EVALUATION OF BIOSORPTION POTENTIALS OF BAMBARA GROUND NUT *(Vigna subterranea)* AND SOUR SOP SEEDS *(Annona muricata)* POWDER FOR THE SELECTED HEAVY METALS FROM AQUEOUS SOLUTION

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A RESEARCH REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN CHEMISTRY IN SCHOOL OF NATURAL AND SOCIAL SCIENCE OF THE STATE UNIVERSITY OF ZANZIBAR

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DECLARATION

I Khadija Ali Mwinyi, declare that this study is my original work and has not been presented in any other University or for any other award.

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We as supervisors confirm that the work reported was carried out by the candidate under our supervision.

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DEDICATION

I dedicate this piece of work to my beloved parents, my siblings, my devoted and caring husband, Ahmed Abdulrahman Rashid for his support, tolerance and care and also to my precious daughter Samim and sons Akmal and Mahsin as a token for their tolerance during my study time.

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All praises are showered to the Almighty Allah (S.W) who is the source of complete knowledge and the transcendent creator of the universe. It is through his favor to give me life, health, strength that helped me to conduct and complete this work.

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Lastly, but not the least, I offer my appreciation to my colleague Saada Rashid Mohammed, whom we were together during the time of our studies, may ALLAH (S.W) shower her with success.

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LIST OF ABBREVIATIONS

BGP	Bambara Groundnut Powder
ICP-OES	Inductively Coupled Plasma Optical Emission Spectroscopy
Ppm	part per million
PVC	Poly Vinyl Chloride
SSSP	Sour Sop Seeds Powder
SPSS	Statistical Package for the Social Science
WHO	World Health Organization

ABSTRACT

Heavy metals have increased a greater consideration to environmental chemists due to their toxic nature. They are persistent in nature and cannot be degraded. Heavy metals can deteriorate the environment resulting in a variety of illness and disorders when entering the living tissue. This study aims at investigating the adsorption capacity of biosorbent (bambara groundnut powder; BGP, and soursop powder; SSSP) on toxic metals from synthetically prepared waste water. The adsorbents were used to examine their respective efficiency on selected metal; cadmium (Cd), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), and thallium (Tl) from the prepared contaminated water. The samples were analysed using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). 0.2 g of (BGP) was added to 50 mL of ultra-pure water. Then separately known concentrations of the analyzed parameter were added to the solution of BGP and SSSP. The results of adsorption efficiency were: 100% each for Cd^{2+}, Tl^{2+} and Pb^{2+}; 94% for Cu^{2+}; 81% for Zn^{2+}; 68% for Co^{2+}; 64% for Mn^{2+}; 46% Fe^{2+}; and 07% for In^{2+}. The results revealed that, the metal ions were removed in the following order: $Cd^{2+} = Tl^{2+} = Pb^{2+} > Cu^{2+} > Zn^{2+} > Co^{2+} > Mn^{2+} > Fe^{2+} > In^{2+}$. With the same conditions as applied in bambara ground nut powder the adsorption efficiency of the soursop seed powder were: for 100% for Cd^{2+}; Cu^{2+}; $Tl^{2+}$and Pb^{2+}; 83% for Zn^{2+}; 62% for Co^{2+}; 49% for Fe^{2+}; 21% for In^{2+}; and 0% for Mn^{2+} with an order of $(Cd^{2+} = Cu^{2+} = Tl^{2+} = Pb^{2+}) > Zn^{2+} > Co^{2+} > Fe^{2+} > In^{2+} > Mn^{2+}$. The analysis showed that both BGP and SSSP have remarkable adsorption capacity on selected metals. Suggestively, the BGP and SSSP are preferable low cost and eco-friendly alternative adsorption materials for toxic metals ions. It is therefore recommended to the society to increase the consumption of bambara ground nut and soursop as well as its seeds being an important way of getting rid of toxic chemicals from the body.

CHAPTER ONE

INTRODUCTION

This chapter concentrates on the background of the study, statement of the problem, objectives of the study, research questions and significance of the study.

1.1 Background

Heavy metals have received a paramount attention to environmental chemists due to their toxic nature (Verma, Kumar & Kumar, 2016). These metals are toxic pollutants that may possibly cause a variety of illness and disorders when they accumulate in the living tissues (Agarwal & Singh 2017).

Heavy metals can be initiated from both natural and anthropogenic processes and end up in different environmental compartments (Sdiri & Higashi 2013).

In natural water, heavy metals are omnipresent, though with their trace amounts can pose detrimental effects (Dubey & Xavier 2015). Metals like lead, cadmium, nickel, mercury, chromium, cobalt, zinc and selenium are highly toxic even in minor quantities (Agarwal & Singh 2017).

Increasing quantity of waste in our environment is an area of greater concern, especially as they may contain toxic metals. Many industries discharge their metal containing effluents into water bodies without prior required treatment (Agarwal & Singh 2017).

Heavy metals may enter human body through food, water, air or absorbed through the skin during agriculture, manufacturing of goods, pharmaceutical and through industrial operations (Verma, Kumar & Kumar 2016).

Exposure of aquatic and terrestrial organisms to toxic metals can have devastating impacts to health of living creatures, toxic heavy metals have been associated with numerous diseases including cancer (Emenike et al. 2016).

1.2 Statement of the problem

Heavy metals concentration increased due to rapid development of science and technology in a way that put a threat to the living world (Wang et al. 2016).

The remarkable increase in the usage of metals has inevitably caused in an increased flux of toxic metal ions in the ecosystem (Jamaluddin, 2018). The discharge of toxic metals to the environment without prior necessary treatment can lead to severe health problems due to their effect on the biodiversity and the entire ecosystems (Akinyeye et al. 2020). These metal ions are non-biodegradable and must be eliminated from wastes before being discharged into the environment (Wang et al. 2016).

Several methods are used for elimination of toxic metals from industrial effluents and wastewater treatment, these include ion exchange, chemical precipitation, filtration, electrochemical treatment and others (Serrano-Gómez et al. 2015). These methods possess several drawbacks, they are very expensive ineffective to eliminate all toxic metals and may yield secondary wastes (Sarada et al. 2014). Thus, biosorption method could be the perfect alternative to remove hazardous metal ions from the environment (Sarada et al. 2014). The use of natural sorbent for removing of toxic metal ions from wastewater has been an effective technique with low cost and high adsorption efficiency(Sdiri & Higashi 2013).

Recently, the study of adsorbent from powder of seed of ajwa dates showed that biosorption could be an effective method for eliminating toxic pollutants such as cadmium, lead, copper, chromium, cobalt and manganese in aqueous solution (Mohamed et al. 2019). Nevertheless, further studies must be undertaken for in-depth identification of the natural sources of low-cost and eco-friendly adsorbents for the removal of toxic substances in an environment. Therefore, the use of bambara groundnut and soursop powders could be the paramount solution for the removal of toxicants in a given system.

1.3 Objective of the study

1.3.1 General objective

The aim of this work is to evaluate the adsorption capacity of bio sorbent developed from Bambara groundnut and soursop seeds powder on selected toxic metals in aqueous solution.

1.3.2 Specific objectives

The objectives of this study were to find out the following:

1. To determine the adsorption capacity of Bambara groundnut (PBS) and soursop seed (SSSP) powder on different heavy metals.
2. To compare the adsorption capacity of the bambara groundnut and the soursop seeds power for selected heavy metals from aqueous solutions.
3. To determine the most highly adsorbed metal by:

   a) Bambara groundnut powder

   b) Soursop seed powder

1.4 Research questions

1. What are the minimum and maximum levels of heavy metals as adsorbed by?

   a) Bambara groundnut powder

   b) Soursop seed powder

2. What is the most effective adsorbent on each of the selected metals?
3. Which of the selected metal is highly adsorbed by?

   a) Bambara groundnut powder

   b) Soursop powder

1.5 Significance of the study

The data obtained from this study could provide a base at advancing the greatest and high efficiency adsorption method for waste water, and hence eliminating toxic pollutants in the environment by using low cost adsorbents.

The knowledge obtained from this study will encourage the frequently consumption of local food along with their seeds as the best and healthy way of getting rid of toxic load due to heavy metals from different systems. Some epidemiological studies concerning these food stuff when undertaken will be of added value.

CHAPTER TWO

LITERATURE REVIEW

This chapter covers areas such as definition of key terms, theoretical background, toxicity of heavy metals, selected heavy metals, natural adsorbents as well as historical background of Bambara groundnuts and soursop fruits.

2.1 Theoretical background

Naturally the earth's crust is composed of toxic metals such as iron, nickel, chromium and aluminium in which their concentrations are highly from anthropogenic sources (Patra, Panda & Dhal 2017).

In the past century, there has been rapid development of science and technology which is directed towards making human society contented, (Abudaia et al 2013). Nevertheless, this trend has destroyed the environment by generating great amount of dangerous wastes including heavy metal which endangers aquatic and human beings (Dubey & Xavier 2015).

2.2 Toxicity of selected heavy metals

Heavy metals toxicity poses a major threat to the environment all over the world, they mostly act as toxic contaminants and a great danger to the animal and the living creatures health due to their persistent nature (Patra, Panda & Dhal 2017). They are chemical pollutants that may lead to diseases and disorders when entering the living tissues (Inyang et al. 2012).

2.3 Selected heavy metals

Heavy metals pollution is a key environmental problem in surface and ground water around the globe (Ibrahim, 2016). These metals are present in our environment due to the industrial processes in modern world such as mining, metal plating, battery manufacturing, manufacturing of electronic devices and pigment production which produce wastes containing toxic metals that are poorly released into the ecosystem (Inyang et al. 2012). The summary of the sources of heavy metals and their effects on human health is represented Appendix 1.

2.4 Need for the removal of heavy metals in the environment

Toxic metals are non-biodegradable and they can accumulate in living tissues via the food chain. Thus, it is necessary to get rid of such dangerous metals to avoid health hazards to the environment and human health (Verma, Kumar & Kumar 2016).

Toxic contaminants from wastewater poses a serious problem in the environment, therefore immediately measures must be taken to remove and to prevent the load of contaminants in the living environment, commercial and biosorption processes are commonly used to eliminate heavy metals in wastewater (Agarwal & Singh 2017).

A number of methods have been employed to treat water contamination of heavy metals such as physio-chemical and biological techniques (Jain, Malik and Yadav, 2016). Physio-chemical methods such as chemical precipitation, chemical oxidation/reduction, filtration, ion exchange, electrochemical treatment have been commonly used for removal of toxic ions in waste water (Serrano-Gómez *et al.*, 2015).

The physio-chemical methods are proving expensive due to the use of chemicals that are non-recyclable and high costs of operations (Prabha, 2018). However, these techniques fail to eliminate all toxic metals and increase the deterioration of the environment by production of secondary wastes (Sarada et al. 2014). These constraints have led innovation of new technologies needed for better treatment and elimination of heavy metals and from environment (Oboh & Aluyor, 2008).

2.5 Natural adsorbents

Bio sorption can be defined as “the ability of biological materials, to accumulate heavy metals from wastewater through metabolically mediated or physio-chemical path ways of uptake” (Dubey and Xavier, 2015). The process involves the passive removal of substances such as pollutants (metal ions and dyes) from solution by using inactive biological materials (Alfara, Ali & Yusoff, 2014).

The method involves a solid phase (sorbet or bio sorbent, biological material) and a liquid phase (solvent usually aqueous solution containing a dissolved particles to be sobbed (sorbet, metal ions) (Dubey & Xavier, 2015). The key mechanism responsible for metal ions accumulation by bio sorbents involve ionic interactions and complex creation between metallic ions and ligand present in bio sorbents surfaces (Verma, Kumar & Kumar 2016).

Biosorption has attained great concern as an alternative method that offers the use of biological materials for the same purpose of treatment of polluted water by eliminating trace metals. This study focuses on finding the solution to treatment of synthetic wastewater from toxic metal ions present in aqueous solution by using local available materials and cheap adsorbent developed from Bambara groundnut and soursop seeds powder.

The use of natural adsorbents for removal of toxic metal ions from wastewater has been an effective technique with low cost and high adsorption efficiency (Sdiri & Higashi, 2013).

Natural adsorbents are essential in the clean-up process because they are reusable in the physical adsorption process, cheaper and preferable for the environmental cleaning up thus, biosorption method could be the perfect alternative method to remove hazardous metal ions from the environment (Sarada et al. 2014).

Developing low cost and eco-friendly technologies for the remuneration of soil and water dirtied with toxic elements is a global concern (Swain, Adhikari & Mohanty, 2014). Many studies indicate that adsorbents from materials of biological origin can be very effective to eliminate toxic chemicals from aqueous solution because of its low cost, locally abundant and environmental friendly (Robalds, 2015).

Adsorption method is being commonly used in the world as an effective method of advanced waste treatment, the study of (Yaacoubi et al. 2014) showed that natural phosphate could be used as an adsorbent capable to eliminate cadmium from aqueous solution.

Furthermore, (Serrano-Gómez et al. 2015) on their study of carbonaceous material obtained from exhausted coffee was used to develop adsorbents which were seem to be a possible adsorbents for removing cobalt and cadmium ions from the aqueous solutions.

Therefore, biosorption method offers eco-friendly, sustainable, rapid and a cost effective solution for the treatment of wastes from industries and eliminating toxic elements in aqueous solution (Sarada et al. 2014).

Some studies have shown that toxic heavy metals can be removed using plant materials such as leaves, flowers, roots, seeds, barks, peels and so on, (Oboh & Aluyor 2008). These materials composed of cellulose and lignin content which are efficient in metal ion biosorption, also the metal binding property of bio sorbents is maintained by functional groups present on the site of adsorbing materials (Jain, Malik & Yadav 2016).

Due to deterious effects of heavy metals around the world, there is a global environmental needs call for the application of new adsorption process in pollution control. Therefore, the present study focuses on using bambara groundnut and sour sop seeds powder as local available materials to develop low cost and eco-friendly adsorbents for removal and recovery of cadmium (Cd), chromium (Cr), copper (Cu), cobalt (Co), indium (In), Iron (Fe), lead (Pb), thallium (Tl) and zinc (Zn).

2.6 Historical background of bambara groundnuts and sour sop seeds

2.6.1 Bambara groundnuts *(Vigna subterranea*)

Bambara groundnut is an indigenous herbaceous annual plant in the family of Leguminous, locally named as njugu mawe (Begemann and Engels 2014). Bambara groundnut beans are invented from North Africa, the name arises after a district on the upper Niger known as Bambara (Swanevelder 1998) the nuts are produced all over Africa.

Despite of many useful of the bambara beans are neglected, studies show that it is highly nutritious food which play great part in human diet, the seeds are eaten either when are young or completely matured and dried, also the nuts are used to feed pigs and poultry (Swanevelder 1998). Bambara groundnut seeds provide a complete meal with required quantities of carbohydrate, protein, fat and fibres needed for the human diet (Begemann & Engels, 2014). Table 2.1 displays the scientific classification of Bambara ground nut.

Table 2.1: Scientific classification of bambara ground nut

Kingdom	Plantae
Division	Angiosperms
Class	Magnoliids
Order	Fabales
Family	Fabaceae
Genus	Vigna
Species	Vigna subterranea

Source: (Temegne 2018)

2.6.2 Sour sop fruit and seeds *(Annona muricata)*

Soursop is originated from South Africa and belonging to the family Annonaceae. It is commonly known around the world as Graviola (Swain, Adhikari & Mohanty, 2014) and locally called as stafeli. It is commercially grown for its fruit crop which is used to make juice, candy and ice cream. The fruit is eaten fresh as a desert or snack item and it is high in carbohydrates, proteins and fats and also a good source of vitamins B, C and K as well as containing large amounts of calcium, magnesium, zinc, and phosphorous (Oboh & Aluyor 2008).

Various parts of soursop tree have been used for medicinal purpose to treat many diseases. Young shoots and leaves are used for treatment of gall bladder infections, relieve coughs, diarrhoea and improve ingestion and flowers are antispasmodic (Tripathi, 2014).

Moreover, studies have shown that soursop is a cancer killing plant, the plant has anti-cancerous properties in seeds, leaves, root, stem and bark in which it is very effective in attacking and destroying cancer cells (Adelaja, Amoo & Aderibigbe, 2011). The scientific classification of soursop is illustrated in table 2.2

Table 2.2: Scientific classification of soursop

Kingdom	Plantae
Division	Angiosperms
Class	Magnoliids
Order	Magnoliales
Family	Annonaceae
Genus	Annona
Species	Annona muricata

Source: (Abbo, Olurin & Odeyemi, 2006)

CHAPTER THREE

RESEARCH METHODOLOGY

This section presents key methodological issues that were followed to conduct this research. Among the areas covered, include: the nature of research design, the area of the study, sample collection and data analysis methods.

3.1 Study design

The study used laboratory experimental method to evaluate the biosorption potentials of the named powder to the selected metals.

3.2 Equipment and apparatus

3.2.1 Apparatus

The following apparatus were used:

Digital analytical balance, crucibles, desiccator, airtight plastic containers, pH meter, 250 mL conical flasks, 100 mL volumetric flasks, filter papers and funnels Inductive couple plasma optical emission spectrophotometer, filter paper and funnels.

3.2.2 Equipment

Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP-OES)

3.3 Sample collection

Mass of 500 g of bambara groundnuts and two (2) soursop fruits were bought from the local market at Mwanakwerekwe. The flesh and the seeds were then separated from the sour sop fruit. The figures of the samples are shown below in Picture 3.1 an and 3.1 b.

Figure 3.1: (a) Bambara ground nut *(b) Soursop fruit and seeds*

3.4 Reagents and chemicals

The following reagents and chemicals were used: ICP multi-element standard solution IV and ultra-pure water.

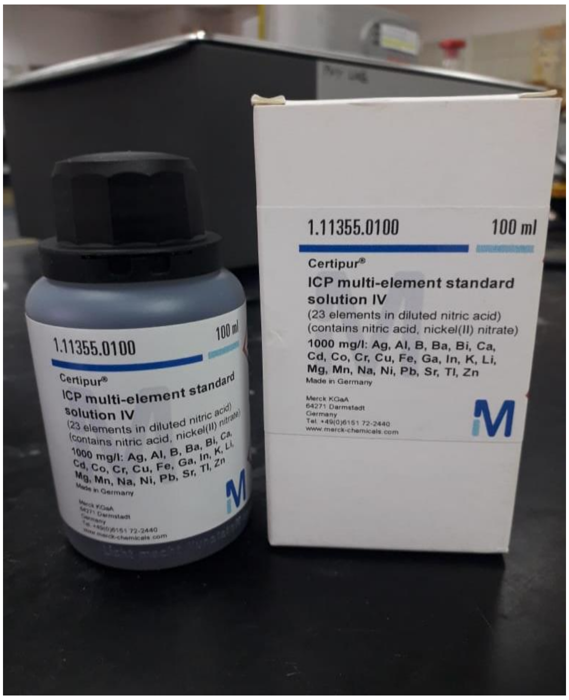

Figure 3.2: ICP multi-element standard solution

3.5 Preparation of adsorbent and contaminated water

Both samples (*Annona muricata* and *Vigna subterranea*) were washed with tap water three times and afterwards with distilled water three times to remove dust particles and then dried by sunlight. The samples were then dried in the oven at 105^0C for five (5) minutes to remove moisture content and cooled to normal temperature in a desiccator. Then the oven temperature was raised to 550^0C, the samples were put in the oven for 30 minutes till black form were observed then, the samples were cooled to normal temperature in a desiccator. The dried samples were crushed in a blender till smooth black powder and stored in airtight containers.

3.6 Calibration and Preparation of standard reagent

Prior to samples analysis, the ICP were calibrated accordingly. 1000 mL volumetric flask were cleaned and dried then labelled as stock standard solution containing 1000 ppm of cadmium (II) ion, chromium (II) ion, cobalt (II) ion, copper (II) ion,

indium (II) ion, thallium (II) ion and zinc (II) ion by continuous dilution. Then the solution was diluted to 100 ppm followed by dilution to 10 ppm and finally were diluted to 2 ppm. 50 mL of 2 ppm of prepared standard solution was put in the flask and then stored in a cool and dry place. 50 mL of ultrapure water used and labelled as blank solution.

The blank and prepared standard solution of 2 ppm were analysed by Optical Inductively Plasma Spectrophotometer (ICP-OES).

3.7 Removal of heavy metal ions by bambara ground nut powder (BGP)

Four conical flasks were cleaned, dried and labelled as B1, B2, B3 and B4. 0.2 g of BGP was added into each flask followed by 50 mL of synthetic waste. The solution was homogenized and allowed to settle over night the solution was separated. The analyte were put in 50 mL flasks labelled B1, B2, B3 and B4 and the filtrates were stored in a cool dry place.

3.8 Removal of heavy metal ions by soursop seed powder (SSSP)

Four conical flasks were cleaned, dried and labelled as S1, S2, S3 and S4.

0.2 g of SSSP was added into each flask followed by 50 mL of synthetic waste. The solution was homogenized and allowed to settle over night to separate inert solution from the filtrate. The analyte were put in 50 mL flasks labelled S1, S2, S3 and S4 and the filtrates were stored in a cool dry place.

3.9 Data analysis

The biosorption capacity of carbonized powder of bambara ground nut (BGP) and sour sop seeds (SSSP) have been examined by using constant mass of 0.2 g on removal of cadmium (II), cobalt (II), copper (II), iron (II), lead (II), manganese (II), indium (II), thallium (II) and zinc (ii). The multielement solution was measured twice prior thee experiment and found to have average concentration of 0.08 ppm of cadmium, 0.20 ppm of cobalt, 0.12 ppm of copper, 0.59 ppm of iron, 0,03 ppm of lead, 1.09 ppm of manganese, 0.16 ppm of indium, 0.51 ppm of thallium and 1.96 ppm of zinc.

The adsorbent efficiency of selected metals was calculated by using the formula:

$$\frac{Di - Df}{Di} \times 100$$

Where D_i and D_f represent initial and final concentrations of heavy metals, in prepared waste water before and after adsorption respectively. Statistical analysis such as minimum and maximum percentage removal, mean and standard deviation were done using IBM SPSS statistics version 20 and Microsoft Excel.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Determination of adsorption capacity of bambara ground nut and Soursop seed

When the adsorbent is placed into the aqueous solution comprising heavy metal ions, the concentrations of selected heavy metals in aqueous solution are lowered. This indicating that the metal ions adhere to the surface of the adsorbents via the functional groups (Reepei 2014).

BGP and SSSP being the plant materials composed of oxygen and nitrogen functional groups such as imide, lactane, amide and pyridine, which have high affinity to adsorb to the binding sites of metal ions surface by forming a complex compound which result to the significant impact on the removal of the toxic to human body (WHO 2006).

The metal ion is binding to the surface of the adsorbent (into the principal binding site of BGP and SSSP) through the functional groups such as amine, carboxylic and hydroxyl groups which are available in plant materials. (Abdolali et al. 2016).

In both samples bambara ground nut powder (BGP) and sour sop powder (SSSP) showed maximum adsorption of 100% of Cd, Cu, Pb and Tl indicating that the two adsorbents were the perfect materials for the removal of these metals, while manganese (Mn) and indium (In) were poorly adsorbed metal ions having the lowest percentage adsorption (appendix 1). Both samples (BGS and SSSP) indicated comparably results in adsorption of Co, Fe, and Zn as indicated in Appendix 3.

The study showed that SSP is the best adsorbent for heavy metals removal except for manganese and indium ions which show poor percentage adsorption, the metal ions were removed in the following order (Cd^{2+}, Cu^{2+} Tl^{2+} and Pb^{2+}) > Zn^{2+} > Co^{2+} > Fe^{2+} > In^{2+} > Mn^{2+}.

The results revealed that heavy metals removal were successfully using BGP except for indium ions whose percentage adsorption was the lowest, the metal ions were removed in the following order (Cd^{2+}, Tl^{2+} and Pb^{2+}) > Cu^{2+} > Zn^{2+} > Co^{2+} > Mn^{2+} > Fe^{2+} > In^{2+}.

Similar study conducted by (Sulaiman 2012) on rubber shells indicate the ability of the plants materials for adsorption of Pb^{2+} , Zn^{2+} and Fe^{2+} from aqueous solution.

4.2 Comparison of adsorption capacity of bambara ground nut and soursop seed for selected toxic metals

4.2.1 Cobalt (Co) and zinc (Zn)

It was found that bambara ground nut powder showed the highest level of adsorption of cobalt and zinc this indicating that the adsorbent was having more functional groups and lager surface areas for the binding site of the metal ions (Elizalde-González 2008). Cobalt was also successively removed by SSSP meanwhile zinc was poorly removed (figure 4.1), poor zinc adsorption of 44% was also indicated by the study of Wu, Kuo & Guan 2015 for the removal of metal ions using coffee residue.

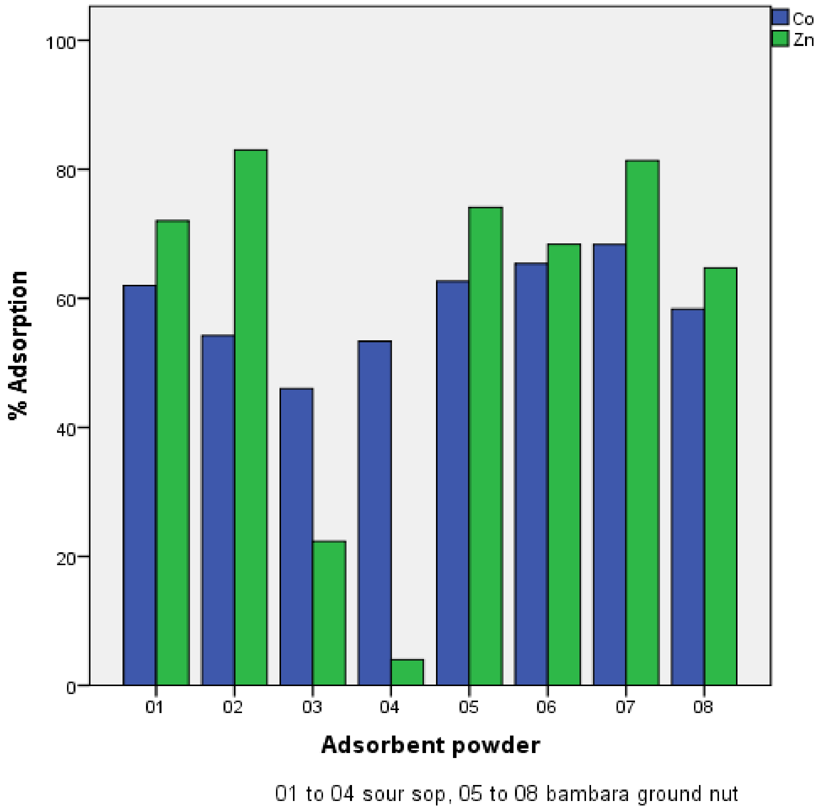

Figure 4.1: Adsorption of Co and Zn

4.2.2 Cadmium (Cd) and copper (Cu)

Bambara groundnut and sour sop powder were good adsorbents for elimination of cadmium and copper in aqueous solution, similar results of copper adsorption was reported by Oboh & Aluyor 2008 in which the percentage adsorption reached 77.9% by using soursop as an adsorbent. Cadmium was successfully adsorbed by BGP having the maximum percentage adsorption whereas copper indicated moderate adsorption (Figure: 4.2)

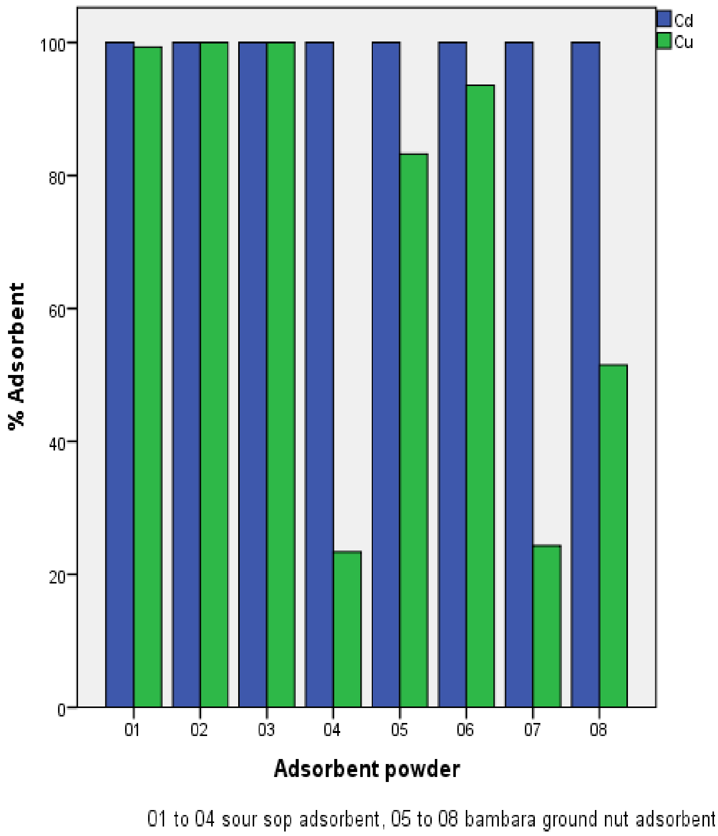

Figure 4.2: Adsorption of Cd and Cu

4.2.3 Lead (Pb) and thallium (Tl)

Lead (Pb) and Thallium (Tl) were highly removed from the aqueous solution by sour sop seeds and bambara ground nut powder. The same results of maximum adsorption of 96% of lead was presented by Wu, Kuo & Guan 2015 on their study of the removal of metal ions using coffee residue.

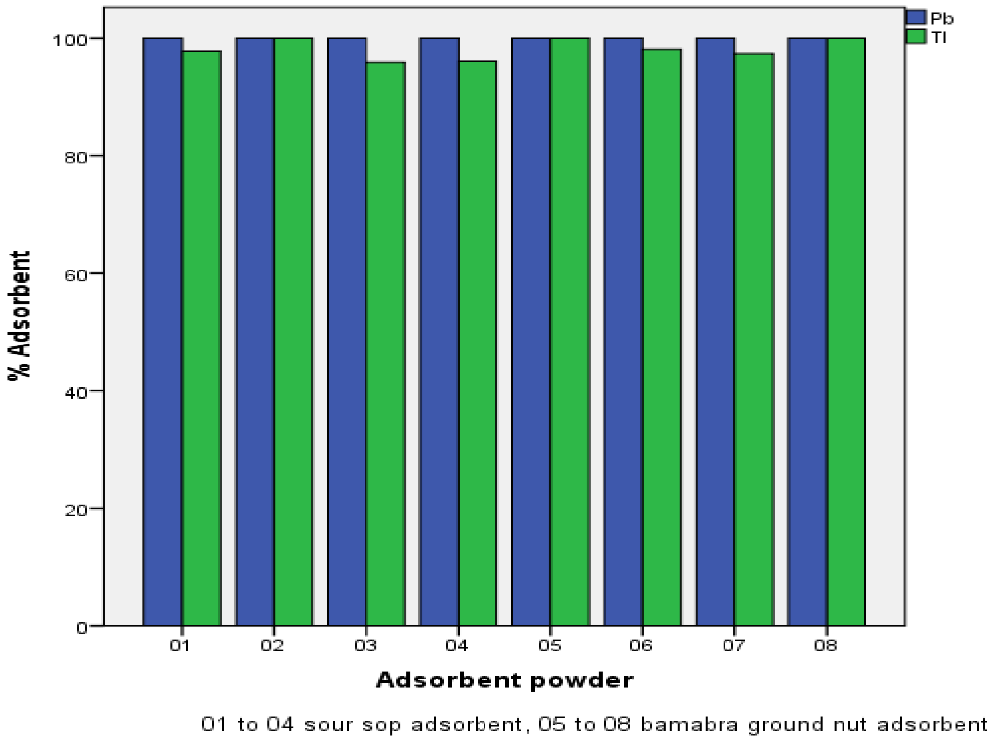

Figure 4.3: Adsorption of Pb and Tl

4.2.4 Indium (In), iron (Fe) and manganese (Mn)

Indium (In), iron (Fe) and manganese (Mn) were poorly removed from the aqueous solution on both adsorbents powder (BGP and SSSP), iron having lowest level of percentage adsorption less than 40%. To some point there were no level of detectable amount of In, Fe and Mn shown on both adsorbents (figure 4.4).

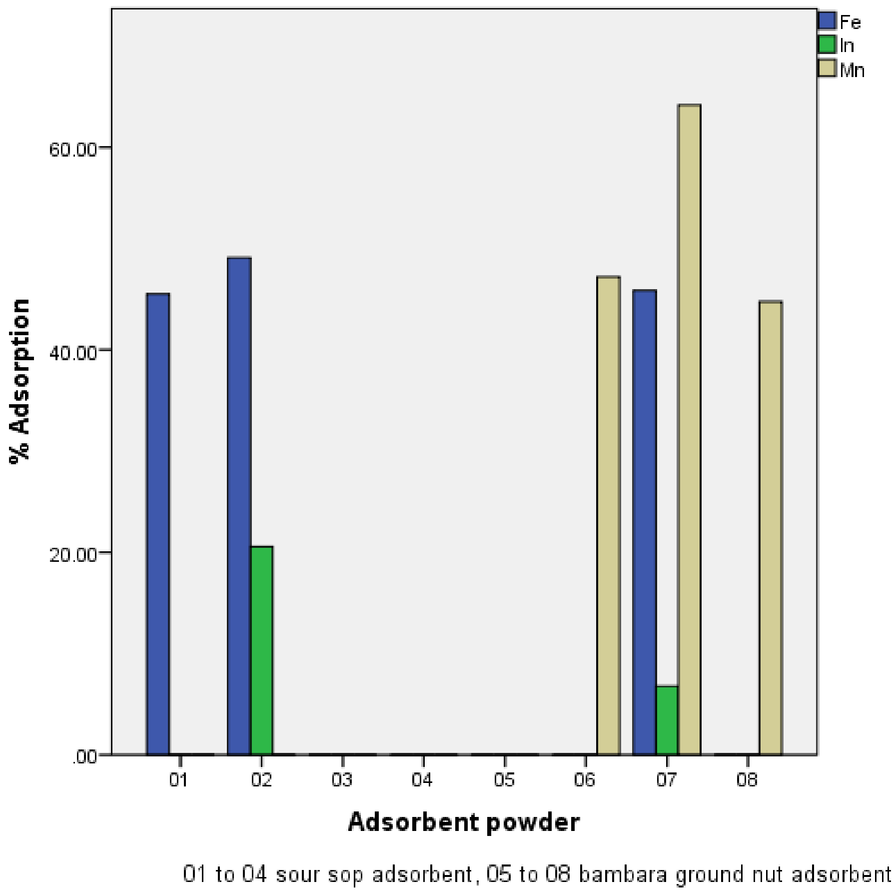

Figure 4.4: Adsorption of Fe, In and Mn

4.3 Adsorption of selected metals

Cadmium, lead and thallium were highly adsorbed metals ions from both adsorbents powder, whereby cobalt, manganese and zinc is greatly adsorbed in BGP, and copper is more adsorbed in SSSP.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Application of bambara ground nut and sour sop seeds powder as an alternative cost-effective and ecofriendly adsorbent were successfully used in this study. The prepared adsorbents were used for the elimination of cadmium (II) ion (Cd^{2+}) , chromium (II) ion (Cr^{2+}), cobalt (II) ion (Co^{2+}), copper (II) ion (Cu^{2+}), iron (II) ion(Fe^{2+}), lead (II) ion (Pb^{2+}) manganese(II) ion,(Mn^{2+}) and thallium (II) ion (Tl^{2+}) and zinc (II) ion (Zn^{2+}) from the artificial contaminated water. Plant biomass such as tree barks, seeds, roots and leaves have been proven to be used as adsorbents for the elimination of toxic of metals in aqueous environment (Şen et al. 2015). The adsorption process is highly affected by the steric hindrance, polarity, textural and chemical characteristics of the adsorbent.

The results revealed that the percentage adsorption of the metals were higher in BGS than the SSSP, the results discovered that Cd^{2+}, Tl^{2+} and Pb^{2+} were the mostly adsorbed metal ions on both adsorbents reaching the maximum percentage adsorption of 100%. SSP also showed the maximum adsorption of Cu^{2+}.

More over the findings indicated that both BGS and SSSP have poor adsorption capacity for Fe^{2+}, $Mn^{2+}$and In^{2+}.

The percentage adsorption of the metal ion using BGP were 100%, 94%, 81%, 68%, 64%, 46% and 07% for (Cd^{2+}, Tl^{2+} and Pb^{2+}), Cu^{2+}, Zn $^{2+,}$ Co^{2+}, Mn^{2+}, Fe^{2+} and In^{2+} respectively, while in SSP were 100%, 83%, 62%, 49%, 21% and 0% for (Cd^{2+}, Cu^{2+},$Tl^{2+}$and Pb^{2+}), Co^{2+}, Fe^{2+} In^{2+} and Mn^{2+} respectively.

Based on the tested adsorbents (BGP and SSSP) were observed to have high adsorption capacity for the metal ions in aqueous solution, thus they are preferable low cost and eco-friendly alternative adsorption materials for toxic metals ions.

5.2 Recommendations

The findings of this study recommend that the society to engage in eating the local food materials such as bambara ground nuts and soursop with their seeds as considerable way of getting rid of toxic chemicals in the body.

More studies should be conducted to identify large scale of cost effective and environmental friendly adsorbents from locally available biomass so as to reduce the cost and to maximize toxic metal removal efficiency.

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APPENDICES

Appendix 1: Sources of heavy metals and their health effects

Metals	Source	Toxic Effect	Reference
Cadmium	Mining and smelting by product PVC plastics, rubber	Carcinogenic	i) 9(Emenike et al. 2016) ii) (Sarada et al. 2014)
Chromium	Steel and textile industries medical and dental implants	Carcinogenic, irritation and obstruction of air ways, kidney, liver and cardiac disorders	i) (González et al. 2017) ii) (Achmad & Auekari 2017)
Cobalt	Burning of fossil fuels, cosmetics and jewellery, paint and pigment production, electric and electronic devices	Hearing and visual impairment, damage of heart muscles and thyroid gland.	i) (Mohamed et al. 2019) ii) (Poznanović et al. 2019) iii) (WHO 2006)
Copper	Water pipes, alcoholic beverage, pesticides, insecticides, fungicides copper cooking pots, copper water heaters	Mental disorder, anaemia, hypertension, heart diseases, insomnia, inflammation and enlargement of liver cystic fibrosis	i) (Emenike et al. 2016) ii) (Parmar & Thahur, 2013)
Indium	Residues of iron, lead and zinc ores, coal and oil industries sewage sludge, welding and semiconductor industries	Lung, cancer, interstitial pneumonia	i) (Akama, Suzuki, & Monobe 2016) ii) (Mitsuhashi 2020)
Lead	Mining and steel industries batteries, paints, automobile	Blood disorder, kidney damage, miscarriage, impaired cognitive functions	i) (Emenike et al. 2016) ii) (Mohamed et al. 2019)
Thallium	Electronic devices and switches, coal burning and smelting	Hair loss, nerve damage, brain injury	CDC, 2009
Zinc	Steel and iron industrial wastes pesticides	Manifest copper deficiency, carcinogenic	i) Parmar & Thakur, 2013 ii) (Agarwal & Singh 2017)

Appendix 2: Maximum and minimum percentage adsorption of soursop and bambara ground nut

Parameter	[a] Maximum % adsorption	[a] Minimum % adsorption	[a] Mean	[b] Maximum % adsorption	[b] Minimum % adsorption	[b] Mean
Cd	100	100	100	100	100	100
Co	62	46	53.83	68	58	64
Cu	100	23	80.67	94	24	63
Fe	47	0	23.64	46	0	11.43
In	0	0	0.00	07	0	1.70
Mn	21	0	5.14	64	0	39
Pb	100	96	97.43	100	100	100
Tl	100	100	100	100	97	98.87
Zn	83	04	19.17	81	65	72.13

a and **b** represent soursop and bambara ground nut respectively

Appendix 3: Range and standard deviation of selected metals

Parameter	[a] Range	[a] standard deviation	[b] Range	[b] Standard deviation
Cd	0	0.00	0	0.00
Co	16	6.54	10	4.25
Cu	77	38.19	69	31.47
Fe	49	27.34	46	22.92
Mn	0	0.00	64	27.41
In	21	10.29	7	3.4
Tl	4	1.92	3	1.34
Pb	0	0.00	0	0.0
Zn	79	38.17	17	7.25

a and **b** represent soursop and bambara ground nut respectively