THE STOCKHOLM JUNIOR WATER PRIZE KENYA COMPETITION

CATEGORY **:** ENVIROMENTAL CHEMISTRY

TITLE **:** REMOVAL OF LEAD (II) AND COPPER **(**II) IONS FROM DRINKING WATER IN DOMESTIC AND COMMERCIAL WATER SUPPLY SYSTEMS

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LEVEL **:** NATIONAL

VENUE **:** SWEDISH AMBASSADOR RESIDENCE

DATE **:** 3rd JUNE 2022

DECLARATION

STUDENT'S DECLARATION

This project is our original work and has not been presented in previous science and engineering fairs.

Name : Signature…….Date……

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Name : Signature…….Date……

SCIENCE PATRON'S DECLARATION

I have checked this document and confirmed it is good for presentation. The work was done under my supervision.

Supervisor : Mr. E. Karanja Signature……Date…….

PLAGIARISM
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ABSTRACT

Water pollution from heavy metal ions is high in towns and rural areas in Kenya. The ions and other pollutants in drinking water are known to cause cancer among other human ailments. The aim of this study was to prepare and determine adsorption capabilities of untreated, acid treated avocado seeds and activated carbon on removal of Pb^{2+} and Cu^{2+} ions from drinking water and finally making a water purification system using the adsorbents. The avocado seeds obtained from Kabare market Kenya were cleaned with deionized water then cut into small pieces, dried in the sun for one week. They were ground using blender, then dried in the sun for 2 days and packed. Some were calcined to form charcoal. Acid treatment and activation was done using 1 molar sulphuric acid in the ratios 1:2, weight to volume; while adsorption tests were done using 2g of adsorbent in 50 ml of Cu^{2+} and Pb^{2+} ions in various appropriate concentrations. The % adsorption was calculated from AAS results of samples from this study done at JKUAT. The study results showed adsorption of the Cu^{2+} and Pb^{2+} ions at 26.7% and 57.0% respectively for unmodified while the removal was 97% Cu^{2+} and 95% Pb^{2+} for modified and 87.6% Cu^{2+} and 89.4% for activated carbon. The results from the study led to a conclusion of using the adsorbents in domestic and commercial water supply systems and also recommends further study on these and other cellulose materials for the adsorption of heavy metal ions and pollutants.

ACKNOWLEDGEMENT

We would like to sincerely appreciate our patron Mr. Karanja for his great support in this project. We sincerely appreciate our principal Mrs. Muhuni for financing the study and providing moral support. We wish to thank the Almighty God, for His continuous mercy and grace upon during the period of this study.

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CHAPTER ONE

INTRODUCTION

1.1. Background

An estimated 1.2 billion people drink unclean water, which is the source of water related ailments killing between five to ten million people, most of them being children around the world as they are the most susceptible to these diseases. Statistics also show that in developing countries, 70% of industrial waste are dumped untreated into the rivers which pollute the usable water supply. Pollution of water source due to disposal of heavy metal ions has been an increasing worldwide concern for the last few decades. These heavy metal ions include: Pb^{2+}, Cu^{2+}, Zn^{2+}, Cd^{2+}, Hg^{2+} and Ni^{+} among others. Pollution by these metal ions is a serious threat to aquatic ecosystems because some are potentially toxic even at low concentrations. They are non-biodegradable and can accumulate in living tissues, thus can easily be absorbed in the human body. Their levels in drinking water should be reduced to recommended concentrations as stated by national and international health authorities such as World Health Organization (WHO) (Nthiga.*et al*, 2016).

1.2. Statement of the problem

Recently drought has been a major problem where many people have suffered shortage of water and rise in cancer cases. However there are permanent rivers which are highly polluted i.e. Nairobi river which about 2.5 tons of industrial wastes containing some harmful heavy metal ions are dumped, in large quantities, consequently destroying the pre-existing aquatic ecosystem, endangering human life in slums along the river .Unfortunately treating the water with chemicals will be too expensive considering that Kenya is a less developed country. Thus the search of low cost and easily available adsorbs has led to investigation of agricultural origin as potential adsorbents. Avocado seeds are widely spread as waste. This has resulted to disposal problems

hence an approach that seeks to use them will be utilizing what has once been and unutilized resource.

1.3. Justification and significance

It is in record that 70% of the world's surface is covered by water. Of which 97% of it is salty thus only 3% of the world's water is fresh. Of this fresh water 70% of it is frozen and only less than 1% of the water is available for drinking purposes. This is further aggregated by anthropogenic stress on the available scarce water source. Industrialization further poses a waste water disposal challenge as most of the generated waste ends up in the water bodies. This waste contains high concentration of heavy metals and organic matter. There was need of use of cheaper methods of adsorption such as the use of avocado seeds. They are locally and globally available and have the adsorption ability and therefore can be used in remediation of waste water. They are also economical as they can be reused upto 5 times (If acidic treated) without reducing efficiency. Mugutha River, Kiambu district in Kenya was 10.9x10-2 mg/1 of the total (Waweru, 2014).

1.4. Hypothesis

Avocado seeds cannot remove heavy metal ions and cannot be used in water purification systems

1.5. General objective

Determination of the efficiency of avocado seeds in removal of heavy metal ions in drinking water

1.5.1. Specific objectives

(i) To determine % removal of Cu^{2+} and Pb^{2+} in aqueous solution using unmodified avocado seed powder

(ii)To determine % removal of Cu^{2+} and Pb^{2+} in aqueous solution using modified avocado seed powder

(iii) To determine % removal of Cu^{2+} and Pb^{2+} in aqueous solution using modified avocado seed powder

(iv) Design and construct a water purification system/plant using avocado seed adsorbents

1.6. Limitations and scope of the study

There are various contaminants that get into the water systems such as organic compounds and bacteria. However in this project only Cu^{2+} and Pb^{2+} ions in water were considered with other interfering ions is not considered.There are many agricultural wastes; however this study only considered avocado seeds without considering their variety, season, or geographical regions where they are grown.

1.6.1. Merits of the study

The water purification method and system is cheap, simple to use and make, reduces the diseases caused by heavy metal ions present in water , helps curb the problem of lack of water during the drought season and removes a high range of heavy metal ions and is not restricted to copper and lead e.g cadium though not considered in this study.

1.6.2 Demerits of the study

The main disadvantage of the method is slowness due to long contact time required and the adsorbents do not last for long and may not be found in all geographical locations globally..

1.7. Assumptions and precautions

The study assumes there are no copper or lead ions on the seeds prior to preparation.

CHAPTER TWO

LITERATURE REVIEW

2.1. Lead ions

It is one of the potentially toxic heavy metals when absorbed in the body. The presence of lead in drinking water may cause neurological, respiratory, urinary and cardiovascular disorders (blood pressure) due to immune modulation, oxidative and inflammatory mechanisms. It may also alter physiological functions of the body such as reducing physical and mental growth in children. Pregnant women exposed to lead have high risks of infertility, miscarriages and stillbirths. Chronic exposure to lead can cause stunted physical growth, anemia, kidney failure and irritable mood. The disposal of lead metals has been creating global threat. Sources of it is through lead batteries, pulp and papers, phosphate fertilizers, sewage waters among others (Samuel,M, 2011**).**

2.2. Copper ions

Copper exists in the environment as a mineral in rocks and soil, commonly found at low levels in water bodies. It is an essential trace element required to maintain good health. It is extensively used in plumbing systems as it does not lower the quality of the water but when the pipes corrode, they release copper in drinking water, polluting it. Among the heavy metals, studies have found that copper is the most abundant heavy metal pollutant in adequate environment. It is due to its wide application in both industries and as farm input. Consumption of high levels of copper may cause nausea, vomiting, diarrhea, liver damage, in the blood system may generate reactive free oxygen species and damage the proteins, lipids and DNA. Excess copper may have an effect on aging, mental illness, gastro-intestinal malfunction and convulsions (Irene,X., 2017).

Identifying copper in drinking water:

- At low levels, copper usually leaves a green-blue stain on taps, pipes and toilets, but has no bitter or metallic taste and is still considered safe for drinking.

- For high levels of copper, it leaves a metallic or unpleasant bitter taste in the drinking water, thus not safe for drinking. Contacting your drinking water provider is advisable or simply applies this study on large-scale treatment of water as it is more efficient and easily manageable.

2.3. Adsorption

Adsorption techniques for wastewater treatment have become popular in recent years due to their efficiency in the removal of pollutants. As a result of industrial activities and technological development, the amount of heavy metal ions discharged into streams and rivers by industrial and municipal waste water has been increasing pollution. Certain heavy metals such as Copper and Lead are required by humans for normal biological functioning, however, heavy metal ions such as lead. Mercury, cadmium and copper are toxic to humans when in excess (Nthiga,E.*et al,*2016). Increase use of metals and chemicals in process are resulted in generation of large quantities of effluent that contains high level of toxic heavy metals and their presence poses environmental disposal problems, so adsorption processes are generally used. However there are other methods of removing the heavy metals, that is; chemical precipitation, membrane filtration, ion exchange, liquid extraction and electro dialysis, sedimentation, disinfection. These methods are based of removing heavy metal ions from aqueous solutions, physical, chemical and biological mechanisms. New technologies such as ultra-filtration, nano-flitration and reverse osmosis but are associated with high capital and operational costs thus are not applicable in this study. For cost effective purposes, we preferably opt avocado seeds, which are locally available and environmental friendly.

2.4 Activated carbon

Activated carbon defines a group of materials which highly develop internal surface area and porosity, and hence a large capacity by adsorbing chemicals from gases and liquids. The processing of activated carbon basically involves selection of raw materials, carbonization and activation. The activated carbon produced is environmentally friendly with industrial applications especially in water and waste water treatments due to its adsorption properties.

2.3.1. Modified and un- modified avocado seeds adsorption of metal ions

Avocado seed powder has phenolic and alcoholic groups and esters. The hydroxyl, carboxylic, alcohols, esters and ethers are responsible for binding of heavy metals. These groups are involved in chemical bonding and are responsible for cation exchange. Modified avocado seeds have more active binding sites providing more surface area for heavy metal ion adsorption while the unmodified avocado seeds have less active binding sites which lower the rate of heavy metal ion adsorption but are easier to prepare and use cost effectively.

CHAPTER THREE

METHODOLOGY

3.1. Requirements

One12V DC battery

10 Clips

One 12V DC fan

1Thermos flask

0.01M KI

Two 12V DC pump

2 Conical flasks

1Burette

1Pipette

1 Clamp and stand

4Beakers

1M H_2SO_4

3 Containers

Pvc tubes

Stirrer

1%$NaHCO_3$

0.01 M Na_2CO_3

Activated carbon

30 cm^2 cotton cloth

Fabricated prototype of water purification

Mortar and pestle

3.2. Procedure

3.2.1. Preparation of avocado seeds adsorbent

The seeds were washed with deionized water, cut into small pieces with a clean knife, dried in the sun for 2 weeks. Some of the dry pieces were calcined to form charcoal. The charcoal and cut seeds were crushed separately and ground using a dry mortar and pestle, sieved and dried for 2 days in the sun then packed in separate dry sealed paper bags.

3.2.2. Acid treatment of avocado seed adsorbent

The natural adsorbent powder and its charcoal were (in separate procedures) mixed with 1 molar H_2SO_4 in the ratio of 1:2 (mass to volume) and thermochemically treated to boiling for 2 hours and left for 22 hours in a thermos flask. The products were then washed with distilled water to remove excess acid, filtered and mixed with 1% N_aHCO_3 over night to eliminate acid (Nthiga, B., *et al* 2016).

3.2.3. Test for adsorption

2g of adsorbent was placed in 50 ml of 0.1 molar Cu^{2+} and Pb^{2+} in a 250 ml volumetric flask and swirled for 1 hour using a centrifuge motor. After filtration using whatman micro filters 25 ml samples were titrated against 0.01M Na_2CO_3 and 0.01M KI respectively to determine residual Cu^{2+} and Pb^{2+} ions respectively. The % recovery was determined.

3.4.2 The filtration system

In the decantation tank the lighter materials float and the heavier materials sink to the lower part of the cylinder. In tank 2 the water mixed with the avocado adsorbent (in the ratio of 50ml: 2g is rotated for 1 hour) after which the water is allowed to decant then passed for final filtration in tank 3 where the filtration involves clean cotton fiber at the bottom, then fine sand, gravel, layer of activated charcoal and finally a gravel layer. The clean water drained from the lower part of

the cylinder is ready is colorless, clean and ready for domestic purposes. Figure 2 below shows asset up of the water treatment system

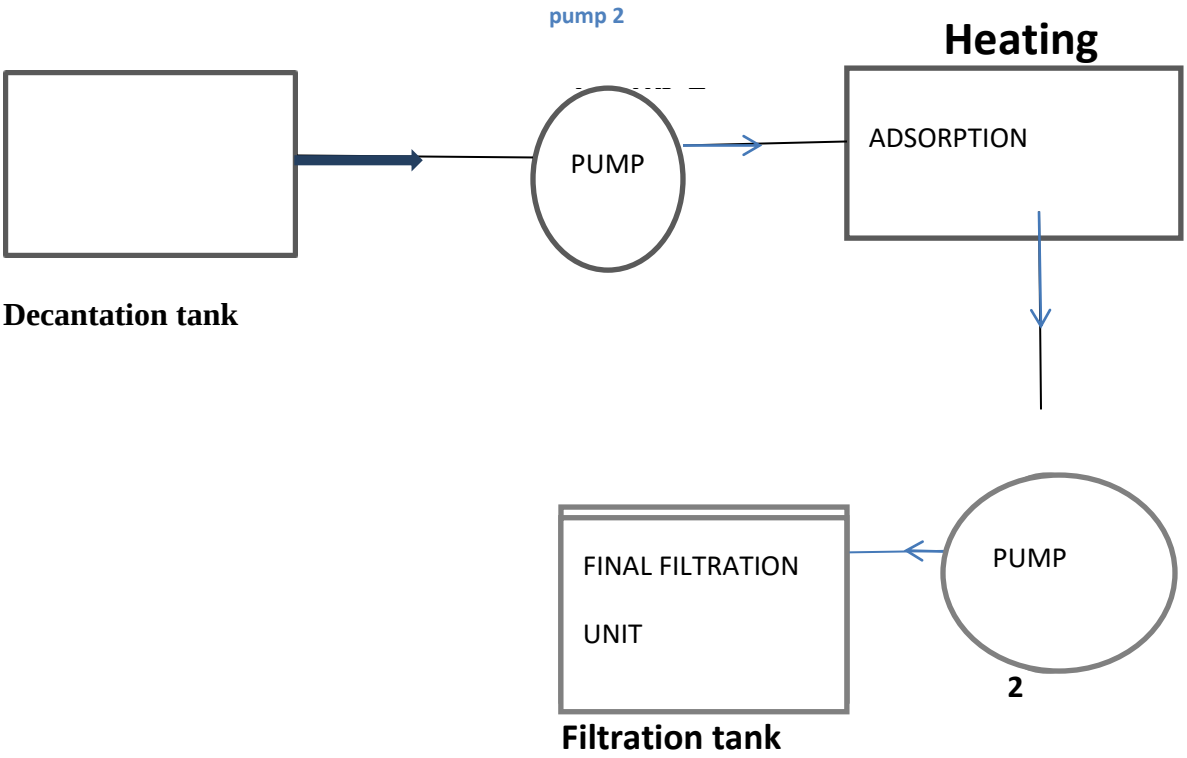

Figure 1: The water filtration system

The figure shows the steps from water entry to final filtration. The unit can be converted to a simple water dispenser for use at home and can as well be converted to a water purification system/plant where water from a river, lake or any other water body is directed appropriately using pumps employing solar, wind or even gravitational pull or rotors connected to the flowing river where applicable. In communities lacking electricity manually moving water into the levels and using manual hastening of adsorption is also viable.

3.2.4. Atomic absorption spectrometry test

2g of adsorbent was placed in 50 ml of 20ppm (20 mg/litre) Cu^{2+} and Pb^{2+} in a 250 ml beaker and swirled for 1 hour using a shaker at 200 rpm . After filtration using what man micro filters samples were analyzed using an AAS machine AA-7000 at the Food science and technology laboratories JKUAT and results provided. The percentage recovery was calculated using equation 1

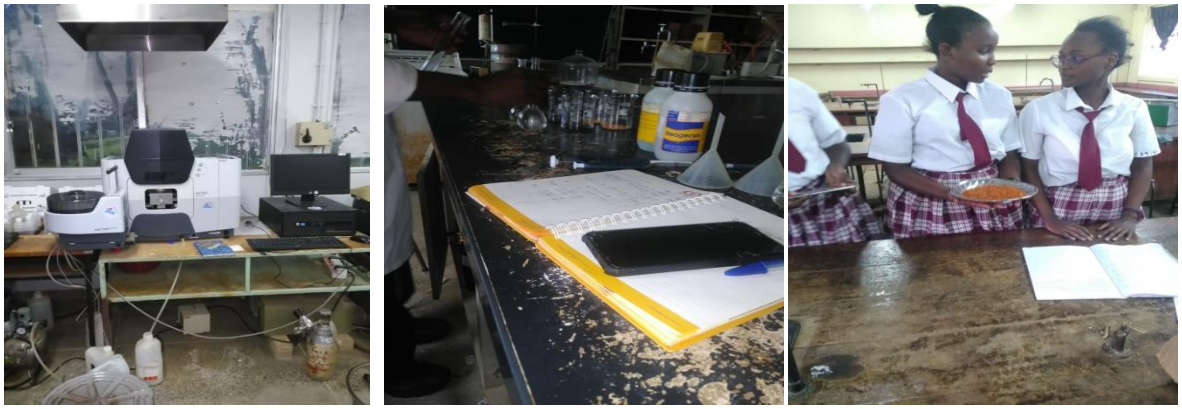

Figure 2: Adsorption tests for lead ii and copper ii ions

3.3. Variables.

The variables in this study % adsorption, type of ion and time of contact. The independent variable was ion type and time of contact, while the dependent variable is % adsorption. The percentage adsorption depends on type of adsorbent, ion and time of contact for adsorption.

3.4. Observations and results

Avocado seeds powder has pores hence adsorbing more metal ions. The increased contact time between the water and the seeds increases the adsorption efficiency adsorbing a higher percentage.

DATA ANALYSIS AND INTERPRETATION

Table 1:Adsorption tests for unmodified avocado seeds.

METAL	TESTS	%REMOVAL	TIME(minutes)
LEAD	1	58.2	60
	2	57.5	60
COPPER	1	26.2	60
	2	26.5	60

As shown in the above test the avocado seeds remove a larger percentage of heavy metal ions present with increased time contact. The highest removal for lead ions is 58% while the recovery for copper ions was 27%, which was high because levels in water bodies are in the range of 1.3mg/L to 1.5mg/l, while the maximum allowed levels are 1.5mg/l.

Table 2: Adsorption tests for modified avocado

METAL	TESTS	%REMOVAL	TIME (min)
LEAD	1	70	60
	2	95	60
COPPER	1	62	60
	2	97	60

As shown in the above test the avocado seeds remove a larger percentage of heavy metal ions present with increased time contact. The highest removal for lead ions is 95% while the recovery for copper ions was 97%.

Table 3: Adsorption test for activated carbon

METAL	TESTS	%REMOVAL	TIME (min)
LEAD	1	89.0	60
	2	89.4	60
COPPER	1	87.6	60
	2	87.0	60

Table 3 shows that activated carbon removes both lead and copper ions at the high of 89.4% and 87.6 % respectively which is appropriate because average are in the range below 1mg/l and the WHO recommended levels are zero tolerance for lead and AL of 0.015mg/l while copper ions the MCL are 1.5 mg/l. The results indicate a synergistic setup like in this study is appropriate for a water purification system.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

In this study, adsorption efficiency of unmodified avocado seeds towards removal of Cu^{2+} and Pb^{2+} ions from water was evaluated. The experimental conditions, such as pH, initial metal concentration, dosage of adsorbent and time of exposure greatly influenced efficiency of removal of the metal ions. Initially there are large number of vacant active binding sites available and consequently large amount of metal ions are bound rapidly on the surface of the avocado seeds at a faster adsorption rate .The binding sites shortly become limited and the remaining vacant surface sites are difficult to be occupied by metal ions due to the formation of repulsive forces between the metal ions on the solid surface and the solution surface. This is the reason why avocado seeds do not adsorb all the metal ions.

5.2. Recommendations

More research should be done on other bio-sorbents so as to adsorb other toxins such as nitrates and chlorides in water.

5.3. Recommendations for further study

The avocado seeds should be investigated for the removal of other heavy metal ions, polyphenols and polyaromatic hydrocarbons.

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