

**SOFTENINIG OF WATER FROM SELECTED WATER SAMPLE IN
BUTALEJA DISTRICT USING ACTIVATED CARBON DERIVED FROM
BANANA PEELINGS**

CHELANGAT LINDA

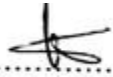
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**A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF CHEMISTRY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD
OF BACHELOR OF SCIENCE EDUCATION DEGREE OF BUSITEMA
UNIVERSITY**

JUNE 2026

DECLARATION

I, CHELANGAT LINDA Declare that this research report titled 'softening of water using activated carbon from selected water sample in butaleja district using activated carbon derived from banana peelings is my own piece of work and has not been submitted to any other institution for academic credit.

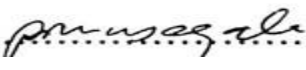
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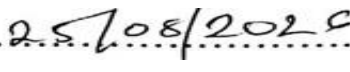
Date: 25/08/2026

APPROVAL

This research project has been submitted with the approval of the supervisor.

Mr. Musagala Peter

Signature .. 

Date ... 

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I thank the almighty God for His guidance, protection and good health throughout my academic journey and also thank my father Mr. Sabila Francis for buying me a personal computer and my mum Mrs Nasambu Ann for supporting me financially.

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ABBREVIATIONS

EDTA Ethylenediaminetetraacetic acid

Erio T Black Eriochrome Black T

NaOH Sodium Hydroxide

ABSTRACT

Water hardness caused by the presence of calcium and magnesium ions in water is a wide spread water quality problem affecting domestic use in busolwe town, Butaleja district. In Busolwe town council, Butaleja district, residents rely on boreholes and taps that supply water which is hard leading to excessive soap consumption, unpleasant taste, scale formation and potential long term health risks. This study aimed to soften hard water from selected water sample in Butaleja district using activated carbon derived from banana peels as low cost, environmentally friendly adsorbent. The specific objectives were to determine the initial concentration of Ca^{2+} and Mg^{2+} ions in the water sample, investigate the effect of adsorbent dosage and the contact time on ion removal and evaluate the effectiveness of banana peel activated carbon for water softening.

Banana peels were collected, washed and dried at 110°C for 24 hours, ground in to powder, activated using 1.5M sulphuric acid at 70°C for 3 hours, neutralized with 0.1M NaOH and dried again. Magnesium concentration was determined using UV-VIS spectrophotometer with Eriochrome Black at 520nm, while total hardness was measured before and after treatment using EDTA titration. Results showed a reduction in EDTA volume used after treatment (from an average of 8.77 mL before treatment to 4.60 mL after treatment) indicating significant removal of hardness ions. This study concludes that banana peel activated carbon is an effective, low-cost adsorbent for removing Ca^{2+} and Mg^{2+} ions from hardwater. This approach offers a sustainable solution for water softening in rural communities while simultaneously addressing agricultural waste disposal.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Water is the most fundamental of natural resources essential to all forms of life on earth supporting ecosystems, sustaining human life and driving economic activities. Water in nature occupies about 71% of the earth surface. While 71% of the earth's surface is covered by water, of this 97% is seawater (non- drinkable) only 2.5% of fresh water is accessible for human use and of this only 0.5% is used as drinking water(Ahn et al., 2018). As it travels through soil and rock layers, it acts as a universal solvent dissolving minerals such as calcium and magnesium. However, the presence of dissolved minerals such as calcium (Ca^{2+}), magnesium (Mg^{2+}) ions are dominant divalent ions responsible for hardness(M et al., 2016). This affects its quality and suitability for its various uses. Hardness due to the presence of elevated concentrations of calcium and magnesium ions is a wide spread water-quality problem overtime. The quantity and type of hardness depends on the surrounding sedimentary rocks and aquifers(Ingin et al., 2024). excessive water hardness can negatively affect water systems and pipes Hardness in water is derived from dissolution of limestone and dolomite rocks in presence of dissolved carbon dioxide and it's expressed in terms of mg/L or ppm as CaCO_3 . WHO recommendation for drinking water's hardness is based on a maximum of 50mg/l calcium carbonate. Although Ca^{2+} and Mg^{2+} in water have no direct health hazards, they are a nuisance because of mineral builds up on fixtures they have unwanted effects such as scaling on water appliances, and reducing washing efficiency of soap and detergent, prolonged consumption of drinking water containing Ca^{2+} and Mg^{2+}

increases the incidence of stone in the human filtration system. In industrial uses hard water cause boiler scales and damage industrial equipment. In addition to industrial risks, it has been estimated that approximately 17% of the world's population uses water from unprotected and remote sources, 32% from some source of protected source and 51 % from some sort of centralized (piped) system to the dwelling or plot (Sengupta, 2013).

Therefore, developing a new method for removing excess Ca^{2+} and Mg^{2+} from water has important application prospects. At present the methods of removal of Ca^{2+} and Mg^{2+} from water mainly include; precipitation, boiling, use of lime-soda ash, ion exchange, electrodialysis and adsorption. Among such methods adsorption has attracted much attention in recent years because of its advantages of simple operation, recyclability and low cost (Wang et al., 2021).

Bbusolwe town is located in Butaleja District, Uganda. Its geographical coordinates are 00 50 57 "North, 330 55' 37" East. It is estimated to have a population of about 1 6,371 people by 2024 (UBOS) With 3800 households. Boreholes and taps in the town council supply people with drinking water and many of the residents complain about salt in water. The immediate effects are large amounts of soap is consumed during washing, a bitter or unpleasant taste, formation of scales on water heaters. This calls for immediate solution of treating the water to remove the salts present and make it suitable for human consumption. This involves identifying the dissolved salts and looking for appropriate techniques of removing them and implementing the techniques.

1.2 Problem statement

Hard water containing high levels of Ca^{2+} and Mg^{2+} ions is a common problem. Over the years, conventional methods such as electrodialysis, ion exchange lime softening and membrane filtration have been studied for removal of ionic species responsible for

hardness. it is obvious that hard water treatment by these methods required high capital operations hence finding inexpensive and efficient developed process remains a major concern. Adsorption process has become a promising approach for water treatment(M et al., 2016). Meanwhile banana peels are abundant agricultural waste materials that may have ability to absorb metal ions in water. Therefore, this study seeks to investigate the potential of banana peels as a low cost and environmentally friendly adsorbent in removing calcium and magnesium ions from water.

1.3 Objectives of the study

The general objective was to soften water from selected water sample in Butaleja district by using banana peelings.

The overall objective will be achieved by the following specific objectives

- i) To determine the concentration of calcium and magnesium ions present in the water sample before treatment
- ii) To investigate the effect of adsorbent dosage and contact time on the removal of Ca^{2+} and Mg^{2+}
- iii) To evaluate the effectiveness of banana peel activated carbon as a low-cost adsorbent for water softening

1.4 Justification of the study

The study for the adsorption of calcium and magnesium ions using banana peelings is justified for, environmental significance where by banana peelings are abundant agricultural waste and utilizing them for water treatment can reduce waste disposal issues. Reducing water hardness can also mitigate related health issues and improve well-being. By exploring the potential of banana peelings for water treatment, the study

addresses environmental, economic, and social concerns contributing to sustainable development and improved public health.

1.5 Literature Review

1.5.1 Introduction

Water can be classified into two that is to say hard water and soft water depending on the amount of calcium and magnesium ions present. The unit of measurement for hardness is milligrams per liter of calcium carbonate ($\text{mgL}^{-1} \text{CaCO}_3$).

Water with less than 50mgL^{-1} of calcium carbonate is regarded as soft, with quantities between 50 and 200mgL^{-1} as intermediate, and with quantities greater than 200mgL^{-1} as hard (Lesson, 2019). The effect of hard water on health is monitored by world health organization (WHO). There may be a relationship between water hardness and cardiovascular health so it is recommended to maintain a minimum total hardness of drinking water of $150\text{mgL}^{-1} \text{CaCO}_3$ (Lesson, n.d.). Since Busolwe water is generally hardwater, the literature review will focus on hard water.

1.5.2 Hard water

Hard water is water that has high mineral content mainly calcium and magnesium ions (Yulianti et al., 2018). Water hardness is measured in terms of the calcium carbonate equivalent and it affects both domestic and industrial systems. Hardness causes scaling on heat exchange surfaces reducing efficiency and increasing energy consumption for example in boilers. Additionally, hard water demands more soap and detergents for effective cleaning which can lead to higher chemical usage and environmental impacts. However, Ca^{2+} and Mg^{2+} found in hard water do not pose any health threat but can be involved in reactions that leave insoluble mineral deposits.

1.5.3 Sources Of hardness

The common sources of hardness in water are minerals that is limestone. When ground water flows through limestone formations, calcium carbonate reacts with carbonic acid to form soluble calcium bicarbonate. This process introduces calcium ions in water. Another mineral is Dolomite $\text{CaMg}(\text{CO}_3)_2$ which introduces magnesium ions to ground water. Dolomite contributes both calcium and magnesium ions

1.5.3.1 Types of hardwater

There are two defined types of hardwater that is to say temporary and permanent which are described below.

Temporary hard water

It is the hard water that consists primarily of calcium (Ca^{2+}) and bicarbonate (HCO_3^-) ions. heating causes the bicarbonate ion in temporary hardwater to decompose in to carbonate ion (CO_3^{2-}), carbon dioxide (CO_2) and water. The resultant carbonate ion can then react with other ions in the solution to form insoluble compounds such as CaCO_3 and MgCO_3 . The interactions of carbonate ion in the solution also cause the well-known mineral build up seen on the sides of pots used to boil water, a rust known as boiler scale. The CaCO_3 or other scale does not completely dissolve back in to the water when it is cooled because it is relatively insoluble. For this reason, this type of water is temporary because boiling can remove the hardness by displacing the offending ions from solution

Permanent hard water consists of high concentrations of anions like (SO_4^{2-}), (Cl^-) except (CO_3^{2-}). It is referred to as permanent because unlike temporary hardwater the hardness cannot be removed simply by boiling. Permanent hard water is responsible for soap scum as it contains calcium and magnesium cations, the cations react with soap to form insoluble compounds. the reaction of these cations with soap is the reason it is difficult for soap to foam or lather well in hard water. In overall, it is important to

distinguish between temporary and permanent hardness because removal methods differ accordingly.

1.5.3.2 Impacts of water hardness

Although Ca^{2+} and Mg^{2+} in water have no direct health hazards, they have unwanted effects such as scaling on water appliances and reduced washing effect of soap and detergent increasing the amount of soap or detergent required for cleaning. Prolonged consumption of drinking water containing Ca^{2+} and Mg^{2+} increases the incidence of stone in the human filtration system. In the industry, precipitation of Ca^{2+} and Mg^{2+} salts forms scale, hinders heat conduction and even causes a boiler expansion in severe cases (Wang et al., 2021). In addition, hard water negatively affects industrial processes for example textile, food processing which leads to reduced efficiency in manufacturing hence interfering with product quality and chemical processes. Spots appear on clothes washed in hardwater and may feel stiff, appear dull and wear out faster. Hard water may also leave residue on skin and hair causing dryness and irritation in some individuals. Hardwater also causes taste problems in drinking water which is one of the most extensive causes of customer complaints. Additionally, World Health Organization (WHO) reports that the excess intake of magnesium leads to diarrhea.

1.5.3.3 Ways of removing hardness in water

There are several methods of making hardwater soft and this includes:

Boiling; Temporal hardness can also be removed by simply boiling the hard water. by boiling the bicarbonates are converted in to insoluble carbonates which can be simply removed by filtration. But for permanent hardness of water, boiling does not help as sulphates do not decompose on heating (prof . Adwaita Joshi, 2023). Although boiling removes hardness in water, it has the following limitations

Boiling only removes temporary hardness and not permanent hardness. It is also not practical for large amounts of water.

Lime-soda process; in this method, hardwater is treated with slaked lime $[\text{Ca}(\text{OH})_2]$ and soda ash $[\text{Na}_2\text{CO}_3]$ in reaction tanks so as to convert hardness producing chemicals in to insoluble compounds which are then removed by settling and filtering(Vishvajit et al., 2019). The following are its limitations:

Produces a lot of sludge that must be disposed of. And it also needs careful chemical control and trained operators.

Ion -exchange method. ion exchange involves removal of hardness ions replacing them with non-hardness ions typically sodium supplied by dissolved sodium chloride salt (brine). The softener contains microporous exchange resin, usually sulfonated polystyrene beads that are supersaturated with sodium to cover the bead surfaces. As water passes through this resin bed, calcium and magnesium ions attach to the resin beds and the loosely held sodium is released from the resin in to the water(Skipton & Dvorak, 2014). The following are its limitations;

Sodium is added to the water which can be a concern for people on low salt diets. The resin must be regenerated regularly with salt brine which produces waste brine that needs disposal.

Distillation method: water is boiled and the steam is condensed leaving hardness ions behind. The limitations are; It is very expensive for large volumes and also a slow process.

Reverse osmosis (RO); it involves a semi-permeable membrane that allows the passage of water molecules but not most of the dissolved salts, organics, bacteria and pyrogens. However, the water must be pushed through the RO membrane by applying pressure greater than the naturally occurring osmotic pressure. When pressure is

applied to the concentrated solution, the water molecules are forced through the semi-permeable membrane while the contaminants are not allowed through (Osmosis et al., n.d.). Its limitations are;

Requires pressure and energy. It also produces a waste stream with concentrated minerals

1.5.4 Other ground contaminants that can affect the adsorption of calcium and magnesium ions

Water contains many substances apart from calcium and magnesium ions that can affect its quality and according to various studies, several substances and conditions can interfere with adsorption of calcium and magnesium ions and these include;

Competing cations: other divalent metal ions in ground water compete for the same exchange sites on adsorbents. High concentrations of iron, manganese and strontium can significantly reduce the removal efficiency of calcium and magnesium.

High Total Dissolved Solids and other ions: the presence of other ions such as sodium or sulphate can create a high ionic strength environment that reduces the selectivity of the adsorbent

Organic matter/complexing Agents: dissolved organic matter/pollutants can form stable complexes with divalent cations making them harder to adsorb.

CHAPTER TWO

EXPERIMENTAL

2.1 Apparatus

Weighing was done on an AX523 analytical balance. drying of banana peels was done on a 30-1060 hot air oven. Grinding of banana peels was be done using a mortar and pestle. Measuring of solutions was done using a measuring cylinder, conical flasks, volumetric flasks, titration was done using burette(50mL) during determination of calcium and magnesium ions using EDTA method. uniform mixing of activated carbon and hardwater was done using a magnetic stirrer. pH was measured using the pH meter. separating activated carbon from treated water after adsorption was done using a filter paper and finally monitoring contact time during adsorption experiments.605UV-VIS spectrophotometer was used to measure the absorbance

2.2 Materials

Ethylenediaminetetraacetic acid (EDTA) solution, Eriochrome Black T indicator, ammonia buffer solution (pH 10), potassium hydroxide, hard water sample, distilled water, activated carbon derived from banana peels, calcium chloride solution.

2.2.1 Ammonia buffer solution

Dilute hydrochloric acid was added slowly to Concentrated ammonia solution(35ml) while measuring the pH until the pH of 10 was obtained.

2.2.2 calcium chloride solution

Calcium chloride dihydrate (1.47g) will be placed in a beaker and added distilled water. It is then transferred to a volumetric flask and diluted with water up to the mark.

2.3 Preparation of activated carbon

Fresh banana peels were collected and washed thoroughly with tap water followed by distilled water to remove dirt and impurities. The peels were cut in to small pieces and oven dried at 110°C for 24 hours to remove moisture. The dried peels were ground in to fine powder using a mortar and pestle and then sieved to obtain uniform particles. The powdered banana peel was soaked in 1.5 M concentrated sulphuric acid. the mixture is heated at a temperature of 70°C for 3 hours while stirring. The mixture was filtered to recover the solid material. The solid was neutralized with 0.1M NaOH until it reached a pH of 7.0. The neutralized material was then dried in an oven at 110°C for 6 hours until it reached a constant weight and then the prepared adsorbent was stored in alright containers for further use.



Figure 1:sample of activated carbon

2.4 Determination of magnesium

The determination of magnesium using EioT via UV-Vis spectrophotometer is a colorimetric method based on the formation of colored complex. ErioT acts as a chelating agent that changes color upon binding with magnesium ions typically in an alkaline medium(pH=10).

To magnesium ions of different concentrations that is to say 1,2,3,4mg/L was added 2 drops of Eriochrome Black T and 1ml of ammonia buffer to each standard to form a red Mg-ErioT complex. The UV-VIS spectrophotometer at approximately 520nm was used to measure the absorbance. A graph of absorbance Vs Mg^{2+} concentration for the standards was plotted. The absorbance of water sample was measured. This is followed by using the calibration curve to find Mg^{2+} concentration.

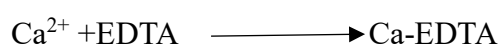
2.5 Preparation and standardization of EDTA

A 0.01M disodium EDTA solution was prepared by dissolving an appropriate mass of EDTA in distilled water and making up to 1L in a volumetric flask.

2.5.1 Standardization of EDTA

25ml of sample of the standard 0.01M CaCl_2 solution was pipetted in a conical flask. 2ml of ammonia buffer solution of pH 10 and 1ml of Eriochrome Black T indicator solution was added. The solution turned red. The EDTA was then be titrated with calcium chloride solution until a permanent color change from red to clear blue at end point. Having determined the average titer of EDTA used, the number of moles used will be determined. Given the Ca^{2+} : EDTA ratio of 1:1, the concentration of EDTA solution was calculated.

The main equation is



indicator reaction: note, ErioT is blue and ErioT-Mg is pink

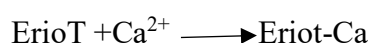


Table 1:results for standardization of EDTA

Experimental No	Initial(mL)	Final(mL)	EDTA used(mL)
Initial	0.00	10.80	10.80
Final	10.80	19.00	8.20
EDTA used	19.00	27.30	8.30

2.6 Sample preparation

0.2g of activated carbon was weighed and put in to a conical flask. 100ml of hardwater was added to the conical flask and the mixture then stirred using a magnetic stirrer for 60 minutes as shown in Fig 2 to ensure proper contact between the activated carbon and the Ca^{2+} and Mg^{2+} ions. The mixture was then filtered in to a clean conical flask to separate activated carbon and treated water as it is in Fig 3. The filtrate was collected for determination of hardness using EDTA titration.

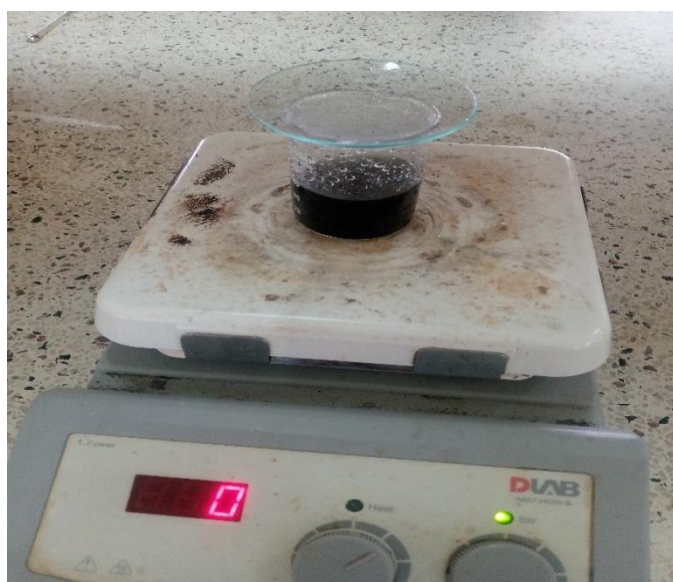


Figure 2:stirring of the mixture of activated carbon and the water sample



Figure 3:Filtering of the sample

2.6.1 EDTA titration of the sample

100ml of the sample solution was put in to a 250ml conical flask. 2ml ammonia buffer solution and 2drops of Eriochrome Black T indicator solution was added. The sample was titrated with the EDTA solution until the color of the mixture turned from wine-red to blue (at end point). The titration was repeated with further samples until concordant results were obtained (titers agreeing within 0.1mL)



Figure 4: Sample solution with EDTA before and after treatment.

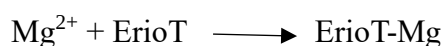
CHAPTER THREE

RESULTS AND DISCUSSION

Table 2: results of absorbances of different concentrations of standards.

	Mg ²⁺ concentration(x-axis)	A520	Mean value A520	A520 sample-blank(y-axis)	Calculated concentration
1	Blank	0.000	0.00	0.00	0.00M
3	Standard 1	0.318	0.318	0.318	0.001M
5	Standard2	0.502	0.502	0.502	0.002M
7	Standard 3	0.723	0.723	0.723	0.003M
9	Standard 4	0.928	0.928	0.928	0.004M
	Unknown sample	0.700	0.700	0.700	0.0039M

Magnesium ions do not absorb light with in the UV-VIS spectrum due to their stable electron configuration, direct spectrophotometric quantification is not possible. To overcome this, Eriochrome Black T was utilized as a chelating agent at pH 10. Upon introduction of ErioT, it binds with Mg²⁺ and forms a complex which is wine red according to the equation below.



According to the equation, it binds in a 1:1 stoichiometric ratio. Because exactly one mole of ErioT complexes with one mole of magnesium, the resulting linear increase in absorbance at 520nm directly reflects the concentration of magnesium ions in the sample.

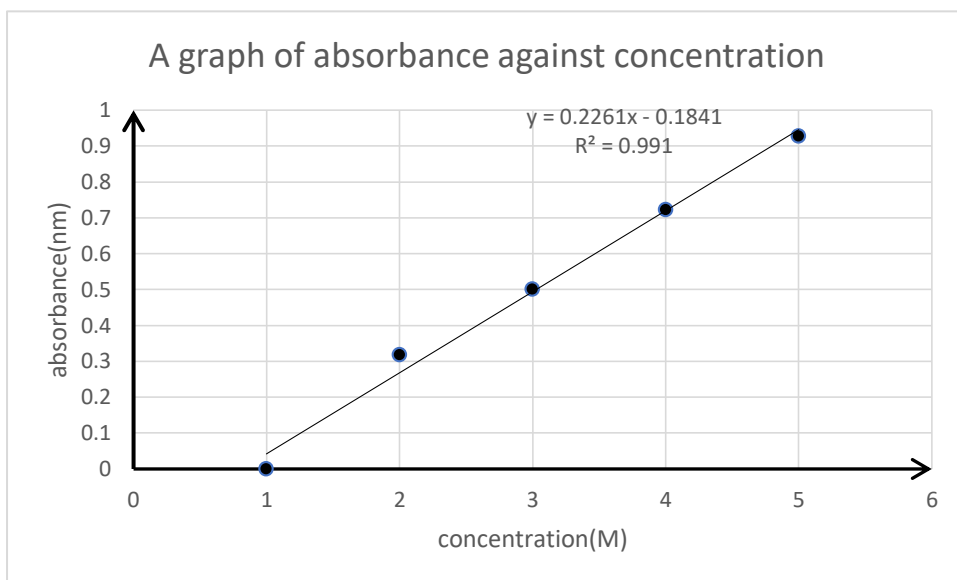


Figure 5:A graph of absorbance against concentration

Using the graph above

$$Y = 0.2261x - 0.1841$$

$$Y = 0.700 \text{ nm}$$

Substituting for the value of y

$$0.7 = 0.2261x - 0.1841$$

$$0.7 + 0.1841 = 0.2261x$$

$$\frac{0.8841}{0.2261} = \frac{0.2261x}{0.2261}$$

$$X = 0.0039 \text{ M}$$

The concentration of magnesium ions therefore is 0.0039M

Table 3: experimental results of EDTA volume used before treatment with activated carbon.

Experiment No	Initial(ml)	Final(ml)	EDTA used(ml)
1	0.00	10.00	10.00
2	0.00	8.10	8.10
3	0.00	8.20	8.20

Table 4: Experimental volume of EDTA used after treatment with activated carbon

Experiment No	Initial(ml)	Final(ml)	EDTA used(ml)
1	0.00	4.80	4.80
2	4.80	9.30	4.50
3	9.30	13.80	4.50

Results

a) Average EDTA volume before treatment

$$\text{Mean} = \frac{8.10+8.20+10.0}{3}$$

$$= 8.77\text{mL}$$

b) Average volume of EDTA after treatment

$$\text{Mean} = \frac{4.50+4.50+4.80}{3}$$

$$=4.60\text{mL}$$

c) Reduction in EDTA volume

$$= 8.77-4.60$$

$$=4.17 \text{ mL}$$

d) Calculation of removal efficiency (%)

$$= \frac{\text{Initial hardness}-\text{Final hardness}}{\text{Initial hardness}} \times 100$$

Initial hardness

$$\text{EDTA concentration} = \frac{2.5 \times 10^{-4}}{0.00825\text{L}} = 0.0303\text{mol/L from standardization}$$

Water sample volume titrated = 100ml = 0.100L

Molar mass of calcium carbonate = 100.09g/mol

$$\text{Hardness(mg/L)} = \frac{\text{CEDTA} \times \text{VEDTA} \times \text{M}_{\text{CaCO}_3}}{V_{\text{Sample}}}$$

Where:

$$\text{CEDTA} = 0.0303 \text{ mol/L}$$

$$\text{VEDTA} = 100.09 \text{ g/mol}$$

$$V_{\text{sample}} = 0.100 \text{ L}$$

Before treatment

$$V_{\text{EDTA}} = 8.77 \text{ mL} = 0.00877 \text{ L}$$

$$\text{Moles of EDTA} = 0.01 \times 0.00877$$

$$\begin{aligned} \text{Hardness (mg/L)} &= \frac{0.0303 \times 0.00877 \times 100.09 \times 1000}{0.100} \\ &= 266 \text{ mg/L} \end{aligned}$$

After treatment

$$\begin{aligned} \text{Hardness (mg/L)} &= \frac{0.0303 \times 0.00460 \times 100.09 \times 1000}{0.100} \\ &= 139 \text{ mg/L} \end{aligned}$$

$$\begin{aligned} \text{Removal efficiency} &= \frac{266 - 139}{266} \times 100 \\ &= 47.7\% \end{aligned}$$

The experimental result showed that activated carbon was effective in softening hard water. Before treatment, hardness was 266mg/L (as CaCO_3), while after treatment hardness was 139mg/L. WHO acceptable limit for drinking water is typically < 150mg/L for palatability so the treated water is acceptable this represents a reduction of 127mg/L and an overall hardness reduction of 47.7%

The decrease in hardness indicates that the concentration of calcium and magnesium ions in the water sample was reduced after treatment with activated carbon since EDTA forms complexes with these ions remained in the treated water. This confirms the hypothesis that banana peels, which are abundant agricultural waste, possess ion-binding capabilities that make them effective for water softening and the activated carbon adsorbed part of the dissolved metal ions responsible for hardness.

Its porous structure and large surface area make it effective in trapping impurities and reducing ion concentration. The percentage reduction in hardness was approximately 47.7% showing that the activated carbon had a noticeable softening effect on the water. Although the hardness was not completely removed, which might have been brought about by other divalent metal ions like iron, manganese which compete for the same binding site with the activated carbon. The presence of these ions would reduce the available sites for Ca^{2+} and Mg^{2+} , potentially explaining why the removal efficiency was not higher than 47.7% The treatment considerably improved the water quality by lowering the concentration of calcium and magnesium ions.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATION

4.1 Summary of the findings

The EDTA titration results confirmed that the water sample in Butaleja district contains significant concentrations of Ca^{2+} and Mg^{2+} with an average of 8.77mL before treatment. This validates the community's complaints regarding excessive soap consumption, unpleasant taste and scale formation on water heaters. Treatment with activated carbon derived from banana peels resulted in to a reduction in EDTA consumption to an average of 4.60ml representing a removal efficiency of 47.7%. This shows that activated carbon is effective in adsorbing hardness causing ions from water.

4.12 The study achieved all the specific objectives

Objective	Outcome
1. Determine concentration of Ca^{2+} and Mg^{2+} before treatment	Initial hardness confirmed with EDTA consumption of 8.77ml, UV-VIS analysis indicated Mg^{2+} of approximately 0.0039M.
2. Investigate the effect of adsorbent dosage and contact time	Using 0.2g of adsorbent per 100ml water with 60minutes contact time achieved significant hardness removal
3. Evaluate effectiveness of banana peel activated carbon	Removal efficiency of 47.7% was achieved, confirming banana peels as a viable low-cost adsorbent.

4.13 significance of the study.

The findings of this study have important implications for butaleja district and similar rural communities and these are;

Banana peels which are abundant agricultural waste, can be converted in to a valuable water treatment material, reducing waste disposal while providing a solution to hard water challenges.

The low-cost nature of this method makes water softening accessible to communities that cannot afford other methods such as ion exchange, reverse osmosis or electrodialysis which require high capital investment and operational costs.

The study addresses environmental, economic and social concerns contributing to sustainable development goals related to clean water and sanitation (SDG 6), responsible consumption and production (SDG 12) and climate action (SDG 13).

4.14 overall conclusion

Activated carbon prepared from banana peels is an effective, low cost and environmentally sustainable adsorbent for removing Ca^{2+} and Mg^{2+} from hardwater.

With a removal efficiency of 47.7%, this method offers a practical and accessible alternative to other methods which are expensive for softening of water particularly for resources limited communities in Butaleja district. The utilization of banana peels which is an abundant agricultural waste not only addresses water quality concerns but also contributes to waste reduction and environmental protection.

4.2 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made for the community, future research and policy makers.

4.21 Recommendations for the community

Residents in Busolwe town council are encouraged to prepare activated carbon from banana peels using the simple method described in the study to treat water before consumption.

They are argued to boil the treated water before drinking to address any biological contaminants that the activated carbon may not remove as the study focuses on chemical hardness.

Spent activated carbon containing calcium and magnesium ions can be composted or used as soil amendment since calcium and magnesium are beneficial to plant nutrients.

4.22 Recommendations for future research.

pH optimization: investigate the effect of pH on adsorption efficiency, as pH influences both the surface charge of the adsorbent and the separation of metal ions.

Temperature studies: Examine the effect of temperature on adsorption to determine whether the process is endothermic or exothermic and to optimize operating conditions.

Comparison with other agricultural wastes: compare the performance of activated carbon with locally available agricultural wastes such as coconut husks, rice husks, orange peels, mango seeds and coffee husks.

Competing ion effect: conduct systematic studies on the effects of competing ions like iron, manganese, sodium chloride and total dissolved solids on the adsorption of calcium and magnesium ions.

Composite adsorbents: combine banana peel activated carbon with other materials such as clay, zeolite, or chitosan to enhance adsorption capacity.

4.23 Recommendation for policy makers and Government agencies

Allocate funding for further research in to low-cost water treatment technologies using locally available agricultural waste materials.

Include banana peel activated carbon as a recommended low-cost intervention in national water quality improvement programs for rural areas.

Organize training workshops for residents of busolwe town and other affected areas on how to prepare and use banana peel activated carbon for water softening.

Encourage the collection and utilization of banana peels for water treatment as part of the district's solid waste management strategy.

4.24 Recommendation for academic institutions

Encourage undergraduate and graduate students to undertake further research on adsorption using locally available materials, building on the findings of this study.

Partner with local industries to scale up promising low-cost water treatment technologies.

Finally, the success of this research opens doors for further investigations in to other agricultural wastes and optimization of the adsorption process. It is hoped that the findings will contribute to improved water quality, reduced household expenses, better health outcomes and more sustainable waste management practices in busolwe town and beyond.

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