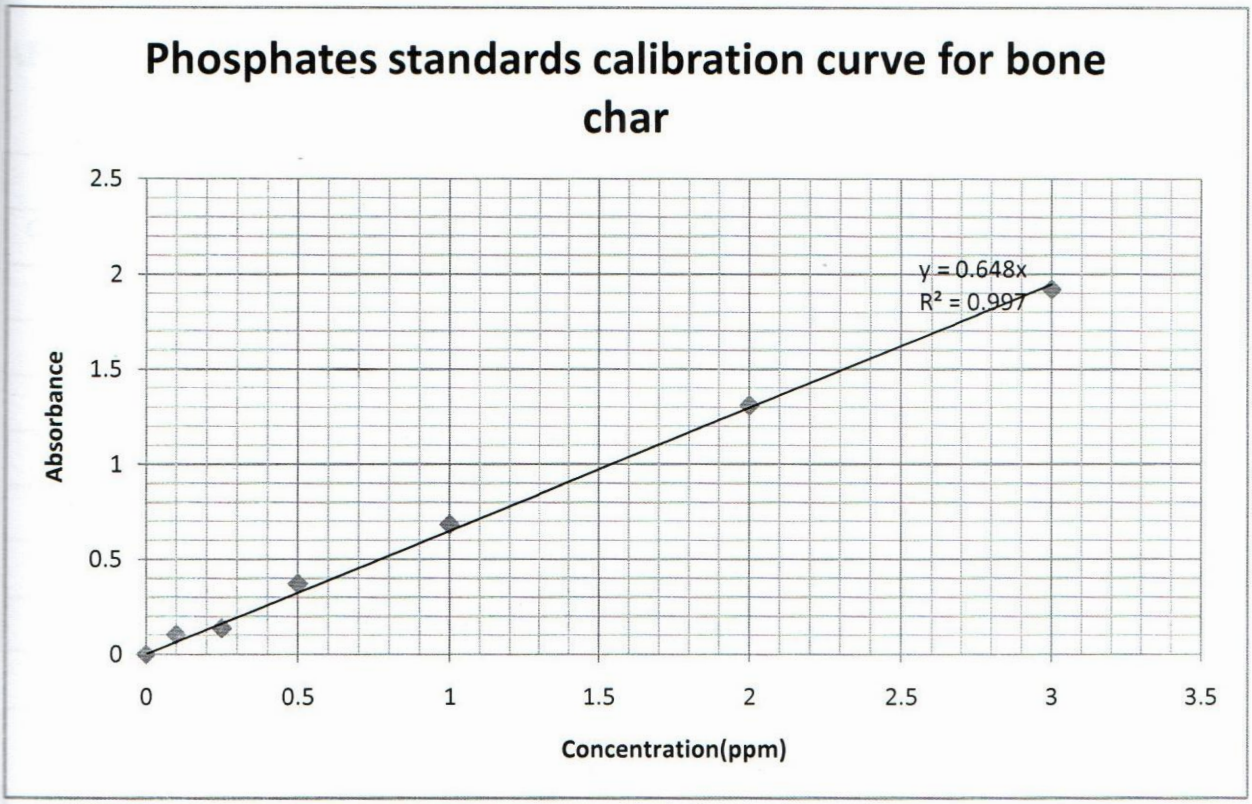
St. Joseph's Kihingo			
Sample	Absorbance	Conc.	Conc.*df
P1	0.112	16.00	64.00
P2	0.124	17.71	70.86
P3	0.121	17.29	69.14
IP1	0.118	16.86	50.57
IP2	0.135	19.29	57.86
IP3	0.123	17.57	52.71
UD	0.123	17.57	87.86

Ng'ondu			
Sample	Absorbance	Conc.	Conc.*df
P1	0.14	20.00	80.00
P2	0.21	30.00	120.00
P3	0.164	23.43	93.71
IP1	0.244	34.86	104.57
IP2	0.182	26.00	78.00
IP3	0.17	24.29	72.86
UD	0.029	4.14	4.14

Egerton BH2			
Sample	Absorbance	Conc.	Conc.*df
P1	0.095	16.71	83.57
P2	0.117	12.57	62.86
P3	0.088	14.29	71.43
IP1	0.1	16.14	64.57
IP2	0.113	17.00	68.00
IP3	0.119	17.00	68.00
UD	0.003	0.43	0.43

Sample	Absorbance	Conc.	Conc.*df
P1	0.192	27.43	82.29
P2	0.228	32.57	97.71
P3	0.119	17.00	51.00
IP1	0.12	17.14	68.57
IP2	0.12	17.14	68.57
IP3	0.111	15.86	63.43
UD	0.092	13.14	13.14

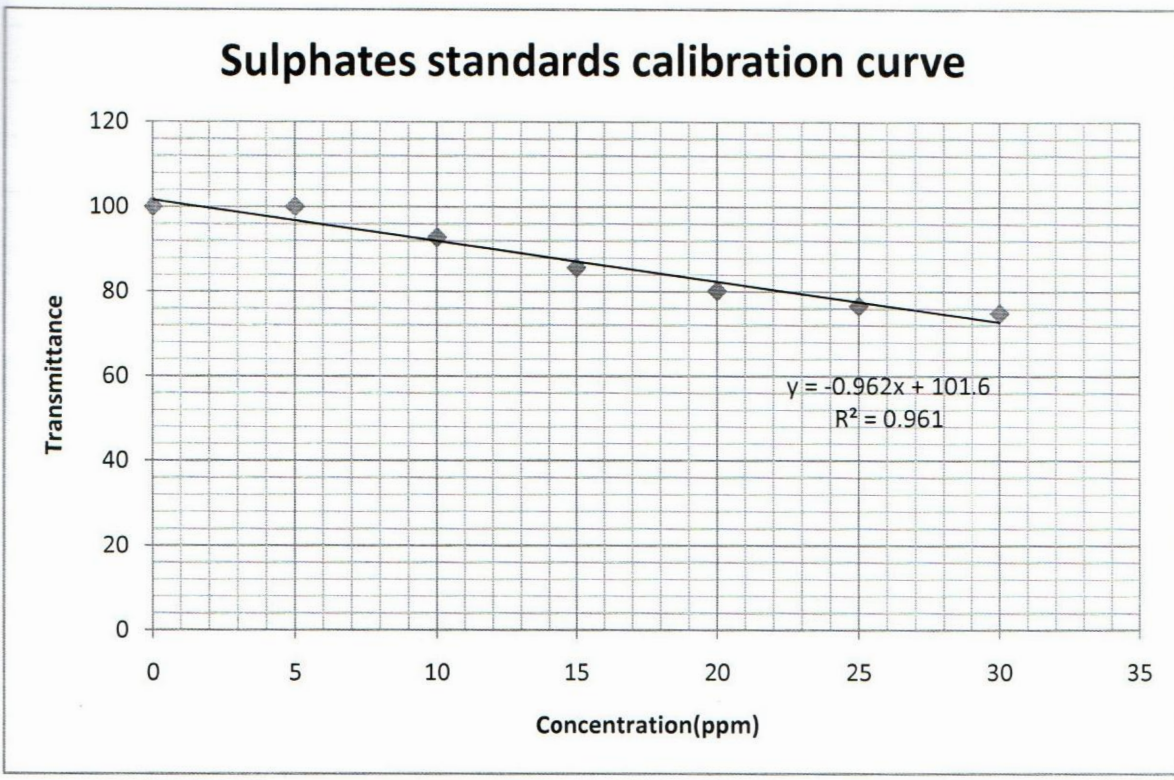
Standards	
Conc.	Absorbance
0	0
0.1	0.103
0.25	0.137
0.5	0.372
1	0.684
2	1.31
3	1.92



Bone char			
Sample	Absorbance	Conc.	Conc.*df
P	1.013	1.56	93.80
IP	1.031	1.59	95.46

APPENDIX 6: CALCULATION OF CONCENTRATION OF SULPHATES FROM ITS STANDARDS CALIBRATION CURVE

Standards	
Conc.	Transmittance
0	100
5	100
10	92.8
15	85.7
20	80.2
25	76.6
30	74.9



Sample	Transmittance	Conc.
P1	92.8	9.15
P2	92.7	9.25
P3	93	8.94
IP1	87.3	14.86
IP2	85.4	16.84
IP3	85.8	16.42

Egerton university tap		
Sample	Transmittance	Conc.
P1	83.4	18.92
P2	82	20.37
P3	81.8	20.58
IP1	83.5	18.81
IP2	85.8	16.42
IP3	84.2	18.09
UD	86.1	16.11

Njugu-ini		
Sample	Transmittance	Conc.
P1	88.6	13.51
P2	90.1	11.95
P3	90.6	11.43
IP1	84.8	17.46
IP2	88.4	13.72
IP3	84.6	17.67
UD	99.2	2.49

Maji-moto		
Sample	Transmittance	Conc.
P1	72.7	30.04
P2	74.5	28.17
P3	74.6	28.07
IP1	78.3	24.22
IP2	75.6	27.03
IP3	75.8	26.82
UD	82.4	19.96

Belbur		
Sample	Transmittance	Conc.
P1	72.8	29.94
P2	74.8	27.86
P3	73.8	28.90
IP1	82.3	20.06
IP2	80.3	22.14
IP3	79.8	22.66
UD	47.2	56.55

Lanet BH2		
Sample	Transmittance	Conc.
P1	81	21.41
P2	78.5	24.01
P3	78.3	24.22
IP1	88.2	13.93
IP2	86.8	15.38
IP3	86.4	15.80
UD	86.9	15.28

Lanet BH1		
Sample	Transmittance	Conc.
P1	60.3	42.93
P2	59.4	43.87
P3	61.8	41.37
IP1	73	29.73
IP2	72.3	30.46
IP3	70.8	32.02
UD	89.2	12.89

St. Joseph's Kihingo		
Sample	Transmittance	Conc.
P1	96.8	4.99
P2	96.8	4.99
P3	92.3	9.67
IP1	91.9	10.08
IP2	93.8	8.11
IP3	96.2	5.61
UD	97.2	4.57

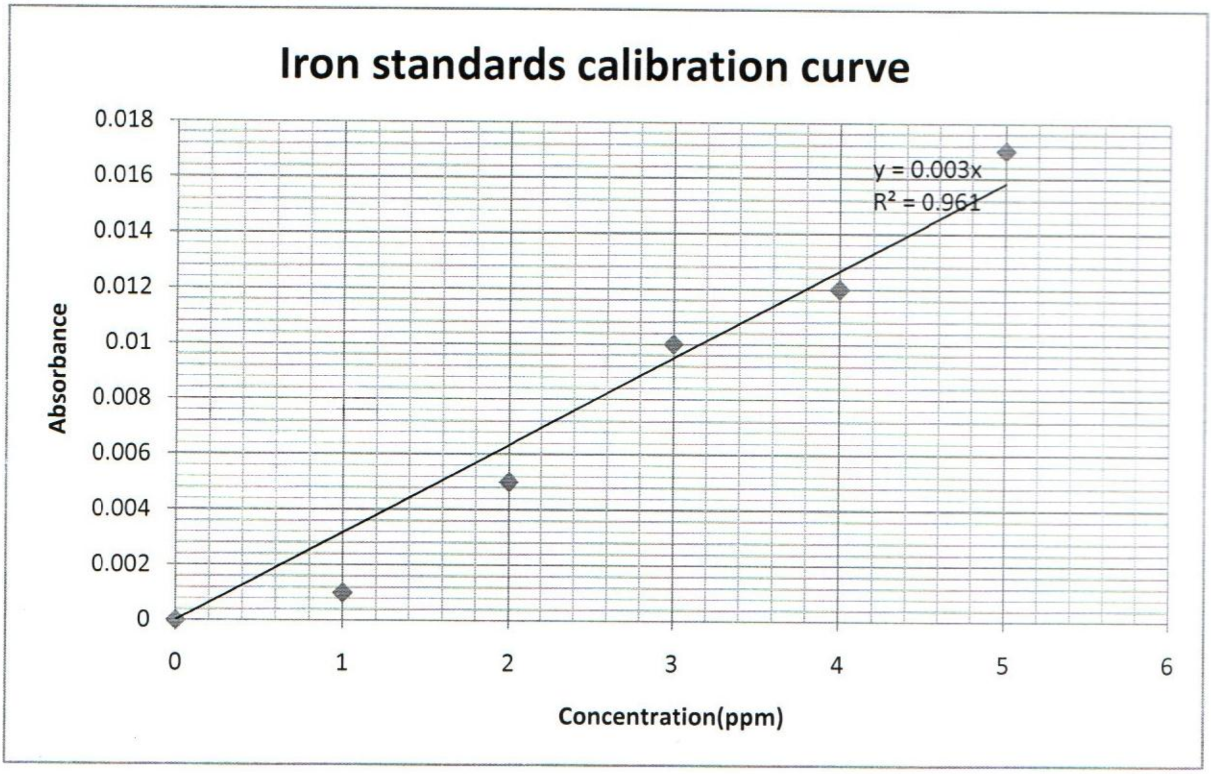
Ng'ondu		
Sample	Transmittance	Conc.
P1	85.6	16.63
P2	88.9	13.20
P3	86.8	15.38
IP1	83.7	18.61
IP2	87.2	14.97
IP3	89.7	12.37
UD	90.5	11.54

Egerton BH2		
Sample	Transmittance	Conc.
P1	85.2	17.05
P2	87.6	14.55
P3	89.5	12.58
IP1	86.3	15.90
IP2	87.6	14.55
IP3	86.5	15.70
UD	90.7	11.33

Egerton BH12		
Sample	Transmittance	Conc.
P1	82.1	20.27
P2	82.3	20.06
P3	83.6	18.71
IP1	83.3	19.02
IP2	81.3	21.10
IP3	84.2	18.09
UD	85.5	16.74

APPENDIX 7: CALCULATION OF CONCENTRATION OF IRON FROM ITS STANDARDS CALIBRATION CURVE

Standards	
Conc.	Absorbance
0	0
1	0.001
2	0.005
3	0.01
4	0.012
5	0.017



Bone char			
Sample	Absorbance	Conc.	Conc.*df
P	0.012	4.00	8.00
IP	0.013	4.33	43.33

Egerton university tap		
Sample	Absorbance	Conc.
P1	<0.001	<0.33
P2	<0.001	<0.33
P3	0.001	0.33
IP1	0.001	0.33
IP2	0.001	0.33
IP3	0.001	0.33
UD	0.001	0.33

Njugu-ini		
Sample	Absorbance	Conc.
P1	0.002	0.67
P2	0.003	1.00
P3	0.003	1.00
IP1	0.002	0.67
IP2	0.002	0.67
IP3	0.002	0.67
UD	0.003	1.00

Maji-moto		
Sample	Absorbance	Conc.
P1	0.002	0.67
P2	<0.001	<0.67
P3	<0.001	<0.67
IP1	<0.001	<0.67
IP2	<0.001	<0.67
IP3	<0.001	<0.67
UD	<0.001	<0.67

Lanet BH2		
Sample	Absorbance	Conc.
P1	<0.001	<0.33
P2	<0.001	<0.33
P3	<0.001	<0.33
IP1	<0.001	<0.33
IP2	<0.001	<0.33
IP3	<0.001	<0.33
UD	0.001	0.33

Lanet BH1		
Sample	Absorbance	Conc.
P1	<0.001	<0.33
P2	<0.001	<0.33
P3	<0.001	<0.33
IP1	<0.001	<0.33
IP2	<0.001	<0.33
IP3	<0.001	<0.33
UD	<0.001	<0.33

St. Joseph's Kihingo		
Sample	Absorbance	Conc.
P1	0.004	1.33
P2	0.005	1.67
P3	0.002	0.67
IP1	0.002	0.67
IP2	0.003	1.00
IP3	0.005	1.67
UD	0.012	4.00

Belbur		
Sample	Absorbance	Conc.
P1	<0.001	<0.33
P2	<0.001	<0.33
P3	<0.001	<0.33
IP1	<0.001	<0.33
IP2	<0.001	<0.33
IP3	<0.001	<0.33
UD	0.001	0.33

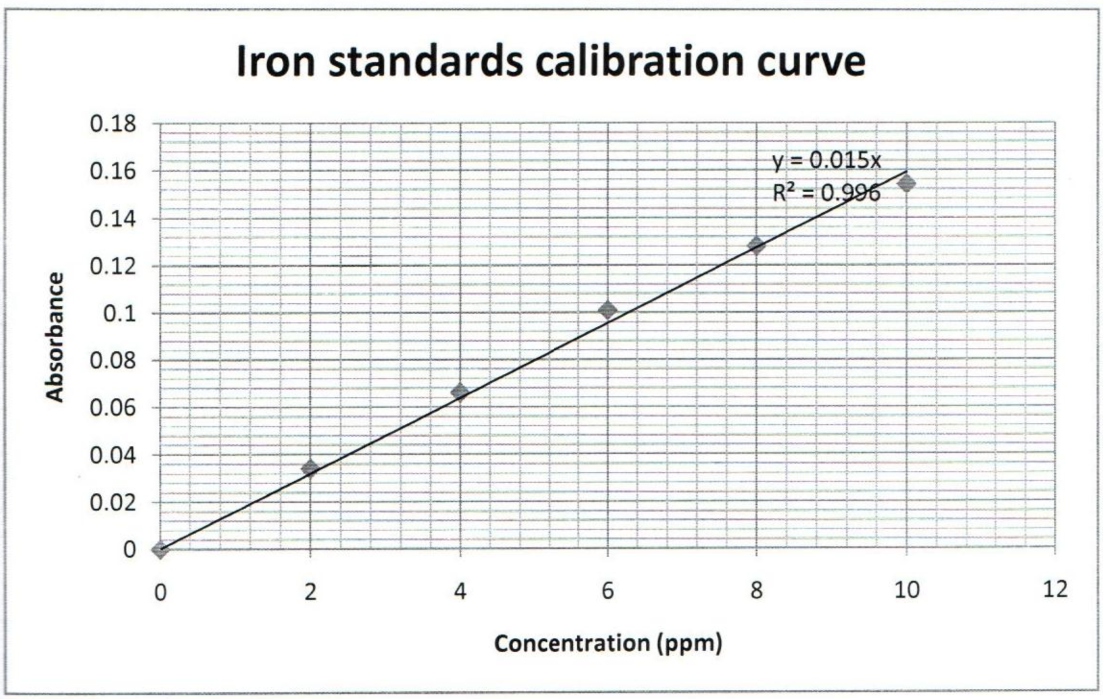
Ng'ondu		
Sample	Absorbance	Conc.
P1	0.007	2.33
P2	0.007	2.33
P3	0.007	2.33
IP1	0.002	0.67
IP2	0.006	2.00
IP3	0.007	2.33
UD	0.013	4.33

Egerton BH2		
Sample	Absorbance	Conc.
P1	0.001	0.33
P2	<0.001	<0.33
P3	<0.001	<0.33
IP1	<0.001	<0.33
IP2	0.001	0.33
IP3	0.001	0.33
UD	0.003	1.00

Sample	Absorbance	Conc.
P1	<0.001	<0.33
P2	<0.001	<0.33
P3	<0.001	<0.33
IP1	<0.001	<0.33
IP2	<0.001	<0.33
IP3	<0.001	<0.33
UD	0.002	0.67

Standards	
Conc.	Absorbance
0	0
2	0.034
4	0.066
6	0.101
8	0.128
10	0.154

Spiked samples		
Sample	Absorbance	Conc.
UD	0.081	5.4
PI	0.011	0.7
P2	0.012	0.8
P3	0.013	0.9
IP1	0.01	0.7
IP2	0.009	0.6
IP3	0.011	0.7



APPENDIX 8: CALCULATION OF CONCENTRATION OF CHLORIDE FROM TITRATION DATA

Vol. of $MgCl_2.6H_2O$	Conc. of $MgCl_2.6H_2O$	Vol. of $AgNO_3$ equivalent	Conc. of $AgNO_3$
10	0.0991	29.9	0.0663
10	0.0991	29.85	0.0664
10	0.0991	29.9	0.0663
Average			0.0663

Belbur							
Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	0.00	34.30	34.30			
P1B	50.00	0.00	34.25	34.25			
P1 Average	50.00			34.28	0.0663	0.0454	1613
P2A	50.00	0.00	33.80	33.80			
P2B	50.00	0.00	33.80	33.80			
P2 Average	50.00			33.80	0.0663	0.0448	1591
P3A	50.00	0.00	34.55	34.55			
P3B	50.00	0.00	34.50	34.50			
P3 Average	50.00			34.53	0.0663	0.0458	1625
IP1A	50.00	0.00	33.65	33.65			
IP1B	50.00	0.00	33.70	33.70			
IP1 Average	50.00			33.68	0.0663	0.0447	1585
IP2A	50.00	0.00	33.65	33.65			
IP2B	50.00	0.00	33.70	33.70			
IP2 Average	50.00			33.68	0.0663	0.0447	1585
IP3A	50.00	0.00	33.80	33.80			
IP3B	50.00	0.00	33.80	33.80			
IP3 Average	50.00			33.80	0.0663	0.0448	1591
UNDEFLUORIDATED I	50.00	0.00	43.00	43.00			
UNDEFLUORIDATED II	50.00	1.00	44.00	43.00			
UD AVERAGE	50.00			43.00	0.0663	0.0570	2024

Egerton University tap

Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	0.00	2.80	2.80			
P1B	50.00	3.00	5.85	2.85			
P1 Average	50.00			2.83	0.0663	0.0037	133
P2A	50.00	8.00	10.80	2.80			
P2B	50.00	11.00	13.85	2.85			
P2 Average	50.00			2.83	0.0663	0.0037	133
P3A	50.00	15.00	18.00	3.00			
P3B	50.00	10.00	13.00	2.80			
P3 Average	50.00			2.80	0.0663	0.0037	132
IP1A	50.00	15.00	17.90	2.90			
IP1B	50.00	18.00	20.95	2.95			
IP1 Average	50.00			2.93	0.0663	0.0039	138
IP2A	50.00	23.00	25.80	2.80			
IP2B	50.00	-	-				
IP2 Average	50.00			2.80	0.0663	0.0037	132
IP3A	50.00	30.00	32.90	2.90			
IP3B	50.00	33.00	35.95	2.95			
IP3 Average	50.00			2.93	0.0663	0.0039	138
UNDEFLUO RIDATED	50.00	36.00	38.95	2.95	0.0663	0.0039	139

Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	0.00	3.95	3.95			
P1B	50.00	4.00	8.00	4.00			
P1 Average	50.00			3.98	0.0663	0.0053	187
P2A	50.00	9.00	13.00	4.00			
P2B	50.00	-	-	-			
P2 Average	50.00			4.00	0.0663	0.0053	188
P3A	50.00	19.00	23.00	4.00			
P3B	50.00	24.00	27.90	3.90			
P3 Average	50.00			3.95	0.0663	0.0052	186
IP1A	50.00	0.00	4.25	4.25			
IP1B	50.00	5.00	9.25	4.25			
IP1 Average	50.00			4.25	0.0663	0.0056	200
IP2A	50.00	10.00	14.20	4.20			
IP2B	50.00	15.00	19.25	4.25			
IP2 Average	50.00			4.23	0.0663	0.0056	199
IP3A	50.00	20.00	24.30	4.30			
IP3B	50.00	25.00	29.30	4.30			
IP3 Average	50.00			4.30	0.0663	0.0057	202
UNDEFLUORIDATED I	50.00	17.00	21.55	4.55			
UNDEFLUORIDATED II	50.00	22.00	26.50	4.50			
UD AVERAGE	50.00			4.53	0.0663	0.0060	213

Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	0.00	1.30	1.30			
P1B	50.00	3.00	4.25	1.25			
P1 Average	50.00			1.28	0.0663	0.0017	60
P2A	50.00	10.00	11.70	1.70			
P2B	50.00	12.00	13.70	1.70			
P2 Average	50.00			1.70	0.0663	0.0023	80
P3A	50.00	14.00	15.45	1.45			
P3B	50.00	16.00	17.50	1.50			
P3 Average	50.00			1.48	0.0663	0.0020	69
IP1A	50.00	18.00	20.50	2.50			
IP1B	50.00	21.00	23.55	2.55			
IP1 Average	50.00			2.53	0.0663	0.0033	119
IP2A	50.00	24.00	26.65	2.65			
IP2B	50.00	27.00	29.70	2.70			
IP2 Average	50.00			2.68	0.0663	0.0035	126
IP3A	50.00	32.00	34.80	2.80			
IP3B	50.00	35.00	37.70	2.70			
IP3 Average	50.00			2.75	0.0663	0.0036	129
UNDEFLUORIDATED I	50.00	10.00	12.95	2.95			
UNDEFLUORIDATED II	50.00	13.00	16.00	3.00			
UD AVERAGE	50.00			2.98	0.0663	0.0039	140

Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	10.00	15.20	5.20			
P1B	50.00	16.00	21.25	5.25			
P1 Average	50.00			5.23	0.0663	0.0069	246
P2A	50.00	24.00	29.20	5.20			
P2B	50.00	30.00	35.30	5.30			
P2 Average	50.00			5.25	0.0663	0.0070	247
P3A	50.00	10.00	15.15	5.15			
P3B	50.00	16.00	21.20	5.20			
P3 Average	50.00			5.18	0.0663	0.0069	244
IP1A	50.00	10.00	15.00	5.00			
IP1B	50.00	15.00	20.00	5.00			
IP1 Average	50.00			5.00	0.0663	0.0066	235
IP2A	50.00	21.00	26.10	5.10			
IP2B	50.00	27.00	32.15	5.15			
IP2 Average	50.00			5.13	0.0663	0.0068	241
IP3A	50.00	13.00	18.00	5.00			
IP3B	50.00	18.00	23.00	5.00			
IP3 Average	50.00			5.00	0.0663	0.0066	235
UNDEFLUORIDATED I	50.00	27.00	33.00	6.00			
UNDEFLUORIDATED II	50.00	33.00	39.00	6.00			
UD AVERAGE	50.00			6.00	0.0663	0.0080	282

St. Joseph's Kihingo							
Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	17.00	21.20	4.20			
P1B	50.00	22.00	26.15	4.15			
P1 Average	50.00			4.18	0.0663	0.0055	197
P2A	50.00	27.00	31.20	4.20			
P2B	50.00	32.00	36.20	4.20			
P2 Average	50.00			4.20	0.0663	0.0056	198
P3A	50.00	6.00	10.60	4.60			
P3B	50.00	11.00	15.60	4.60			
P3 Average	50.00			4.60	0.0663	0.0061	217
IP1A	50.00	16.00	20.30	4.30			
IP1B	50.00	21.00	25.35	4.35			
IP1 Average	50.00			4.33	0.0663	0.0057	204
IP2A	50.00	5.00	9.50	4.50			
IP2B	50.00	10.00	14.50	4.50			
IP2 Average	50.00			4.50	0.0663	0.0060	212
IP3A	50.00	15.00	19.55	4.55			
IP3B	50.00	20.00	24.60	4.60			
IP3 Average	50.00			4.58	0.0663	0.0061	215
UNDEFLUORIDATED I	50.00	5.00	10.70	5.70			
UNDEFLUORIDATED II	50.00	11.00	16.60	5.60			
UD AVERAGE	50.00			5.65	0.0663	0.0075	266

Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	6.00	11.70	5.70			
P1B	50.00	12.00	17.70	5.70			
P1 Average	50.00			5.70	0.0663	0.0076	268
P2A	50.00	18.00	24.20	6.20			
P2B	50.00	25.00	31.15	6.15			
P2 Average	50.00			6.18	0.0663	0.0082	291
P3A	50.00	9.00	14.90	5.90			
P3B	50.00	15.00	20.95	5.95			
P3 Average	50.00			5.93	0.0663	0.0079	279
IP1A	50.00	22.00	27.50	5.50			
IP1B	50.00	28.00	33.50	5.50			
IP1 Average	50.00			5.50	0.0663	0.0073	259
IP2A	50.00	6.00	12.40	6.40			
IP2B	50.00	13.00	19.35	6.35			
IP2 Average	50.00			6.38	0.0663	0.0085	300
IP3A	50.00	21.00	26.70	5.70			
IP3B	50.00	27.00	32.65	5.65			
IP3 Average	50.00			5.68	0.0663	0.0075	267
UNDEFLUORIDATED I	50.00	26.00	30.40	6.40			
UNDEFLUORIDATED II	50.00	31.00	35.45	6.45			
UD AVERAGE	50.00			6.43	0.0663	0.0085	302

Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	9.00	11.50	2.50			
P1B	50.00	12.00	14.55	2.55			
P1 Average	50.00			2.53	0.0663	0.0033	119
P2A	50.00	15.00	17.60	2.60			
P2B	50.00	19.00	21.60	2.60			
P2 Average	50.00			2.60	0.0663	0.0034	122
P3A	50.00	23.00	25.65	2.65			
P3B	50.00	27.00	29.65	2.65			
P3 Average	50.00			2.65	0.0663	0.0035	125
IP1A	50.00	30.00	32.95	2.95			
IP1B	50.00	34.00	37.00	3.00			
IP1 Average	50.00			2.98	0.0663	0.0039	140
IP2A	50.00	37.00	40.05	3.05			
IP2B	50.00	41.00	44.00	3.00			
IP2 Average	50.00			3.03	0.0663	0.0040	142
IP3A	50.00	44.00	47.10	3.10			
IP3B	50.00	0.00	2.95	2.95			
IP3 Average	50.00			3.03	0.0663	0.0040	142
UNDEFLUORI DATED I	50.00	0.00	3.50	3.50			
UNDEFLUORI DATED II	50.00	5.00	8.55	3.55			
UD AVERAGE	50.00			3.53	0.0663	0.0047	166

Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	13.00	14.95	1.95			
P1B	50.00	16.00	18.00	2.00			
P1 Average	50.00			1.98	0.0663	0.0026	93
P2A	50.00	18.00	20.10	2.10			
P2B	50.00	21.00	23.10	2.10			
P2 Average	50.00			2.10	0.0663	0.0028	99
P3A	50.00	24.00	25.95	1.95			
P3B	50.00	27.00	29.00	2.00			
P3 Average	50.00			1.98	0.0663	0.0026	93
IP1A	50.00	29.00	31.50	2.50			
IP1B	50.00	32.00	34.50	2.50			
IP1 Average	50.00			2.50	0.0663	0.0033	118
IP2A	50.00	35.00	37.60	2.60			
IP2B	50.00	38.00	40.60	2.60			
IP2 Average	50.00			2.60	0.0663	0.0034	122
IP3A	50.00	42.00	44.60	2.60			
IP3B	50.00	45.00	47.65	2.65			
IP3 Average	50.00			2.63	0.0663	0.0035	124
UNDEFLUORIDATED I	50.00	5.00	8.15	3.15			
UNDEFLUORIDATED II	50.00	9.00	12.10	3.10			
UD AVERAGE	50.00			3.13	0.0663	0.0041	147

Egerton BH12

Sample	Volume of sample	Initial Volume of $AgNO_3$	Final volume of $AgNO_3$	Titre	Conc. of $AgNO_3$	Chloride conc. In sample	Conc. in ppm
P1A	50.00	9.00	12.00	3.00			
P1B	50.00	12.00	14.95	2.95			
P1 Average	50.00			2.98	0.0663	0.0039	140
P2A	50.00	16.00	18.90	2.90			
P2B	50.00	20.00	23.00	3.00			
P2 Average	50.00			2.95	0.0663	0.0039	139
P3A	50.00	25.00	28.00	3.00			
P3B	50.00	28.00	31.00	3.00			
P3 Average	50.00			3.00	0.0663	0.0040	141
IP1A	50.00	31.00	33.85	2.85			
IP1B	50.00	34.00	37.20	3.20			
IP1 Average	50.00			3.03	0.0663	0.0040	142
IP2A	50.00	38.00	41.25	3.25			
IP2B	50.00	42.00	45.25	3.25			
IP2 Average	50.00			3.25	0.0663	0.0043	153
IP3A	50.00	46.00	49.20	3.20			
IP3B	50.00	0.00	3.25	3.25			
IP3 Average	50.00			3.23	0.0663	0.0043	152
UNDEFLUORIDATED I	50.00	0.00	3.60	3.60			
UNDEFLUORIDATED II	50.00	4.00	7.65	3.65			
UD AVERAGE	50.00			3.63	0.0663	0.0048	171

APPENDIX 9: CALCULATION OF CONCENTRATION OF BICARBONATE FROM TITRATION DATA

Ng'ondu							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.3	0.707547	9.5	8.056	22.41278	7	224
P2	0.3	0.707547	9.5	8.056	22.41278	7	224
P3	0.5	1.179245	11.2	9.4976	25.37098	12	254
IP1	0.4	0.943396	9	7.632	20.40024	9	204
IP2	0.5	1.179245	11	9.328	24.8537	12	249
IP3	0.3	0.707547	9.5	8.056	22.41278	7	224
UD	0.45	1.061321	11.5	9.752	26.50657	11	265

Belbur							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.3	0.707547	7.3	6.1904	16.7227	7	167
P2	0.3	0.707547	7.4	6.2752	16.98134	7	170
P3	0.5	1.179245	8.6	7.2928	18.64634	12	186
IP1	0.25	0.589623	6.5	5.512	15.01325	6	150
IP2	0.4	0.943396	6.9	5.8512	14.9688	9	150
IP3	0.25	0.589623	6.25	5.3	14.36665	6	144
UD	0.3	0.707547	15.6	13.2288	38.18982	7	382

St. Joseph's Kihingo							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.3	0.707547	11.2	9.4976	26.80966	7	268
P2	0.5	1.179245	11	9.328	24.8537	12	249
P3	0.6	1.415094	10.4	8.8192	22.58252	14	226
IP1	0.5	1.179245	10.5	8.904	23.5605	12	236
IP2	0.5	1.179245	11.4	9.6672	25.88826	12	259
IP3	0.4	0.943396	10.4	8.8192	24.0212	9	240
UD	0.2	0.471698	11.4	9.6672	28.04628	5	280

Egerton tap							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.5	1.179245	9.8	8.3104	21.75002	12	218
P2	0.4	0.943396	9.9	8.3952	22.728	9	227
P3	0.5	1.179245	11.2	9.4976	25.37098	12	254
IP1	0.5	1.179245	8.7	7.3776	18.90498	12	189
IP2	0.6	1.415094	10.5	8.904	22.84116	14	228
IP3	0.5	1.179245	9	7.632	19.6809	12	197
UD	0.5	1.179245	12	10.176	27.4401	12	274

Lanet BH1							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.7	1.650943	15.2	12.8896	34.2779	17	343
P2	0.3	0.707547	13.7	11.6176	33.27566	7	333
P3	0.6	1.415094	15.3	12.9744	35.25588	14	353
IP1	0.4	0.943396	9.1	7.7168	20.65888	9	207
IP2	0.4	0.943396	9.1	7.7168	20.65888	9	207
IP3	0.5	1.179245	10.1	8.5648	22.52594	12	225
UD	0.5	1.179245	15.9	13.4832	37.52706	12	375

Lanet BH2							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.4	0.943396	11.1	9.4128	25.83168	9	258
P2	0.3	0.707547	10.2	8.6496	24.22326	7	242
P3	0.4	0.943396	11.8	10.0064	27.64216	9	276
IP1	0.4	0.943396	7.6	6.4448	16.77928	9	168
IP2	0.3	0.707547	8.9	7.5472	20.86094	7	209
IP3	0.3	0.707547	7.5	6.36	17.23998	7	172
UD	0.15	0.353774	12.15	10.3032	30.34575	4	303

Egerton BH12							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.15	0.353774	9.45	8.0136	23.36247	4	234
P2	0.2	0.471698	10.5	8.904	25.71852	5	257
P3	0.2	0.471698	10.1	8.5648	24.68396	5	247
IP1	0.6	1.415094	9.5	8.056	20.25476	14	203
IP2	0.4	0.943396	8.7	7.3776	19.62432	9	196
IP3	0.4	0.943396	10.7	9.0736	24.79712	9	248
UD	0.15	0.353774	11.25	9.54	28.01799	4	280

Egerton BH2							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.4	0.943396	10.6	8.9888	24.53848	9	245
P2	0.4	0.943396	9.1	7.7168	20.65888	9	207
P3	0.4	0.943396	10.5	8.904	24.27984	9	243
IP1	0.4	0.943396	10	8.48	22.98664	9	230
IP2	0.5	1.179245	8.9	7.5472	19.42226	12	194
IP3	0.4	0.943396	8.7	7.3776	19.62432	9	196
UD	0.6	1.415094	11.4	9.6672	25.16892	14	252

Njugu-ini							
sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.4	0.943396	10.9	9.2432	25.3144	9	253
P2	0.5	1.179245	9.5	8.056	20.9741	12	210
P3	0.4	0.943396	10.9	9.2432	25.3144	9	253
IP1	0.5	1.179245	7.9	6.6992	16.83586	12	168
IP2	0.4	0.943396	9	7.632	20.40024	9	204
IP3	0.4	0.943396	7.8	6.6144	17.29656	9	173
UD	0.7	1.650943	12.3	10.4304	26.77734	17	268

Maji moto							
Sample	phenolphthalein reading(a)	(b)	methyl reading(c)	(d)	d-b	CO_3	HCO_3
P1	0.7	1.650943	9.9	8.3952	20.56998	17	206
P2	0.5	1.179245	10.9	9.2432	24.59506	12	246
P3	0.6	1.415094	10.15	8.6072	21.93592	14	219
IP1	0.6	1.415094	10.4	8.8192	22.58252	14	226
IP2	0.6	1.415094	9.35	7.9288	19.8668	14	199
IP3	0.5	1.179245	10.7	9.0736	24.07778	12	241
UD	0.6	1.415094	11.6	9.8368	25.6862	14	257

1. Ng'ondu Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	265.00	0.00	0.00
A1	6	229.83	18.55	7.57
Difference	6	35.17	18.55	7.57

95% CI for mean difference: (15.70, 54.64)

T-Test of mean difference = 0 (vs not = 0): T-Value = 4.64 P-Value = 0.006

2. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	382.00	0.00	0.00
A1	6	161.17	15.96	6.51
Difference	6	220.83	15.96	6.51

95% CI for mean difference: (204.09, 237.58)

T-Test of mean difference = 0 (vs not = 0): T-Value = 33.90 P-Value = 0.000

3. St. Joseph Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	280.00	0.00	0.00
A1	6	246.33	15.47	6.32
Difference	6	33.67	15.47	6.32

95% CI for mean difference: (17.43, 49.91)

T-Test of mean difference = 0 (vs not = 0): T-Value = 5.33 P-Value = 0.003

4. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	274.00	0.00	0.00
A1	6	218.83	23.47	9.58

95% CI for mean difference: (30.53, 79.80)

T-Test of mean difference = 0 (vs not = 0): T-Value = 5.76 P-Value = 0.002

5. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	375.0	0.0	0.0
A1	6	278.0	71.8	29.3
Difference	6	97.0	71.8	29.3

95% CI for mean difference: (21.7, 172.3)

T-Test of mean difference = 0 (vs not = 0): T-Value = 3.31 P-Value = 0.021

6. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	303.0	0.0	0.0
A1	6	220.8	45.1	18.4
Difference	6	82.2	45.1	18.4

95% CI for mean difference: (34.8, 129.5)

T-Test of mean difference = 0 (vs not = 0): T-Value = 4.46 P-Value = 0.007

7. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	280.0	0.0	0.0
A1	6	231.3	25.6	10.4
Difference	6	48.7	25.6	10.4

95% CI for mean difference: (21.8, 75.5)

T-Test of mean difference = 0 (vs not = 0): T-Value = 4.66 P-Value = 0.006

8. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	252.00	0.00	0.00
A1	6	219.17	23.11	9.44
Difference	6	32.83	23.11	9.44

95% CI for mean difference: (8.58, 57.09)

T-Test of mean difference = 0 (vs not = 0): T-Value = 3.48 P-Value = 0.018

9. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	268.0	0.0	0.0
A1	6	210.2	37.1	15.1
Difference	6	57.8	37.1	15.1

95% CI for mean difference: (18.9, 96.7)

T-Test of mean difference = 0 (vs not = 0): T-Value = 3.82 P-Value = 0.012

10. Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	257.00	0.00	0.00
A1	6	222.83	18.67	7.62
Difference	6	34.17	18.67	7.62

95% CI for mean difference: (14.57, 53.76)

T-Test of mean difference = 0 (vs not = 0): T-Value = 4.48 P-Value = 0.007

11. Ng'ondu Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	11.00	0.00	0.00
A1	6	9.00	2.45	1.00
Difference	6	2.00	2.45	1.00

95% CI for mean difference: (-0.57, 4.57)

T-Test of mean difference = 0 (vs not = 0): T-Value = 2.00 P-Value = 0.102

12. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	7.000	0.000	0.000
A1	6	7.833	2.317	0.946
Difference	6	-0.833	2.317	0.946

95% CI for mean difference: (-3.264, 1.598)

T-Test of mean difference = 0 (vs not = 0): T-Value = -0.88 P-Value = 0.419

13. St. Joseph Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	5.00	0.00	0.00
A1	6	11.00	2.53	1.03
Difference	6	-6.00	2.53	1.03

95% CI for mean difference: (-8.65, -3.35)

T-Test of mean difference = 0 (vs not = 0): T-Value = -5.81 P-Value = 0.002

14. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	12.000	0.000	0.000
A1	6	11.833	1.602	0.654

Difference	6	0.167	1.602	0.654

95% CI for mean difference: (-1.515, 1.848)

T-Test of mean difference = 0 (vs not = 0): T-Value = 0.25 P-Value = 0.809

15. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	12.00	0.00	0.00
A1	6	11.33	3.72	1.52
Difference	6	0.67	3.72	1.52

95% CI for mean difference: (-3.24, 4.57)

T-Test of mean difference = 0 (vs not = 0): T-Value = 0.44 P-Value = 0.679

16. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.000	0.000	0.000
A1	6	8.000	1.095	0.447
Difference	6	-4.000	1.095	0.447

95% CI for mean difference: (-5.150, -2.850)

T-Test of mean difference = 0 (vs not = 0): T-Value = -8.94 P-Value = 0.000

17. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.00	0.00	0.00
A1	6	7.67	3.78	1.54
Difference	6	-3.67	3.78	1.54

95% CI for mean difference: (-7.63, 0.30)

T-Test of mean difference = 0 (vs not = 0): T-Value = -2.38 P-Value = 0.063

18. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	14.000	0.000	0.000
A1	6	9.500	1.225	0.500
Difference	6	4.500	1.225	0.500

95% CI for mean difference: (3.215, 5.785)

T-Test of mean difference = 0 (vs not = 0): T-Value = 9.00 P-Value = 0.000

19. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	17.000	0.000	0.000
A1	6	10.000	1.549	0.632
Difference	6	7.000	1.549	0.632

95% CI for mean difference: (5.374, 8.626)

T-Test of mean difference = 0 (vs not = 0): T-Value = 11.07 P-Value = 0.000

20. Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	14.000	0.000	0.000
A1	6	13.833	1.835	0.749
Difference	6	0.167	1.835	0.749

95% CI for mean difference: (-1.759, 2.092)

T-Test of mean difference = 0 (vs not = 0): T-Value = 0.22 P-Value = 0.833

Magnesium

21. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.050	0.000	0.000
A1	6	4.830	0.593	0.242
Difference	6	-4.780	0.593	0.242

95% CI for mean difference: (-5.402, -4.158)

T-Test of mean difference = 0 (vs not = 0): T-Value = -19.74 P-Value = 0.000

22. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.080	0.000	0.000
A1	6	6.252	1.898	0.775
Difference	6	-6.172	1.898	0.775

95% CI for mean difference: (-8.164, -4.180)

T-Test of mean difference = 0 (vs not = 0): T-Value = -7.96 P-Value = 0.001

23. Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.070	0.000	0.000
A1	6	5.683	1.525	0.623
Difference	6	-5.613	1.525	0.623

95% CI for mean difference: (-7.214, -4.013)

T-Test of mean difference = 0 (vs not = 0): T-Value = -9.02 P-Value = 0.000

24. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.950	0.000	0.000
A1	6	2.272	0.880	0.359
Difference	6	-1.322	0.880	0.359

95% CI for mean difference: (-2.246, -0.398)

T-Test of mean difference = 0 (vs not = 0): T-Value = -3.68 P-Value = 0.014

25. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.2600	0.0000	0.0000
A1	6	0.5650	0.0266	0.0109
Difference	6	-0.3050	0.0266	0.0109

95% CI for mean difference: (-0.3330, -0.2770)

T-Test of mean difference = 0 (vs not = 0): T-Value = -28.04 P-Value = 0.000

26. St. Joseph Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.890	0.000	0.000
A1	6	5.967	1.180	0.482
Difference	6	-5.077	1.180	0.482

95% CI for mean difference: (-6.315, -3.839)

T-Test of mean difference = 0 (vs not = 0): T-Value = -10.54 P-Value = 0.000

27. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.2700	0.0000	0.0000
A1	6	0.3867	0.0814	0.0332
Difference	6	-0.1167	0.0814	0.0332

T-Test of mean difference = 0 (vs not = 0): T-Value = -3.51 P-Value = 0.017

28. Ng'ondu Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.0000	0.0000	0.0000
A1	6	0.3800	0.0559	0.0228
Difference	6	-0.3800	0.0559	0.0228

95% CI for mean difference: (-0.4386, -0.3214)

T-Test of mean difference = 0 (vs not = 0): T-Value = -16.66 P-Value = 0.000

29. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.0100	0.0000	0.0000
A1	6	0.3867	0.0497	0.0203
Difference	6	-0.3767	0.0497	0.0203

95% CI for mean difference: (-0.4288, -0.3245)

T-Test of mean difference = 0 (vs not = 0): T-Value = -18.58 P-Value = 0.000

30. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.02000	0.00000	0.00000
A1	6	0.31167	0.01835	0.00749
Difference	6	-0.29167	0.01835	0.00749

95% CI for mean difference: (-0.31092, -0.27241)

T-Test of mean difference = 0 (vs not = 0): T-Value = -38.94 P-Value = 0.000

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31. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	22.000	0.000	0.000
A1	6	14.333	0.516	0.211
Difference	6	7.667	0.516	0.211

95% CI for mean difference: (7.125, 8.209)

T-Test of mean difference = 0 (vs not = 0): T-Value = 36.37 P-Value = 0.000

32. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	20.000	0.000	0.000
A1	6	14.833	1.329	0.543
Difference	6	5.167	1.329	0.543

95% CI for mean difference: (3.772, 6.562)

T-Test of mean difference = 0 (vs not = 0): T-Value = 9.52 P-Value = 0.000

33. Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	22.000	0.000	0.000
A1	6	15.000	1.414	0.577
Difference	6	7.000	1.414	0.577

95% CI for mean difference: (5.516, 8.484)

T-Test of mean difference = 0 (vs not = 0): T-Value = 12.12 P-Value = 0.000

34. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	63.000	0.000	0.000
A1	6	25.500	0.837	0.342

95% CI for mean difference: (36.622, 38.378)

T-Test of mean difference = 0 (vs not = 0): T-Value = 109.79 P-Value = 0.000

35. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	18.000	0.000	0.000
A1	6	12.167	2.041	0.833
Difference	6	5.833	2.041	0.833

95% CI for mean difference: (3.691, 7.975)

T-Test of mean difference = 0 (vs not = 0): T-Value = 7.00 P-Value = 0.001

36.Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	22.00	0.00	0.00
A1	6	15.83	5.31	2.17
Difference	6	6.17	5.31	2.17

95% CI for mean difference: (0.60, 11.74)

T-Test of mean difference = 0 (vs not = 0): T-Value = 2.85 P-Value = 0.036

37. St. Joseph Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	14.000	0.000	0.000
A1	6	9.667	0.516	0.211
Difference	6	4.333	0.516	0.211

95% CI for mean difference: (3.791, 4.875)

T-Test of mean difference = 0 (vs not = 0): T-Value = 20.55 P-Value = 0.000

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	9.000	0.000	0.000
A1	6	7.500	0.837	0.342
Difference	6	1.500	0.837	0.342

95% CI for mean difference: (0.622, 2.378)

T-Test of mean difference = 0 (vs not = 0): T-Value = 4.39 P-Value = 0.007

39. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	13.000	0.000	0.000
A1	6	8.667	0.516	0.211
Difference	6	4.333	0.516	0.211

95% CI for mean difference: (3.791, 4.875)

T-Test of mean difference = 0 (vs not = 0): T-Value = 20.55 P-Value = 0.000

40. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	17.0000	0.0000	0.0000
A1	6	11.0000	0.0000	0.0000
Difference	6	6.00000	0.00000	0.00000

95% CI for mean difference: (6.00000, 6.00000)

T-Test of mean difference = 0 (vs not = 0): T-Value = * P-Value = *

* NOTE * All values in column are identical.

41. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	139.00	0.00	0.00
A1	6	134.33	2.88	1.17
Difference	6	4.67	2.88	1.17

95% CI for mean difference: (1.65, 7.68)

T-Test of mean difference = 0 (vs not = 0): T-Value = 3.98 P-Value = 0.011

42. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	2024.00	0.00	0.00
A1	6	1598.33	16.67	6.81
Difference	6	425.67	16.67	6.81

95% CI for mean difference: (408.17, 443.16)

T-Test of mean difference = 0 (vs not = 0): T-Value = 62.55 P-Value = 0.000

43. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	213.00	0.00	0.00
A1	6	193.67	7.39	3.02
Difference	6	19.33	7.39	3.02

95% CI for mean difference: (11.57, 27.09)

T-Test of mean difference = 0 (vs not = 0): T-Value = 6.41 P-Value = 0.001

44. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	140.0	0.0	0.0
A1	6	97.2	31.0	12.6

```
95% CI for mean difference: (10.3, 75.3)
T-Test of mean difference = 0 (vs not = 0): T-Value = 3.39  P-Value = 0.019
```

45. Njugu-ini Paired T-Test and CI: B1, A1

```
Paired T for B1 - A1

            N    Mean  StDev  SE Mean
B1          6  282.00   0.00     0.00
A1          6  241.33   5.32     2.17
Difference  6   40.67   5.32     2.17

95% CI for mean difference: (35.09, 46.25)
T-Test of mean difference = 0 (vs not = 0): T-Value = 18.74  P-Value = 0.000
```

46. St. Joseph Kihingo Paired T-Test and CI: B1, A1

```
Paired T for B1 - A1

            N    Mean  StDev  SE Mean
B1          6  266.00   0.00     0.00
A1          6  207.67   8.57     3.50
Difference  6   58.33   8.57     3.50

95% CI for mean difference: (49.34, 67.33)
T-Test of mean difference = 0 (vs not = 0): T-Value = 16.67  P-Value = 0.000
```

47. Maji moto Paired T-Test and CI: B1, A1

```
Paired T for B1 - A1

            N    Mean  StDev  SE Mean
B1          6  302.00   0.00     0.00
A1          6  277.33  15.71     6.41
Difference  6   24.67  15.71     6.41

95% CI for mean difference: (8.18, 41.15)
T-Test of mean difference = 0 (vs not = 0): T-Value = 3.85  P-Value = 0.012
```

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	166.00	0.00	0.00
A1	6	131.67	10.78	4.40
Difference	6	34.33	10.78	4.40

95% CI for mean difference: (23.02, 45.65)

T-Test of mean difference = 0 (vs not = 0): T-Value = 7.80 P-Value = 0.001

49. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	147.00	0.00	0.00
A1	6	108.17	14.72	6.01
Difference	6	38.83	14.72	6.01

95% CI for mean difference: (23.39, 54.28)

T-Test of mean difference = 0 (vs not = 0): T-Value = 6.46 P-Value = 0.001

50. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	171.00	0.00	0.00
A1	6	144.50	6.28	2.57
Difference	6	26.50	6.28	2.57

95% CI for mean difference: (19.90, 33.10)

T-Test of mean difference = 0 (vs not = 0): T-Value = 10.33 P-Value = 0.000

51. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.1900	0.0000	0.0000
A1	6	0.1700	0.0452	0.0184
Difference	6	4.0200	0.0452	0.0184

95% CI for mean difference: (3.9726, 4.0674)

T-Test of mean difference = 0 (vs not = 0): T-Value = 218.02 P-Value = 0.000

52. St. Josephs Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	3.1200	0.0000	0.0000
A1	6	0.1800	0.0261	0.0106
Difference	6	2.9400	0.0261	0.0106

95% CI for mean difference: (2.9126, 2.9674)

T-Test of mean difference = 0 (vs not = 0): T-Value = 276.16 P-Value = 0.000

53. Ng'ondu Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	5.8900	0.0000	0.0000
A1	6	0.1633	0.0258	0.0105
Difference	6	5.7267	0.0258	0.0105

95% CI for mean difference: (5.6996, 5.7538)

T-Test of mean difference = 0 (vs not = 0): T-Value = 543.28 P-Value = 0.000

54. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	2.9600	0.0000	0.0000
A1	6	0.1700	0.0261	0.0106

95% CI for mean difference: (2.7626, 2.8174)

T-Test of mean difference = 0 (vs not = 0): T-Value = 262.07 P-Value = 0.000

55. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	1.5800	0.0000	0.0000
A1	6	0.1967	0.0388	0.0158
Difference	6	1.3833	0.0388	0.0158

95% CI for mean difference: (1.3426, 1.4241)

T-Test of mean difference = 0 (vs not = 0): T-Value = 87.30 P-Value = 0.000

56. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.4900	0.0000	0.0000
A1	6	0.2067	0.0301	0.0123
Difference	6	4.2833	0.0301	0.0123

95% CI for mean difference: (4.2517, 4.3149)

T-Test of mean difference = 0 (vs not = 0): T-Value = 348.44 P-Value = 0.000

57. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	3.1200	0.0000	0.0000
A1	6	0.1717	0.0534	0.0218
Difference	6	2.9483	0.0534	0.0218

95% CI for mean difference: (2.8922, 3.0044)

T-Test of mean difference = 0 (vs not = 0): T-Value = 135.12 P-Value = 0.000

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	5.1200	0.0000	0.0000
A1	6	0.1650	0.0274	0.0112
Difference	6	4.9550	0.0274	0.0112

95% CI for mean difference: (4.9263, 4.9837)

T-Test of mean difference = 0 (vs not = 0): T-Value = 443.19 P-Value = 0.000

59. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.79000	0.00000	0.00000
A1	6	0.14833	0.01472	0.00601
Difference	6	4.64167	0.01472	0.00601

95% CI for mean difference: (4.62622, 4.65711)

T-Test of mean difference = 0 (vs not = 0): T-Value = 772.42 P-Value = 0.000

60. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	5.1200	0.0000	0.0000
A1	6	0.1667	0.0280	0.0115
Difference	6	4.9533	0.0280	0.0115

95% CI for mean difference: (4.9239, 4.9828)

T-Test of mean difference = 0 (vs not = 0): T-Value = 432.59 P-Value = 0.000

61.Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	8.0000	0.0000	0.0000
A1	6	8.1267	0.1432	0.0585
Difference	6	-0.1267	0.1432	0.0585

95% CI for mean difference: (-0.2769, 0.0236)

T-Test of mean difference = 0 (vs not = 0): T-Value = -2.17 P-Value = 0.082

62.Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	7.4600	0.0000	0.0000
A1	6	8.4833	0.0589	0.0240
Difference	6	-1.0233	0.0589	0.0240

95% CI for mean difference: (-1.0851, -0.9615)

T-Test of mean difference = 0 (vs not = 0): T-Value = -42.57 P-Value = 0.000

63. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	7.1200	0.0000	0.0000
A1	6	8.4683	0.0354	0.0145
Difference	6	-1.3483	0.0354	0.0145

95% CI for mean difference: (-1.3855, -1.3111)

T-Test of mean difference = 0 (vs not = 0): T-Value = -93.17 P-Value = 0.000

64. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	6.8300	0.0000	0.0000
A1	6	8.4083	0.0960	0.0392

95% CI for mean difference: (-1.6791, -1.4776)

T-Test of mean difference = 0 (vs not = 0): T-Value = -40.27 P-Value = 0.000

65. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	7.0000	0.0000	0.0000
A1	6	8.6133	0.1864	0.0761
Difference	6	-1.6133	0.1864	0.0761

95% CI for mean difference: (-1.8090, -1.4177)

T-Test of mean difference = 0 (vs not = 0): T-Value = -21.20 P-Value = 0.000

66. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	7.4800	0.0000	0.0000
A1	6	8.7033	0.1986	0.0811
Difference	6	-1.2233	0.1986	0.0811

95% CI for mean difference: (-1.4317, -1.0150)

T-Test of mean difference = 0 (vs not = 0): T-Value = -15.09 P-Value = 0.000

67. St Josephs Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	6.3600	0.0000	0.0000
A1	6	8.6483	0.0854	0.0349
Difference	6	-2.2883	0.0854	0.0349

95% CI for mean difference: (-2.3780, -2.1987)

T-Test of mean difference = 0 (vs not = 0): T-Value = -65.62 P-Value = 0.000

68. Ng'ondu Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	8.1200	0.0000	0.0000
A1	6	8.6267	0.0513	0.0209
Difference	6	-0.5067	0.0513	0.0209

95% CI for mean difference: (-0.5605, -0.4529)

T-Test of mean difference = 0 (vs not = 0): T-Value = -24.22 P-Value = 0.000

69. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	8.11000	0.00000	0.00000
A1	6	8.63000	0.02366	0.00966
Difference	6	-0.52000	0.02366	0.00966

95% CI for mean difference: (-0.54483, -0.49517)

T-Test of mean difference = 0 (vs not = 0): T-Value = -53.83 P-Value = 0.000

70. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	8.1400	0.0000	0.0000
A1	6	8.5233	0.1622	0.0662
Difference	6	-0.3833	0.1622	0.0662

95% CI for mean difference: (-0.5535, -0.2131)

T-Test of mean difference = 0 (vs not = 0): T-Value = -5.79 P-Value = 0.002

71. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	16.110	0.000	0.000
A1	6	18.865	1.536	0.627
Difference	6	-2.755	1.536	0.627

95% CI for mean difference: (-4.367, -1.143)

T-Test of mean difference = 0 (vs not = 0): T-Value = -4.39 P-Value = 0.007

72. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	2.49	0.00	0.00
A1	6	14.29	2.69	1.10
Difference	6	-11.80	2.69	1.10

95% CI for mean difference: (-14.62, -8.98)

T-Test of mean difference = 0 (vs not = 0): T-Value = -10.76 P-Value = 0.000

73. Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	19.960	0.000	0.000
A1	6	27.392	1.929	0.787
Difference	6	-7.432	1.929	0.787

95% CI for mean difference: (-9.456, -5.408)

T-Test of mean difference = 0 (vs not = 0): T-Value = -9.44 P-Value = 0.000

74. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	56.55	0.00	0.00
A1	6	25.26	4.13	1.69

95% CI for mean difference: (26.95, 35.63)

T-Test of mean difference = 0 (vs not = 0): T-Value = 18.54 P-Value = 0.000

75. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	15.28	0.00	0.00
A1	6	19.13	4.63	1.89
Difference	6	-3.85	4.63	1.89

95% CI for mean difference: (-8.70, 1.01)

T-Test of mean difference = 0 (vs not = 0): T-Value = -2.03 P-Value = 0.098

76. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	12.89	0.00	0.00
A1	6	37.56	7.92	3.23
Difference	6	-24.67	7.92	3.23

95% CI for mean difference: (-32.99, -16.36)

T-Test of mean difference = 0 (vs not = 0): T-Value = -7.63 P-Value = 0.001

77. St Josephs Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.570	0.000	0.000
A1	6	7.242	2.346	0.958
Difference	6	-2.672	2.346	0.958

95% CI for mean difference: (-5.133, -0.210)

T-Test of mean difference = 0 (vs not = 0): T-Value = -2.79 P-Value = 0.038

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	11.540	0.000	0.000
A1	6	15.193	2.270	0.927
Difference	6	-3.653	2.270	0.927

95% CI for mean difference: (-6.036, -1.271)

T-Test of mean difference = 0 (vs not = 0): T-Value = -3.94 P-Value = 0.011

79. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	11.330	0.000	0.000
A1	6	15.055	1.533	0.626
Difference	6	-3.725	1.533	0.626

95% CI for mean difference: (-5.333, -2.117)

T-Test of mean difference = 0 (vs not = 0): T-Value = -5.95 P-Value = 0.002

80. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	16.740	0.000	0.000
A1	6	19.542	1.122	0.458
Difference	6	-2.802	1.122	0.458

95% CI for mean difference: (-3.980, -1.624)

T-Test of mean difference = 0 (vs not = 0): T-Value = -6.11 P-Value = 0.002

81. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	110.00	0.00	0.00
A1	6	44.67	4.13	1.69
Difference	6	65.33	4.13	1.69

95% CI for mean difference: (61.00, 69.67)

T-Test of mean difference = 0 (vs not = 0): T-Value = 38.74 P-Value = 0.000

82. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	79.00	0.00	0.00
A1	6	93.67	15.44	6.30
Difference	6	-14.67	15.44	6.30

95% CI for mean difference: (-30.87, 1.53)

T-Test of mean difference = 0 (vs not = 0): T-Value = -2.33 P-Value = 0.067

83. Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	135.00	0.00	0.00
A1	6	54.00	4.69	1.91
Difference	6	81.00	4.69	1.91

95% CI for mean difference: (76.08, 85.92)

T-Test of mean difference = 0 (vs not = 0): T-Value = 42.30 P-Value = 0.000

84. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	115.00	0.00	0.00
A1	6	59.50	8.87	3.62

95% CI for mean difference: (46.19, 64.81)

T-Test of mean difference = 0 (vs not = 0): T-Value = 15.32 P-Value = 0.000

85. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	90.00	0.00	0.00
A1	6	65.83	12.86	5.25
Difference	6	24.17	12.86	5.25

95% CI for mean difference: (10.67, 37.66)

T-Test of mean difference = 0 (vs not = 0): T-Value = 4.60 P-Value = 0.006

86. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	84.00	0.00	0.00
A1	6	58.50	14.88	6.08
Difference	6	25.50	14.88	6.08

95% CI for mean difference: (9.88, 41.12)

T-Test of mean difference = 0 (vs not = 0): T-Value = 4.20 P-Value = 0.009

87. St Josephs Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	125.00	0.00	0.00
A1	6	51.00	2.97	1.21
Difference	6	74.00	2.97	1.21

95% CI for mean difference: (70.89, 77.11)

T-Test of mean difference = 0 (vs not = 0): T-Value = 61.10 P-Value = 0.000

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	104.00	0.00	0.00
A1	6	82.00	6.66	2.72
Difference	6	22.00	6.66	2.72

95% CI for mean difference: (15.01, 28.99)

T-Test of mean difference = 0 (vs not = 0): T-Value = 8.09 P-Value = 0.000

89. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	108.00	0.00	0.00
A1	6	79.00	8.56	3.49
Difference	6	29.00	8.56	3.49

95% CI for mean difference: (20.02, 37.98)

T-Test of mean difference = 0 (vs not = 0): T-Value = 8.30 P-Value = 0.000

90.Ng'ondu Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	104.00	0.00	0.00
A1	6	81.33	8.80	3.59
Difference	6	22.67	8.80	3.59

95% CI for mean difference: (13.43, 31.90)

T-Test of mean difference = 0 (vs not = 0): T-Value = 6.31 P-Value = 0.001

91. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	2.14	0.00	0.00
A1	6	59.81	19.56	7.99
Difference	6	-57.67	19.56	7.99

95% CI for mean difference: (-78.20, -37.14)

T-Test of mean difference = 0 (vs not = 0): T-Value = -7.22 P-Value = 0.001

92. Njugu-ini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.00	0.00	0.00
A1	6	47.97	19.31	7.88
Difference	6	-47.97	19.31	7.88

95% CI for mean difference: (-68.24, -27.71)

T-Test of mean difference = 0 (vs not = 0): T-Value = -6.09 P-Value = 0.002

93. Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.00	0.00	0.00
A1	6	48.64	18.20	7.43
Difference	6	-48.64	18.20	7.43

95% CI for mean difference: (-67.74, -29.54)

T-Test of mean difference = 0 (vs not = 0): T-Value = -6.55 P-Value = 0.001

94. Belbur Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.00	0.00	0.00
A1	6	29.24	10.36	4.23

95% CI for mean difference: (-40.11, -18.37)

T-Test of mean difference = 0 (vs not = 0): T-Value = -6.92 P-Value = 0.001

95. Lanet BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	1.4	0.0	0.0
A1	6	69.2	37.2	15.2
Difference	6	-67.7	37.2	15.2

95% CI for mean difference: (-106.8, -28.7)

T-Test of mean difference = 0 (vs not = 0): T-Value = -4.46 P-Value = 0.007

96. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	1.7	0.0	0.0
A1	6	84.2	41.3	16.8
Difference	6	-82.5	41.3	16.8

95% CI for mean difference: (-125.8, -39.2)

T-Test of mean difference = 0 (vs not = 0): T-Value = -4.90 P-Value = 0.004

97. St Josephs Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	87.86	0.00	0.00
A1	6	60.86	8.48	3.46
Difference	6	27.00	8.48	3.46

95% CI for mean difference: (18.10, 35.90)

T-Test of mean difference = 0 (vs not = 0): T-Value = 7.80 P-Value = 0.001

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.43	0.00	0.00
A1	6	69.74	7.41	3.02
Difference	6	-69.31	7.41	3.02

95% CI for mean difference: (-77.08, -61.54)

T-Test of mean difference = 0 (vs not = 0): T-Value = -22.92 P-Value = 0.000

99. Egerton BH12 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	13.14	0.00	0.00
A1	6	71.93	16.15	6.60
Difference	6	-58.79	16.15	6.60

95% CI for mean difference: (-75.74, -41.84)

T-Test of mean difference = 0 (vs not = 0): T-Value = -8.91 P-Value = 0.000

100. Ng'ondu Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.14	0.00	0.00
A1	6	91.52	18.17	7.42
Difference	6	-87.38	18.17	7.42

95% CI for mean difference: (-106.45, -68.32)

T-Test of mean difference = 0 (vs not = 0): T-Value = -11.78 P-Value = 0.000

101. Egerton tap Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.3300	0.0000	0.0000
A1	6	0.2867	0.0671	0.0274
Difference	6	0.0433	0.0671	0.0274

95% CI for mean difference: (-0.0271, 0.1138)

T-Test of mean difference = 0 (vs not = 0): T-Value = 1.58 P-Value = 0.175

102. Njugini Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	1.0000	0.0000	0.0000
A1	6	0.7800	0.1704	0.0696
Difference	6	0.2200	0.1704	0.0696

95% CI for mean difference: (0.0412, 0.3988)

T-Test of mean difference = 0 (vs not = 0): T-Value = 3.16 P-Value = 0.025

103. Maji moto Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.670000	0.000000	0.000000
A1	6	0.670000	0.000000	0.000000
Difference	6	0.000000	0.000000	0.000000

95% CI for mean difference: (0.000000, 0.000000)

T-Test of mean difference = 0 (vs not = 0): T-Value = * P-Value = *

* NOTE * All values in column are identical.

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.330000	0.000000	0.000000
A1	6	0.330000	0.000000	0.000000
Difference	6	0.000000	0.000000	0.000000

95% CI for mean difference: (0.000000, 0.000000)
T-Test of mean difference = 0 (vs not = 0): T-Value = * P-Value = *

* NOTE * All values in column are identical.

105. Lanet BH1 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.330000	0.000000	0.000000
A1	6	0.330000	0.000000	0.000000
Difference	6	0.000000	0.000000	0.000000

95% CI for mean difference: (0.000000, 0.000000)
T-Test of mean difference = 0 (vs not = 0): T-Value = * P-Value = *

* NOTE * All values in column are identical.

106. St Josephs Kihingo Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.000	0.000	0.000
A1	6	1.168	0.459	0.187
Difference	6	2.832	0.459	0.187

95% CI for mean difference: (2.350, 3.314)
T-Test of mean difference = 0 (vs not = 0): T-Value = 15.10 P-Value = 0.000

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	0.330000	0.000000	0.000000
A1	6	0.330000	0.000000	0.000000
Difference	6	0.000000	0.000000	0.000000

95% CI for mean difference: (0.000000, 0.000000)

T-Test of mean difference = 0 (vs not = 0): T-Value = * P-Value = *

* NOTE * All values in column are identical.

108. Ng'ondu Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	4.330	0.000	0.000
A1	6	1.998	0.664	0.271
Difference	6	2.332	0.664	0.271

95% CI for mean difference: (1.635, 3.028)

T-Test of mean difference = 0 (vs not = 0): T-Value = 8.60 P-Value = 0.000

109. Egerton BH2 Paired T-Test and CI: B1, A1

Paired T for B1 - A1

	N	Mean	StDev	SE Mean
B1	6	1.00000	0.00000	0.00000
A1	6	0.33000	0.00000	0.00000
Difference	6	0.670000	0.000000	0.000000

95% CI for mean difference: (0.670000, 0.670000)

T-Test of mean difference = 0 (vs not = 0): T-Value = * P-Value = *

* NOTE * All values in column are identical.

116. Egerton B1:T2 Paired T-Test and CI: B1, A1

```
Paired T for B1 - A1

             N      Mean     StDev   SE Mean
B1           6  0.670000  0.000000  0.000000
A1           6  0.330000  0.000000  0.000000
Difference   6  0.340000  0.000000  0.000000

95% CI for mean difference: (0.340000, 0.340000)
T-Test of mean difference = 0 (vs not = 0): T-Value = *  P-Value = *

* NOTE * All values in column are identical.
```

Ng'ondu Paired T-Test and CI: B, A

Paired T for B - A

	N	Mean	StDev	SE Mean
B	6	0.0000	0.0000	0.0000
A	6	0.4667	0.0816	0.0333
Difference	6	-0.4667	0.0816	0.0333

95% CI for mean difference: (-0.5524, -0.3810)

T-Test of mean difference = 0 (vs not = 0): T-Value = -14.00 P-Value = 0.000

Egerton BH2 Paired T-Test and CI: B, A

Paired T for B - A

	N	Mean	StDev	SE Mean
B	6	0.0000	0.0000	0.0000
A	6	0.4667	0.0816	0.0333
Difference	6	-0.4667	0.0816	0.0333

95% CI for mean difference: (-0.5524, -0.3810)

T-Test of mean difference = 0 (vs not = 0): T-Value = -14.00 P-Value = 0.000

Egerton BH12 Paired T-Test and CI: B, A

Paired T for B - A

	N	Mean	StDev	SE Mean
B	6	0.3000	0.0000	0.0000
A	6	0.6000	0.1095	0.0447
Difference	6	-0.3000	0.1095	0.0447

95% CI for mean difference: (-0.4150, -0.1850)

T-Test of mean difference = 0 (vs not = 0): T-Value = -6.71 P-Value = 0.001

Spiked Iron Sample Paired T-Test and CI: B, A

Paired T for B - A

	N	Mean	StDev	SE Mean
B	6	5.4000	0.0000	0.0000
A	6	0.7333	0.1033	0.0422

95% CI for mean difference: (4.5583, 4.7751)

T-Test of mean difference = 0 (vs not = 0): T-Value = 110.68 P-Value = 0.000

Spiked Calcium Sample Paired T-Test and CI: B, A

Paired T for B - A

	N	Mean	StDev	SE Mean
B	6	10.700	0.000	0.000
A	6	0.733	0.280	0.115
Difference	6	9.967	0.280	0.115

95% CI for mean difference: (9.672, 10.261)

T-Test of mean difference = 0 (vs not = 0): T-Value = 87.04 P-Value = 0.000