Shendi University
College of Graduate Studies and Scientific Research

Phytochemical Screening of some of Sudanese Herbs and their Efficiency in Removing of Heavy Metals from Aqueous solutions

المسح الكيميائي النباتي لبعض الأعشاب السودانية وكفاءتها في إزالة المعادن الثقيلة من المحاليل المائية

A thesis submitted for the fulfillment of the requirement of the degree of PhD of Inorganic Chemistry

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(الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ)

صدق الله العظيم

سورة الفاتحة، الآية (2)

Dedication

To my parents, sisters and brothers

To everyone who helped me

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thank Almighty Allah ,with countless thanks and gratitude ,for all his blessing and for giving me this great opportunity to complete this work.|I would like to humbly express my sincere gratitude, appreciation and thanks to my supervisor **Dr.Mohammed Sulieman Ali Eltoum** (AssociateProfessor,Sudan University of Science and Technology, Chemistry Department) for support and his helpful suggestions and close supervision throughout the experimental work.I am deeply greatful to my co-supervisor **prof.Hassan AlaminAlkhidir** (Professor,Shendi University, Chemistry Department) for his supervision and encouragement.Special thanks, to **Dr. Ebraheem Mohammed Ebraheem** and **Mr . Eman Abdullah Albashir** from the Department of Applied Statistics Faculty of Sciences and Technology .Also my thanks to **Dr. Atif Babkir Ahmed** and from the Department of botony Faculty of Sciences and Technology.

Abstract

biosorption processes are extensively used in water treatment and heavy metal removal. Also; heavy metals are hazard even in trace concentrations, so an environmentally safe method of their removal necessitated the requirement of low cost adsorbents.adsorption is acost – effective technique for removing organic and inorganic pollutants from polluted water .This study focuses on the process of biosorption and the types of biosorbent used. The present study was conducted to evaluate the phytochemical composition of the stem bark extracts (Distilled Water ,Ethanol and Chloroform) of *kaya senegalensis*, *Acacia seyal*,and stem bark and leaves of *Azadirachata indicia* and leaves *Cymbopogon schoenanthus*.In Preliminary phytochemical analysis showed that the ethanol extraction possess has the largest number of phytochemical constituents compared to water and chloroform, the results showed that the presence of natural products namely Tannins , Flavonoids, , Sterols, Terpenes, Alkaloids, Glycosides were present in ethanol extract of all the parts and absence Alkaloids in stem bark of *kaya senegalensis* while its appearance in chloroform and water and saponins in Leaves of *Azadirachata indicia* appearing in the water extract .the results showed the absence of saponins in the *Cymbopogon schoenanthus* in all extracts. In another investigation the plants was used to remove heavy metals from water. The heavy metals in this study were analyzed using Atomic Absorption Spectrophotometer (AAS) and direct mercury analyzer(DMA) and the results showed these plants has a good capability to remove the cadmium ,lead , zinc and mercury from aqueous medium, it was arranged in order of preference in 5ppm as follows leaves of *Azadirachata indicia* to Hg , stem bark of *Acacia seyal* to Pb,Cd and Leaves of *Azadirachata indicia* to Zn .and the case 0f 10ppm was arrangement stem bark of *kaya senegalensis* to Hg, Pb, stem bark of *Acacia seyal* to Cd and stem bark of

Azadirachata indicia to Zn. we also find that the *Cymbopogon schoenanthus* showed their efficiency for the adsorption of these heavy metals , but they did not take preference for any of these heavy metals .some results also showed that with increasing solution concentration, the removal percentage decreased , while in others it increased with increasing concentration, cadmium gave a maximum percentage removal at the two concentrations 5,10 ppm of **91.28 ,90.9%** and **98,95.91%** lead by stem bark of *Acacia seyal* , zinc **53.06 ,75.19 %** by stem bark of *kaya Senegalensis*, **91.644, 87.892%** for mercury with leaves of *Azadirachata indicia* . The results revealed that these Parts of plants is an effective biosorbents for removal of cadmium, lead, zinc and mercury ions from aqueous solutions.

المستخلص

تستخدم عمليات الامتزاز الحيوي على نطاق واسع في معالجة المياه الملوثة لإزالة المعادن الثقيلة. أيضا المعادن الثقيلة سامة حتى بالتركيزات القليلة ،لذا فأن الطريقة الآمنة بيئيا لإزالتها تستلزم الحاجة الى مواد ماصة منخفضة التكلفة. الامتزاز هو تقنية فعالة من حيث التكلفة لإزالة الملوثات الغير عضوية والعضوية من المياه الملوثة. تركز هذه الدراسة على أنواع الممتزات المستخدمة وتكمن حداثة هذه الدراسة في تغطية مجموعة واسعة من الممتزات بكفاءتها في إزالة المعادن الثقيلة من المياه الملوثة. أجريت الدراسة الحالية لتقييم التركيب الكيميائي النباتي لمستخلصات (ماء مقطر، إيثانول والكلوروفورم) للحاء المهوقني والطلح ولحاء وأوراق النيم وأوراق المحريب. أظهر التحليل الكيميائي النباتي الأولي أن مستخلص الإيثانول يمتلك أكبر عدد من المكونات الكيميائية النباتية مقارنة بالماء والكلوروفورم، أظهرت النتائج وجود منتجات طبيعية وهي التانينات والفلافونويد والإستيرول والتربين والقلويدات والجلايكوسيدات في مستخلص الإيثانول لجميع الأجزاء وغياب القلويدات في لحاء المهوقني بينما ظهورها في مستخلص الكلوروفورم والماء ، وظهور الصابونيات في مستخلص الماء للحاء النيم .كما نلاحظ غياب الصابونيات في جميع المستخلصات لأوراق المحريب. تم تحليل المعادن الثقيلة في هذه الدراسة بإستخدام مقياس الامتصاص الذري(AAS) ومحلل الزئبق المباشر (DMA) وأظهرت النتائج أن هذه النباتات لديها قدرة جيدة على إزالة الكادميوم والرصاص والزنك والزئبق من الوسط المائي، فكان ترتيبها حسب الأفضلية عند التركيز5ppm كالتالي أوراق النيم للزئبق ، لحاء الطلح للرصاص والكادميوم وأوراق النيم للزنك . وفي حالة التركيز 10ppmكان الترتيب لحاء المهوقني للزئبق , والرصاص ،لحاء الطلح للكادميوم ولحاء النيم للزنك. كما نجد أن أوراق المحريب أظهرت كفاءتها لإمتزاز هذه المعادن لكنها لم تأخذ تفضيلاً لأي من هذه المعادن. كما أظهرت بعض النتائج أن بزيادة تركيز المحلول انخفضت نسبة الازالة وفي البعض الاخر زادت بزيادة التركيز، أعطى الكادميوم أعلى نسبة إمتزاز عند التركيزين 5 ppm، 10وهي 91.28 , 90.9% والرصاص98, 95.91 % بواسطة لحاء الطلح والزنك 53.06, 75.19% بواسطة لحاء المهوقني و 87.892,91.644% للزئبق مع أوراق النيم .كما أوضحت النتائج أن هذه الأجزاء من النباتات فعالة لإزالة أيونات الكادميوم, الرصاص, الزنك والزئبق من محاليلها المائية.

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INTRODUCTION

1.1.water pollution

Five elements make up the universe namely Earth, Water, Air, Fire and Space . all of these elements have been polluted by Industrial Development. They are essential elements for human life and one cannot live without them . Among these important elements of human life , Water occupies a unique place- the total volume of water on earth is about 1400 million km^3 of which only 2.5 percent ,or about 35 million km3 is freshwater (Pathak, 2013). Environmental pollution by industrial wastes is one of the major contemporary issues. Enterprises of metallurgy, mechanical engineering, fuel and energy complex make the largest negative contribution to environmental pollution (including heavy metal compounds). At
the same time, environmental damage caused by waste disposal is more than 60% of the total damage caused by the industry as a whole.(Tatyana and Aleksandr.2017)Water is an important natural resource for achieving agricultural sustainability and human civilization. Water covers more than 70 % of the earth crust and majority of the water has been exposed to maximum pollution due to human activities. (Obinnaa and Ebere 2019).Water is the most vitality element in the life. But it was contaminated with toxic inorganic industrial pollutants ,which resulted in many problems such as unsafe for consumption for humans and irrigation activities. This reduce the availability of water in the ecosystem and hence The main reason behind water crisis is water pollution. It should not be polluted to a certain value for being used in irrigation and drinking water purpose (Singh, et al. 2021). Now Water pollution is a global problem that needs to be evaluated to confornet it. water pollution causes diseases and Deaths, and approximately 14000 people die every day due to this pollution (Chaudhry et al.2017). Due to the fast increase in population and industrial growth, safe drinking water is at hazard of pollution. Accordingly,

access to safe water is considered one of the most fundamental goals of humanity and remains a major global challenge in the 21st century. Pollution happens when contaminants alter the physical properties, aesthetic qualities, or odor of water. Although some pollutants may not change the physical properties of water, water pollution can be caused by the toxicity of water pollutants. These pollutants contain heavy metal ions, dyes, drugs, pesticides, organic compounds, and other dangerous compounds that can accumulate in the tissues of living organisms and lead to creation of dangerous diseases heavy metals, even in very low concentrations. These substances can create serious problems for humans, animals, and environment (Kordbacheh and Heidari. 2023). Water pollution is any unfavorable change in the state of water, contaminated with harmful substances. It is the second most significant environmental issue next to air pollution. Any change in the physical, chemical and biological properties of water that has a harmful effect on living things is termed as ‘water pollution’(Gambhir, et al. 2012). in the natural resources, water is unarguably the most essential and priceless. It is a universal solvent and as a solvent it provides ionic balance and nutrients that support all forms of life. It is obtained from two major natural sources: surface water such as freshwater lakes, rivers, and streams, and groundwater such as borehole water and well water. Water is typically referred to as polluted when it is impaired by human contaminants and either does not support human use, such as drinking water, and/or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish(Barkouch et al. 2016).Types of water pollutantsWater pollution happen when one or more added substances cause negative changes in its color, taste, or odor. Whereas some pollutants may not alter the physical properties of water, they can still create toxicity in it. (Kordbacheh and Heidari, 2023)There are various types of pollutants that are classified in the following paragraphs

1.2.Organic pollutants

Organic pollutants are pollutants that are organic in nature i.e essentially containing carbon covalently bonded with other compounds. They are known to be toxic or carcinogenic in nature. Their presence in water in large quantity causes considerable and widespread concern. Rivers serves as hotspot for organic pollutant loading, particularly those in lowland regions. (Obinnaa and Ebere, 2019) The occurrence of organic pollutants in wastewater have increased highly in modern years and has become a critical concern because of their toxicity, semi volatile nature, low water solubility, high bioaccumulation and non-biodegradability under normal environmental condition.These types of organic pollutants such as phenolic compounds, polycyclic aromatic hydrocarbons (PAHs) and agricultural chemicals (organic pesticides and organic herbicides) have been considered as critical problems as it leads to aquatic system depletion, environmental degradation and also affect human health like reproductive system disorders, endocrine disruption, obesity and cancer (Bhomick, et al. 2017).

1.3.Inorganic pollutants

Most of the inorganic chemicals existing in aquatic environments are heavy metals, inorganic anions and radioactive materials. It is to be noted pertinently that it is not presence of a particular chemical but its concentration which indeed matters in chemical toxicology. Thus elements such as As , Al, Sb, Ba, Be, Cd, Co, Cu, Ce, Pb, Mo, Hg, Zn etc., which are listed as environmental hazards, act as nutrients in trace concentrations and are necessary for normal growth and development of animals and human beings. And these heavy metals get transferred through food web into human beings creating public health problems (Thangamalathi and Anuradha, 2018). Heavy metals, nutrients, sediments, and industrial waste are examples of inorganic pollutants. The increase in anthropogenic activities and the set-up of industries related to mining, agriculture, etc., has increased the appearance of these environmental contaminants. These environmental contaminants are present in different water bodies. The primary components of inorganic pollutants are connected to operations like mining and the burning of fossil fuels, municipal solid waste, industrial waste, and fertilizers. There are various types of inorganic pollutants in water that are responsible for various diseases and other comorbidities(Kumar et al .2023).

1.3.1.Heavy metals

Heavy metals have been one of the main contributing sources to water pollution throughout the decades. Water supplies may have naturally occurring ores wealthy in harmful metals, which leak into water causing pollution. These ores are associated with occurrences of high arsenic and lead contamination(Zaimee et al 2021). As opposed organic wastes, heavy metals are non-biodegradable and they can be accumulated in living tissues, causing various diseases and disorders; therefore they must be removed before discharge.(Ngah and Hanafiah 2008) There are many sources of the heavy metals in the ecosystem that come with the wastewater streams such as electroplating, smelting, paint pigments, batteries, mining operations and agriculture activities. he main attention of environmentalists toward heavy metal is that these elements are highly toxic and their serious effect on human health and surroundings can't ignore.(Abd El-Azim and Fekry,2018). The presence of heavy metals in the environment has lead to a number of environmental problems. In order to meet the water quality standards for most of countries, the concentration of heavy metals in wastewater must be controlled.
(Kim et al .2005). Metal plating industry is one of the main chemical processes that discard large amounts of wastewaters. These industrial wastewaters contain various types of harmful heavy metals and poisonous substances like chromium, nickel, copper, zinc, cyanide and degreasing solvents. (Al-Shannag et al. 2015). These metal

ions are highly toxic and if they are directly discharged can cause environmental disruption and can damage the subsequent treatments associated in the wastewater purification plants.(Chaemiso and Nefo , 2019).Low concentration of heavy metals will not affect the growth of the plants in a certain range. But if the concentration is too high, the content of heavy metals enriched by the plant overtake its tolerance threshold, and therefore the plant will be poisoned and it even leads to death of the plant. Vascular aquatic macrophytes may accumulate considerable amounts of heavy metals in their tissues. Heavy metal affects the urban environmental quality and damage human health indirectly through polluting the food, water and atmosphere. The higher concentration of chemicals in environment, the more children with inconsistent physiological reaction were found(Unadkat and Parikhm,2017)The description of these toxic metals will be presented as following.

1.3.1.1. Cadmium

Cadmium exist in naturally high abundance in zinc and lead ores and in phosphate fertilizers High concentrations of cadmium were also found in some sewage sludge Agricultural uses of phosphate fertilizers and sewage sludge and industrial uses of cadmium have been identified as a major cause of widespread dispersion of the metal at trace levels into the general environment and human foodstuffs. Other causes of cadmium dispersion are enhanced natural emission and bioaccumulation taking place in certain plants, mammals and filter feeder organisms which include crustaceans and molluscs.(Satarug et al .2003) .Cadmium (Cd) is one of the most toxic and mobile elements in the environment It can replace calcium in minerals because its similar ionic radius, identical charge and similar chemical behavior .Therefore,Cd can enter the human body and accumulate to a high level in several organs(Kubier et al. 2019). Cd sources in natural waters are more commonly found in basic sediments and suspended particles. Besides, that Cd will be influenced by the degree of acidity of the water. The presence of cadmium in groundwater or well water is dangerous if it is consumed by humans.(Sholehhudin et al . 2021).

1.3.1.2. Lead

Throughout our environment some amount of lead is found. An increased amount of lead in our environment comes from human activities including burning fossil fuels, mining, and manufacturing. Lead occurs naturally in the environment. However, most lead concentrations that are found in the environment are a result of human activities. Due to the application of lead in gasoline an unnatural lead cycle has consisted. Lead is one out of four metals that have the most harmful effects on human health . Lead is an important environmental contaminant because of its known toxicity to humans and other living organisms. Lead is one of a limited class of elements that can be described as purely toxic. Lead toxicity occurs when people are exposed to lead and chemicals that contain lead, breathing air, taking drinks such as water and milk, eating foods such as fruits, vegetables, meats, grains and seafood, swallowing or touching dust or dirt that contains lead.(Tiwari et al. 2013) Contamination of soil, water, and air by heavy metals, particularly lead, constitutes harm to our environment, humans, animals, plants, and marine life. Lead uptake, transport, and accumulation by plants and animals as well as the potential for its propagation into the food chain exacerbate its toxic health effects. Lead pollution is a result of many human activities such as lead paint production,mining ,agricultural fertilizers, insecticides and pesticides (Agwaramgbo et al . 2013).

1.3.1.3. Zinc

Water is a valuable and most frequently used resource. Zinc is one of the most copious compounds on earth ,and covers two thirds of the earth's surface . Humans lack arrival to clean and pure safe water . Zinc is Avery communal pollutant in environment; its occurrence may be impends the water ecological environment.

Consequently, much study effort has been directed toward the spreading of Zn in water environment. Anthropogenic actions counting municipal wastewater releases, coalburning power plants; industrial methods involving metals; and atmospheric outcome are the main source of Zn contamination. **(**Sankhla et al .2019).Major zinc sources in environment are copper and bronze alloys production and galvanization . For example, it is vital for more than 200 enzymes correct operation, DNA stabilization, genes expression and signals transmission from nervous system. Human body contains 2 to 3 g of zinc (for 7 g of iron), which are found throughout the body, but with higher concentrations in muscles, liver, kidneys, bones and prostate . and also used in paints, rubber, plastics, cosmetics and pharmaceuticals. the allowable maximum zinc concentrations in drinking water are 3 to 5 mg/l according to the World Health Organization .and 5 mg/l by Algerian standards.
(Larakeb et al. 2016).In water the Zinc circulation can be abundant as a result of leaching of Zinc from piping and fittings . Increased Zinc can origin eminent health difficulties such as stomach cramps, skin irritations, vomiting, nausea, anemia, root trouble in pancreas, protein metabolism and further it can cause arteriosclerosis.
(Hasan et al . 2017).

1.3.1.4.Mercury

The mercury (Hg) contamination still becomes large problem for the environment and health in developing countries. Mercury belongs to heavy metal which is classified as Hazardous and Toxic Material waste because it has poisonous and persistent properties so that it harms the living environment and human .Mercury is cheap and easily accessed metal. This metal is admitted to be priority dangerous substances by the Agency of Toxic Substances and List of Diseases because of the high toxicity, mobility and the long living period , and was identified by the World Health Organization as global contaminant which has high risk for the human's health (Heumasse et al . 2019).Water pollution with mercury is particularly associated with the possibility of environmental methylation by the inorganic divalent form of the metal, Hg^{2+}through bacteria and complexation with dissolved organic compounds that enable it to remain in the water column in relatively high concentrations and leak back into the biota. as methylmercury is liposoluble, it is therefore easily absorbed by biological membranes in general and by the digestive tracts of practically all food chains. these processes help the permanency and diffusion of mercury in the aquatic environment, as well as its dissemination to other ecosystems far removed from the contamination source. the organification of mercury therefore accelerates its bioaccumulation in the food chain and maximizes its threat to natural ecosystems and to human health.(De LacerDa and MaLM, 2008)

1.4. Metal ions removal methods

The most important pollutants in water and wastewater are heavy metals. Heavy metals and their compounds are more used in many industrial applications resulting in their increase in aquatic systems. The methods of elimination are chemical precipitation, ion exchange, membrane systems, alum coagulation and adsorption.
(Moslehi and Nahid 2007).

1.4.1. Chemical precipitation

Chemical precipitation is one of the most widely used methods for heavy metal elimination from inorganic effluent in laboratory and even in industry due to its simple operation .These conventional chemical precipitation processes produce insoluble precipitates of heavy metals as hydroxide, sulfide, carbonate and phosphate. The mechanism of this process is based on to produce insoluble metal precipitation by reacting dissolved heavy metals in the waste water solution which discharge from chemical laboratory (Chaemiso and Nefo2019). Chemical precipitation is effective and most common process in industry because it is relatively simple and cheap to operate. In precipitation processes, the chemicals react with heavy metal ions to form insoluble precipitates. The forming precipitates can be separated from the water by sedimentation or filtration. And the treated water is then decanted and appropriately discharged or reused(Chaudhry et al .2014). Chemical precipitation is an effective and widely used process in the industry. It is characterized by simplicity and it is inexpensive to operate. It can be used to remove pollutants from municipal and industrial wastewater. It can also be used for water softening, heavy metal removal from metal plating wastes, oil and grease removal from emulsified solutions, and phosphate removal from wash-waters and other wastewater. One of the most important parameters regulating chemical precipitation is pH. For the coagulation process, pH is a critical parameter. Effectiveness of the chemical precipitation is also influenced by the type and concentration of metal ions present in the solution, precipitation reagent used, reaction conditions, and presence of other compounds that can inhibit the reaction (Pohl 2020).

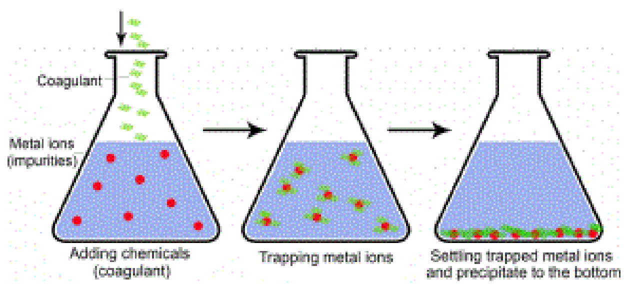

Figure. 1.1 chemical precipitation process.

1.4.2. Coagulation- flocculation

Basically, coagulation is a physical-chemical process aiming at reducing the repulsive potential of electrical double layer of colloids using various coagulants. Coagulation has been conventionally applied in water treatment to decrease turbidity and color and remove suspended particles and pathogens. In practice, water treatment by coagulation is carried out by the addition of a determined amount of coagulants (mostly inorganic coagulants such as aluminum or iron salts), which, in the water solution, are dissociated into their trivalent ionic form ($Al^{3+}$and Fe^{3+}), hydrolyzed and end up forming positively- charged complexes highly interactive with the negatively-charged colloids. According to the related literature, the two main operating conditions affecting the overall efficiency of any coagulation process are pH and coagulants' type and dosage (Sillanpää et al .2018). The terms "Coagulation" and "Flocculation" describe procedures that cause particles to clump or bind together to speed up the rate at which they settle. The clump is also known as aggregation, agglomeration, or floc. These terms are used interchangeably; flocculation refers to adding long -chain polymers that bind the particles together, while coagulation is more related to altering the surface charge of the particles to produce aggregation. During chemical coagulation/flocculation, various chemicals (such as Alum and Poly Aluminum Chloride) are used to remove undesired particles from water (Alazaiza et al. 2022) .

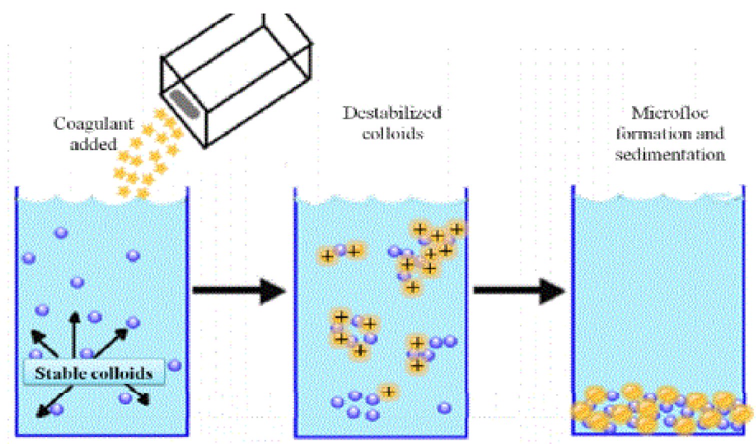

Figure 1.2Coagulation-flocculation process

1.4.3.Membrane Filtration

Membrane technology has become increasingly attractive for treating and recycling wastewater in the plating industry because of it high efficiency, ease of operation and low cost. The process involves flowing the solution under pressure through an appropriate porous membrane and extracting permeate or clean water flow of the membrane at atmospheric pressure. There are many types of membrane filtration techniques including reverse osmosis (RO), microfiltration (MF), Nano-filtration (NF) and ultrafiltration (UF) . For membrane filtration treatment aimed to remove heavy metals, NF and RO is the separation process needed. These two processes can filter particle lower than 0.001µm. NF membrane's technology applies pressure to discrete soluble ions from water through a semi permeable membrane. Nano filtration (NF) is the transitional process between UF and RO (Noor et al .2019). Principle factors applied to the application of the membrane process are pore size, pore distribution, degree of hydrophilicity, surface charge, solution flow, and presence of functional groups. These factors play a crucial role in the interpretation of the overall membrane process of water production rate and heavy metal removal efficiency. The performance of the membrane is generally determined by its flux rate and selectivity. Cellulose acetate, polyamide, polysulfone, etc. are porous membranes used in this process where solution flow under pressure and withdrawing the membrane releases water at atmospheric pressure. For reverse osmosis (RO), the applied pressure must always be greater than osmotic pressure for sufficient water flux(Yadav et al .2021).

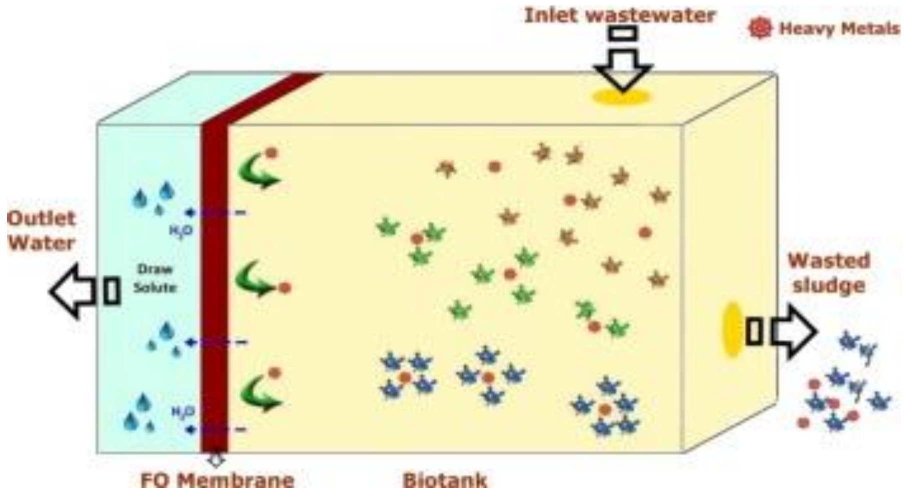

Figure. 1.3. Membrane Filtration process.

1.4.4. Ion exchange resin

Ion-exchange processes have been widely used to remove heavy metals from wastewater due to their many advantages, such as high treatment capacity, high removal efficiency and fast kinetics . Ion-exchange resin, either synthetic or natural solid resin, has the specific ability to exchange its cations with the metals in the wastewater. Among the materials used in ion-exchange processes, synthetic resins are commonly preferred as they are effective to nearly remove the heavy metals from the solution .The most common cation exchangers are strongly acidic resins with sulfonic acid groups (eSO3H) and weakly acid resins with carboxylic acid groups (eCOOH). Hydrogen ions in the sulfonic group or carboxylic group of the resin can serve as exchangeable ions with metal cations. As the solution containing heavy metal passes through the cations column, metal ions are exchanged for the hydrogen ions on the resin (Ali 2015).Ion exchange is the most common and effective process, particularly in drinking water purification and the concentration and removal of hazardous substances at very low concentrations in chemical process industries. Therefore, ion exchange appears to be a promising candidate for this purpose (Bai and.Bartkiewicz 2009). ion exchange is an ancient technique documented more than hundred years ago. Since then, this technique has been used for softening water to an incomparable wider scale of applications and has become an integral part of new technical and industrial processes. There is a vast diversity of ion-exchange materials. They have many appearances like natural and synthetic, organic and inorganic, cationic, anionic, and amphoteric. Ion exchange is a reversible stoichiometric chemical reaction wherein an ion from solution or electrolyte or molten salt is exchanged for a similarly charged ion attached to an immobile and insoluble solid material, maintaining the overall electro neutrality. Commonly used matrices for ion-exchange materials are: synthetic organic resins, inorganic three-dimensional matrix, and new-generation hybrid materials (Bashir et al. 2019).

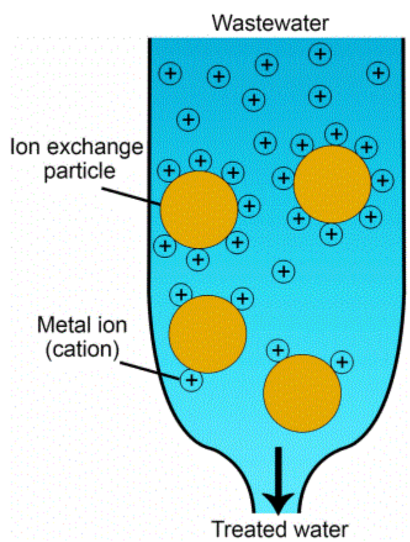

Figure. 1.4. Schematic of the ion exchange process.

1.4.5. Adsorption

The mechanisms of adsorption process occurred by adhesion of material either gaseous, liquid, or solid called substrate on the surface of solid, or liquid, called sorbent or adsorbent. There are different adsorption systems, liquid-gas or liquid-liquid (Alaqarbeh 2021). The process of adsorption can be achieved by batch, semi batch, and continuous processes. In batch, processes contact time of adsorbing material and adsorbent play's an important role . Adsorbate and adsorbent are attracted to one other by attractive forces such as weak Van der Waals forces or strong chemical bonds. At low temperatures, weak van Der Waals forces are active in physisorption .While chemical forces or chemical bonds are active in chemisorption, its efficacy is determined by the adsorbent's surface area (Harshala and Wagh 2022).Adsorption is one of the best and the most efficient methods applied to remove pollutants such as heavy metals and dyes from effluents. It has some useful features such as reversibility, high adsorption capacity, lower cost, cost effectiveness, and high energy efficiency. Active carbon is one of the most widely used adsorbents due to its active surface and high adsorption capacity in the process of pollutants adsorption from aqueous solutions. However, it is not applied to adsorb metals and dyes in a large scale due to its high cost of production . Therefore, the acquisition of low-cost adsorbents has received much attention. Inexpensive adsorbents are usually divided into 5 main categories including (i) agricultural waste, (ii) industrial by -products, (iii) sludge, (IV) marine material, (v) soils and minerals .Agricultural waste is a low cost, abundant and environmentally friendly resource that is used as a very effective adsorbent. The most common sources to remove dye and heavy metals are coconut shells, orange peel, pomegranate peel, banana peel, squash coal, tea waste, pistachio peel, rice hulls ash, coffee powder, pomelo peel, garlic peel and peat bagasse. The main components of agricultural waste include hemicelluloses, lignin, lipids, proteins, simple sugars, water, hydrocarbons and starches which contain various types of functional groups. These functional groups lead to increasement of active sites and better adsorption of pollutants (Farhadi et al. 2021).

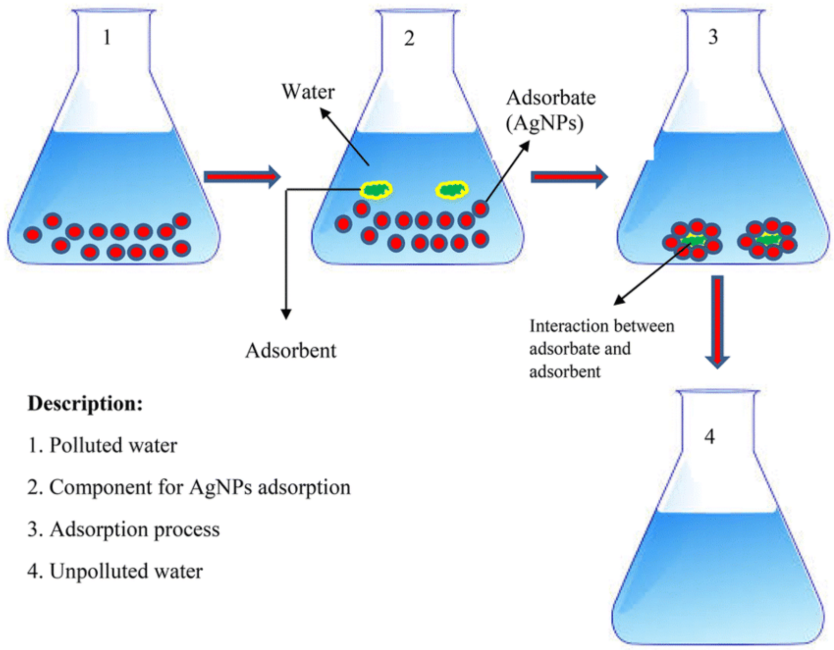

Figure. 1.5 adsorption treatment process

Various biomaterials produced or harvested from natural resources or agricultural products, mostly in metabolically inactive states, have been used in disposal of heavy metal effluents by bio sorption (Qi and Aldrich 2008).

1.5. Biosorption

The bio sorption process involves a solid phase (sorbent or bio sorbent; adsorbent; biological material) and a liquid phase (solvent, normally water) containing a dissolved species to be sorbet (adsorbate, metal). Due to the higher affinity of the adsorbent for the adsorbate species, the latter is attracted and bound there by different mechanisms. The process continues till equilibrium is established between the amount of solid-bound adsorbate species and its portion remaining in the solution. The degree of adsorbent affinity for the adsorbate determines its distribution between the solid and liquid phases . Bio sorption is a rapid phenomenon of passive metal sequestration by the non-growing biomass/adsorbents. It has advantages compared with conventional techniques. (Abbas et al . 2014).

1.6.Factors Effecting on Biosorption

Factors Effecting on Bio sorption of Metals Bio sorption depends on many factors that can effect on it. Some of these factors are related to the biomass and metal and the others are related to environmental conditions. The major factors that affect the bio sorption process are:

1.6.1.Acidity

pH seems to be the most important parameter in the bio sorption processes. Bio sorption is similar to an ion-exchange process, i.e. biomass can be considered as natural ion-exchange materials which mainly contain weakly acidic and basic groups. Therefore, pH of solution influences the nature of biomass binding sites and metal solubility; it affects the solution chemistry of the metals, the activity of the functional groups in the biomass and the competition of metallic ions. Metal bio sorption has frequently been shown to be strongly pH dependent in almost all systems examined, including bacteria, cyanobacteria, algae, and fungi. Competition between cations and protons for binding sites means that bio sorption of metals like Cu, Cd, Ni, Co and Zn is often reduced at low pH values . Generally, the heavy metal uptake for most of the biomass types decline significantly when pH of the metal solutions is decreased from pH 6.0 to 2.5. At pH less than 2, there are minimum or negligible removal metal ions from solutions. The metal uptake increases when pH increases from 3.0 to 5.0. Optimum value of pH is very important to get a highest metal sorption, and this capacity will decrease with further increase in pH value (Abbas et al . 2014).

1.6.2.Temperature

The temperature has a substantial impact on the sorption process . Thermodynamic parameters are altered by temperature change, which affects sorption capacity . The best temperature range for biosorption efficiency is between 20 and 35°C . High temperatures such as 50 degrees Celsius may occasionally improve biosorption, but they can also permanently destroy live microbes, reducing metal absorption . Adsorption increases with decreasing temperature, which is generally due to exothermic absorption events (Gouda and Taha2023).

1.6.3.Biosorbent dose

Biosorbent dosage has a strong influence on bio sorption of heavy metals because the Biosorbent provides the sorption site for metal ions. Mostly, higher bio sorbent dose at a given initial metal concentration increases percentage biosorption (%) due to larger surface area (which in turn increases the number of available sorption sites) but decreases the metal uptake per unit mass of bio sorbent. Therefore, comparing sorbent using percentage bio sorption is crude and inaccurate. It can only serve the purpose of quick and approximate screening of biosorbents. The better approach is to use metal uptake per unit mass of adsorbent(Abdulwasiu 2021).

1.6.4.Contact Time

Biosorption is also affected by contact time between biomass and the solution containing metals. Bio sorption proceeds fast and most metals are adsorbed at the very beginning of the process. Equilibrium is reached during the first couple of minutes starting from the moment of exposure of biomass to the solution Świątek and Krzywonos 2014).

1.6.5.Initial metal ion concentration

The initial concentration of metal ions in the solution plays akey role as a driving force to overcome the mass transfer resistance between the aqueous and solid phases .It is generally agreed that the bio sorption capacity increases as the initial metal ion concentration in the solution increases, whereas the metal removal percentage (also called removal efficiency) decreases by increasing the metal ion initial concentration. As a rule, increasing the initial metal concentration results in an increase in the bio sorption capacity because it provides a driving force to overcome mass transfer resistance between the bio sorbent and bio sorption medium . The removal efficiency of the ions by the bio sorbent initially increases with increasing the initial ion concentration. At lower ions concentration in the solution, the ions would interact with the binding sites and thus facilitated almost 100% adsorption whereas at higher concentrations, more ions are left un-adsorbed in the solution due to the saturation of the binding sites (Abdel-Ghani and El-Chaghaby, 2014).

1.7. Mechanism of biosorption

In biosorption, adsorption is a result of the interactions of weak forces, chemical reactions and ionic strength leading to stronger binding. These interactions may occur inside the pores, outside the pores, or on the surface of agricultural wastes . The adsorption mechanism depends on the physico- chemical characteristics of agricultural wastes as well as on some mass transport processes . Usually, for the adsorption of pollutants onto agricultural waste, carboxylic and hydroxyl groups are found to be more responsible than the other groups (sulfhydryl, thio, aldehyde, ketones, amino, etc.) present on the surface. Carboxylic groups are mainly responsible for metal binding. The chemical structure and the functional groups present on the agricultural waste surface are difficult to fix due to their different origins, types, seasonal variations, and geographic locations. Particularly acid base functional groups present on the adsorbent surface might play a vital role in ionic interactions taking place during adsorption. These interactions help to postulate the involved mechanisms such as chemisorption, complexation reactions, surface adsorption, ion exchange, diffusion through pores and electrostatic interactions, or some other (Khatoon and Narayan Rai,2016).

1.8. Agricultural wastes as low cost biosorbent for metals removal

Agricultural wastes and by products were found to be low cost and alternate adsorbents for heavy metals and synthetic dyes removal. Agro wastes are rich inorganic contents with variety of functional groups which can cooperate binding of cations and anions. The other advantages of agricultural wastes are easily available, non-hazardous and no disposal problems. The conversion of these materials into adsorbents can help to reduce the cost of waste disposal and provide an alternative treatment to replace the commercial activated carbon (Khatoon and Narayan Rai,2016). Several agricultural wastes have been studied and reported for heavy metals removals, some of them are as follows :

1.8.1.*Cymbopogon schoenanthus* (L.) Spreng

Family : *Poaceae (Graminae).*

Vernacular name: Maharabe.

1.8.1.1. Botanical description

Cymbopogon schoenanthus is a perennial grass, forming dense tussocks at the base and numerous erect 60-80 cm stems. The leaves are linear, tough and strongly curved. The inflorescence is contracted at the base, becomes looser towards the end and is protected by a distinctive spathe. Each spike contains a single flower, between the spikes, several characteristic small whitish hairs appear. The roots have a pleasant aromatic smell . The plant is widely distributed in Africa (northwest tropical, northeast tropical and east tropical), temperate Asia (western Asia and Arabia) and tropical Asia (Indian and Indo-China). *Cymbopogon schoenanthus* is also found in central and northern Sudan (Atif ,2019).

1.8.1.2.Chemical constituents

Chemical analysis showed that *Cymbopogon schoenanthus* contained tannins, saponins, saponin glycosides, flavonoids, alkaloids, triterpens, balsams, cardiac glycosides, glycosides, steroids and volatile oils .The chemical composition of the essential oils of *Cymbopogon schoenanthus* was investigated by GC and GC/MS. The major constituents were found to be 2-undecanone (14.68 %) and limonene (19.54 %). However, citral (3,7-dimethyl-2,6-octadien-1-al) was one of the main constituents of many different species of lemongrass .The essential oil of *Cymbopogon schoenanthus* of Burkina Faso contained compounds belong to the two classes regularly met in essential oils: the mono ones and sesquiterpenes. However, proportion of monoterpenes (53.2%) (Al-Snafi ,2016).

1.8.1.3.Uses

Cymbopogon schoenanthus was an aromatic herb consumed in salads and used to prepare traditional meat recipes. The plant was used in traditional medicine as antihelminthes, antidiarrhea, antirheumatic, carminative, diaphoretic, stomachic, diuretic, emenagogue, antipyretic, for treatment of jaundice and as tonic. It was also used foranorexia; astringent, sudorific and to cure dromedary wounds. In Morocco and Egypt an infusion of the flowers and the whole plant were used as febrifugal, diuretic, antirheumatismal and antigastralgic . The plant was used in Sudan for the treatment of gout, prostate inflammation, kidney diseases, and for stomach pains. (Al-Snafi, 2016).

1.8.2.Khaya senegalensis (Desr) A. Juss

Family : *Meliaceae* .

Vernacular name: mahogany

1.8.2.1.Botanical description

Khaya senegalensis, a tree in the family Meliacea, is anative of West Africa (Senegal) and extends to Sudan and Uganda (Keay, 1989). The tree is commonly called the dry zone mahogany, and it is widely distributed in the Savannah regions. In its natural habitat, the plant is a medium to large sized tree that grows up to 30 m. The bark and the leaves of the plant are used by the local people of Keffi for the treatment of diarrhoea, dysenteryand wound infections. Medicinal plants are of great importance to the health of individuals and the local communities of Nigeria. The medicinal values of theseplants rely in the presence of certain chemical substances that produce a definite physiological effect on the human body. The most important of these bioactive constituent of plants are alkaloids, tannins, flavonoids, and phenolic compounds This investigation is aimed at screening for the compounds and the antimicrobial activity of the crude extracts of the leaves and bark of *khaya senegalensis*.(Makut et al. 2008)

1.8.2.2.Chemical constituents

The phytochemical constituents of stem bark extracts of *Khaya senegalensis* were isolated and analyzed using Gas Chromatography-Mass Spectrometry (GC-MS). A shade-dried stem bark of *Khaya senegalensis* was extracted using methanol and water as solvents. The main chemical compositions of the extracts were analyzed by GC-MS and preliminary phytochemical analysis was performed to confirm the various classes of active chemical. The chemical composition of methanolic stem bark extract of *Khaya senegalensis* included: 4-Hepten-3-one, 2, 6-Pyridinedicarboxylic acid,3-O-methyl-d-glucose, myristic acid, pentadecanoic acid, n-Hexadecanoic acid, 9, 12-Octadecadienoic acid, and 11-Octadecenoic acid. Others are 9-Hexadecenoic acid, Stearic acid, I, E-11, Z-13-Octadecatriene, Cyclododecyne, Hexadecanoic acid, Ricinoleic acid, 13-Decosenoic acid, and 9-Hexadecenal. The Chemical composition of aqueous stem bark extract of K. senegalensis included 1, 2, 3-benzenetriol, n-Hexadecanoic acid, oleic acid, (Z)6,(Z)9-pentadecadeien-1-ol, 1,E-11,Z-13-octadecatriene, and 1-flourodecane. Other chemical constituents of the aqueous extract included 9-octadecanal, E-9-tetradecanal, and 2-methyl-Z, Z-3, 13-octadecadienol. The molecular weight of these compounds ranged from low to high with carbon skeleton of between C_7 and C_{37}. Both aromatic and aliphatic compounds were identified. *khaya senegalensiscontains* alkaloid, saponin, tannins and flavonoids. A good number of bioactive compounds were present in the stem bark of *Khaya senegalensis* (Aguoru et al. 2017).

1.8.2.3.Uses

In its natural range *Khaya sengalensis* provides cattle fodder, edible and cosmetic oils, medicinal products, shade and shelter as well as providing fuelwood and valuable timber. In Mali, Niger and parts of the Sahel *Khaya sengalensisrates* highly as an agroforestry tree species, based on farmers' preferences, market demand and potential for genetic improvement . As an exotic, it is valued for both amenity applications and timber production. It is mainly in the drier parts of its natural range that *Khaya senegalensis* foliage is used as fodder for cattle and other livestock . However, while its foliage is known to be useful to cure and prevent a range of livestock diseases, it has poor nutritive value relative to the foliage of a range other fodder trees . Thus, foliage of *Khaya senegalensisis* typically used as a fodder source in combination with that from a number of other trees of the African savannah, such as Faidherbia albida and Balanites aegyptiaca. Spatial and temporal proximity of *Khaya senegalensis* to other fodder yielding trees is a key factor in determining the value of individual trees as fodder sources . The bark of *Khaya senegalensisis* also useful for livestock, being used to treat a range of diseases including liver fluke, ulcers and internal ailments associated with mucous diarrhoea (Arnold ,2004).

1.8.3.*Acacia seyal (Del)*

Family : Fabaceae (Mimosoideae) .

Vernacular name: Talih

1.8.3.1. Botanical description

Acacia seyal trees are up to 17 m tall in Sudan, with a flat top crown. It has a distinctive smooth powdery bark, from white to greenish yellow or orange red, with a green layer beneath. In some population both red and yellow barked trees can be found. There are two varieties, differing primarily in whether or not pseudo-galls ("ant galls") develop and in bark colour. seyal var. seyal, there are no pseudo-galls and a reddish bark color prevails, although periodic bark exfoliation exposes a pale powdery surface which darkens slowly. In *acacia seyal*. fistulapseudo-galls are present and the powdery bark typically remains whitish or greenish-yellowIn general, there are two main varieties of *Acacia seyal*; variety seyal and variety fistula. Variety seyalis found in both western and eastern Africa and also on the Arabian Peninsula, whilevariety fistula is found in the eastern parts of Africa indicate that variety seyal is native to northern-tropical Africa and Egypt. The two varieties can be easily distinguished; variety seyal has a greenish-yellow to reddish-brown bark, while variety fistula has white to greenish-yellow bark. However, *Acacia seyal* trees are naturally grown in the Sudan till yet no reforestation done by human been (Sara et al .2016).

1.8.3.2.Chemical constituents

The Fabaceae family produces more nitrogen-containing secondary metabolites than other plant families such as quinolizidine, pyrrolizidine, indolizidine, piperidine, pyridine, pyrrolidine and many other nitrogenous compounds . Acacia genus was reported to have many secondary metabolites such as amines, alkaloids, cyanogenic glycosides, cyclitols, fatty acids and seed oils, fluoroacetate, amino acids, essential oils, diterpenes, phytosterol, triterpenes, saponins and hydrolyzable tannins. The most evident and best known are polysaccharides (gums) and complex phenolic substances (condensed tannins). Acacia seyal is highly nitrogen-fixing and moderately salt tolerant species and characterized by high content of proteins ,phenols and flavonoids (Eltayeb et al 2017)

1.8.3.3.Uses

The bark is extensively used for feeding cattle, sheep and goats during the dry season. When fresh, it is smooth and relatively soft. In February to March (the dry season in Kenya) thick branches are lopped and animals browse the bark and eat the leaves, which are relatively few at that time. The pods and leaves are nutritious and palatable to livestock. The feed value crude protein content is 11-15 % in leaves and 15-24 % in fruits. Digestible protein is 8-12 % in leaves and 13-15 % in fruits, which have a high digestibility. Leaves, pods and flowers are a major source of early dry-season fodder for sheep and goats over much of Africa. *Acacia seyal* is considered the best fodder plant in northern Nigeria and the Sahelian savannah. In the dry season in western Sudan, the Fulani drive their cattle to the districts where it grows. Branches (sometimes even the entire crown) are lopped in times of fodder scarcity. *Acacia seyal* produces good, dense firewood that is used widely throughout its range. The smoke is pleasantly fragrant and the wood burns rather quickly. In Sudan it is used to make a fragrant fire over which women perfume themselves. *Acacia seyal var. seyal* is an important source of rural energy as both firewood and charcoal. Roots are used for making staves. The bark of *Acacia seyal* is used for making rope. The fibre has promising technological characteristics for use as particleboard. . seyal gum (talha gum) is darker and inferior in quality to that of *Acacia senegal* (gum arabic). However, it forms 10% of the Sudanese gum exported to India and Europe. The gum is edible when fresh, with a slightly acidic taste. Talha does not meet the requirements of the food industry because it has not been toxicologically evaluated and contains tannins. For technological use outside the food industry, talha gum is attractive because of its clarity and solubility (Orwa et al. 2009).

1.8.4. *Azadirachta indica A.Juss*

Family : Meliaceae .

Vernacular name: Neem

1.8.4.1.Botanical description

Azadirachta indica A. Juss. is a tree of small to medium-sized around 18 m, tall up to 15-30 m, with large crown up to 10-20 m diameter . The leaves are light green simply pinnate alternate with 20-40 cm long. The flowers are pentamerous, small, white or pale yellow, slightly sweet and bisexual. The plants fruits are greenish yellow to yellow or purple and have one or two seeded drupe, ellipsoidal, 1-2 cm long. They are greenish when ripe and their seeds are ovoid or spherical . Neem's leaves, seeds, bark, roots, fruits and oil have become a cynosure of modern medicine and used medicinally for treatment various diseases specially in Indian Ayurvedic medicine, Homoeopathic medicine and Unani **(**Eid et al. 2017).

1.8.4.2.Chemical constituents

The chemical constituents include many biologically active substances, including alkaloids, flavonoids, triterpenoids, phenolic compounds, carotenoids, steroids, and ketones that can be extracted from Neem. Antibiotic resistance is a major concern and it may be useful to develop new plant agents to meet the need for new antimicrobial agents with increased protection and efficacy . The strong anti-bacterial activity of Azadirachta indica leaves indicates the existence of bioactive compounds and is useful for rationalising the use of this plant in primary health care. Hill (1985) stated that in certain chemical substances that create a definite physiological effect on the human body,the medical importance of plants lies.Alkaloids, tannins, flavonoids and phenolic compounds are the most significant of these bioactive constituents of plants. Many scientists and organisations are actively looking for alternative drugs to conventional remedies. It has been estimated that about 25 percent of all medicines prescribed today are plant-based substances (Mohapatro et al .2021).

1.8.4.3.Uses

The leaves, flowers, seeds, fruits, roots and bark of neem tree are used for the treatment The leaves of neem are used to treat skin allergies, and healing of wound of small pox and chicken pox . The antimicrobial activity of neem leaves extract against Staphylococcusspp.,Streptococcusspp., Pseudomonasspp., E. coli, and some fungal strains have been. The use of neem leaf extract in immunosuppressed birds increased humoral and cell mediate immunity .Pasteurella multocida, Salmonella pullorum, Salmonella gallinarum and Escherichia coliare known to cause fowl cholera, fowl typhoid, pullorum diseases, and colibacillosis in poultry. These bacterial diseases are prevalent in Bangladesh and causing significant economic losses in poultry industries due to high morbidity and mortality. Antibiotics are being used for treating these bacterial diseases which often leads to the developments of multidrug resistant (MDR) bacteria. Extract of neem leaf is known to have antibacterial activity without drug resistant problem. Therefore neem leaf extract may be used as an alternative to antibiotics to treat MDR bacterial diseases. The objective of the present research was to determine antibacterial efficacy of neem leaf extract against MDR pathogenic bacteria of poultry: P. multocida, S. pullorum, S. gallinarumand E. coli1(Ali,et al. 2021).

1.9.Phytochemistry

Phytochemicals (from the Greek word phyto, meaning plant) are biologically active, naturally occurring chemical compounds found in plants, which provide health benefits for humans further than those attributed to macronutrients and Micronutrients.They protect plants from disease and damage and contribute to the plant's color, aroma and flavor. In general, the plant chemicals that protect plant cells from environmental hazards such as pollution, stress, drought, UV exposure and pathogenic attack are called as phytochemicals (Saxena et al .2013). The medicinal properties of the plants are determined by the phytochemical constituents . Some of the important phytochemicals include alkaloids, flavonoids, phenolics, tannins, saponins, steroids, glycosides, terpenes, etc. which are distributed in various parts of the plants . Nature is a unique source of structures of high phytochemical diversity representing phenolics (45%), terpenoids and steroids (27%) and alkaloids (18%) as major groups of phytochemicals. Although, these compounds seem to be non-essential to the plant producing them, they play a vital role in survival by mediation of ecological interactions with competitors, protect them from diseases, pollution, stress, UV rays and also contribute for colour, aroma and flavour with respect to the plant. The metabolites produced by the plants to protect themselves against biotic and abiotic stresses have turned into medicines that people can use to treat various diseases (Shaikh and Pati, 2020).

1.9.1.Classification of Phytochemicals

The exact classification of phytochemicals has not been given so far, because of their diverse forms and structures. Classically, the phytochemicals have been classified as primary or secondary metabolites, depending on their role in plant metabolism. Primary metabolites include the common sugars, amino acids, proteins, purines and pyrimidines of nucleic acids, chlorophylls etc. Secondary metabolites are the remaining plant chemicals such as alkaloids, terpenes, flavonoids, lignans, plant steroids, curcumines, saponins, phenolics and glucosides (koche et al . 2016).

1.10. Instruments used in elemental analysis

Many instrumental analytical methods may be employed to measure the concentration level of heavy metals in various samples. The most predominant techniques are atomic absorption spectrometry (AAS); atomic emission/ fluorescence spectrometry (AES/AFS); inductively coupled plasma mass spectrometry (ICP-MS); inductively coupled plasma optical emission spectrometry (ICP-OES); neutron activation analysis (NAA), X-ray fluorescence (XRF); and anodic striping voltammetry (AVS) (Helaluddin et al .2016).In this work direct mercury analyzer(DMA) device was used in addition to an AAS device.

1.10.1. Atomic absorption spectrometry (AAS)

AAS is a quantitative method of metal analysis suitable for the determination of approximately 70 elements. This method measures the concentration of the element by passing light in specific wave length emitted by a radiation source of a particular element through cloud of atoms from a sample. . Atoms will absorb light from an energy source known as hollow cathode lamp (HCL).The reduction in the amount of light intensity reaching the detector is seen as a measure for the concentration of particular element in the original sample. A typical AA spectrometer consists of energy (light) source, sample compartment (atomizer) monochromator, detector, and a data process system . The radiation source is usually a hollow cathode lamp (HCL) or electrodeless discharge lamp

(EDL), while different atomizers are used in various AAS techniques such as flame, a graphite furnace, or a quartz tube. The Monochromator is eliminating scattered light of other wavelengths by a number of lenses and mirrors to focus the radiation and the detector is typically a photomultiplier tube that converts the light signal to an electrical signal proportional to the light intensity (Helaluddin et al .2016).

Figure 1.6: atomic absorption spectrometer

1.10.2. Direct mercury analyzer (DMA)

Direct mercury analyser DMA-80is a dedicated technique used for quantification of mercury in different types of samples. Many types of this instrument are available commercially and the type used in this study is the Direct Mercury analyser-DMA-80. In Principle, the sample (solid, gas or liquid) is introduced to the instrument and a series of events takes place in the analyser. First the sample is dried and thermally decomposed in a furnace in a presence of oxygen. After this step, the sample is carried over where it is further combusted and decomposed in a catalyst section where halogen, nitrogen, sulphur oxides are eliminated. Mercury vapour is selectively trapped by and an amalgamator and then directed to the atomic absorption set at mercury line (253.7 nm). Quantification of mercury is achieved by the use of external standard calibration curve method (Elhag et al .2015).

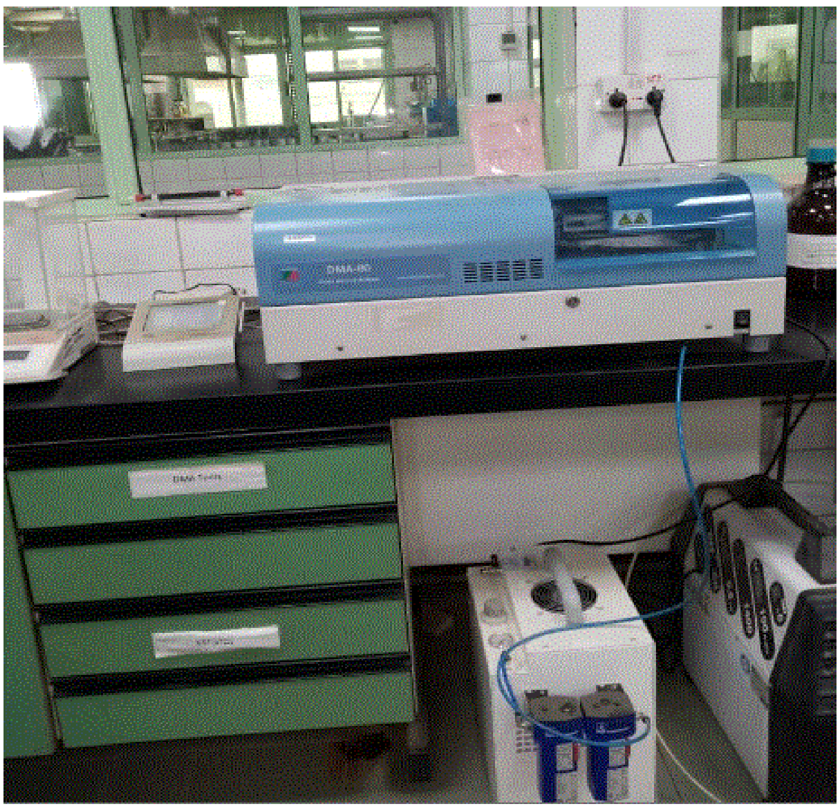

Figure 1.7. Direct mercury analyzer by Milestone

1.11.Previous studies

- march 2013 Hala Ahmed Hegazi used Agricultural and industrial waste by-products such as rice husk and fly ash have be used for the elimination of heavy metals from wastewater for the treatment of the EL-AHLIA Company wastewater for electroplating industries as an actual case study.Results showed that low cost adsorbents can be fruitfully used for the removal of heavy metals with a concentration range of 20–60 mg/l also, using real wastewater showed that rice husk was effective in the simultaneous removal of Fe, Pb and Ni, where fly ash was effective in the removal of Cd and Cu.

- Manal Larakeb , et al in May 2016 they studied zinc removal possibility by adsorption on an Algerian bentonite (bentonite of Maghnia), goethite, powdered activated carbon (PAC) and kaolin. Various reaction parameter effects on process where tested. Kinetic of adsorption results showed that after 20 minutes, zinc removal is maximal with 98.24 % efficiency for bentonite. Using Goethite, we obtained 18% efficiency after 30 minutes of equilibrium time. After 3 hours of stirring, zinc removal by PAC was maximal with 27.54% efficiency and after 1 hour for kaolin with 45.48%. Increasing in adsorbent dose (0.5 to 8 g/l) improves zinc removal efficiency for an initial 5mg/l concentration. Zinc removal efficiency by any adsorbent decreases with the increase of initial zinc concentration (2 to 20 mg/l). pH of treatment affects considerably zinc retention rate. Zn removal efficiencies are noticeable at basic pH. Order of efficiency of tested adsorbents for zinc removal in synthetic solution follows: bentonite > kaolin > PAC > Goethite.
- July 2007 W.S. Wan Ngah , M.A.K.M. Hanafiah they mentioned that use The application of low-cost adsorbents obtained from plant wastes as a replacement for costly conventional methods of removing heavy metal ions from wastewater has been reviewed. It is well known that cellulosic waste materials can be obtained and employed as cheap adsorbents and their performance to remove heavy metal ions can be affected upon chemical treatment. In general, chemically modified plant wastes exhibit higher adsorption capacities than unmodified forms. Numerous chemicals have been used for modifications which include mineral and organic acids, bases, oxidizing agent, organic compounds, etc. In this

review, an extensive list of plant wastes as adsorbents including rice husks, spent grain, sawdust, sugarcane bagasse, fruit wastes, weeds and others has been compiled. Some of the treated adsorbents show good adsorption capacities for Cd, Cu, Pb, Zn and Ni.

- In June , 2013Lovell Agwaramgbo et al evaluates the ability of charcoal, un-brewed coffee and tea, fishbone, and caffeine to remove lead from contaminated aqueous solutions. The order of lead removal from 1300 ppm of lead solution is Charcoal (100%) > Tea (97%) > Coffee Ground (88%) > Instant Coffee (83.5%) > Coffee Bean (82%) > Fishbone (76%) > Caffeine (1.3%). These results clearly demonstrate that not all solid biomaterials can adsorb lead and that caffeine, a component of coffee and tea does not participate in the removal of lead from contaminated solutions. Furthermore, the results suggest that two possible processes may be involved in the reactions presented here: adsorption of lead by the solid substrates and precipitation of lead by the solubilized biochemical components of the substrates.
- December 2017 Abhishek Saxena et al they used three non-living biomass/wastes to develop biosorbents and examined their maximum adsorption capacities for lead(II) and nickel(II) usually found in Industrial wastewater samples from Common Effluent Treatment Plant. The results emphasized that the primary adsorption mechanism is the complexation of metal ions at the biosorbent surfaces. Adsorption Isotherm indicate that Pb(II) has higher adsorption property than Ni(II), on the selected biosorbents. Among the selected biosorbents, castor leaves (CL) collected from roadside possess higher adsorption capacities, which can be further developed as a lead(II) selective biosorbents.
- In June 2009 Sardar Khan et al they investigated conducted to investigate the effectiveness of a continuous free surface flow wetland for removal of heavy

metals from industrial wastewater, in Gadoon Amazai Industrial Estate (GAIE), Swabi,Pakistan. Industrial wastewater samples were collected from the in-let, out-let and all cells of the constructed wetland (CW) and analyzed for heavy metals such as lead (Pb), cadmium (Cd), iron (Fe), nickel (Ni), chromium (Cr) and copper (Cu) using standard methods. Similarly, samples of aquatic macrophytes and sediments were also analyzed for selected heavy metals. Results indicate that the removal efficiencies of the CW for Pb, Cd, Fe, Ni, Cr, and Cu were 50%, 91.9%, 74.1%, 40.9%, 89%, and 48.3%, respectively. Furthermore, the performance of the CW was efficient enough to remove the heavy metals, particularly Cd, Fe, and Cu, from the industrial wastewater fed to it. However, it is suggested that the metal removal efficiency of the CW can be further enhanced by using proper management of vegetation and area expansion of the present CW.

- May 2007 P. Moslehi* and P. Nahid heavy metal removal from water and wastewater was investigated by using raw and modified diatomite from Iranian mines. Modification of diatomitewas done by impregnating the diatomite surface with 0.35 g of manganese oxide in one gram of diatomite. This modified diatomite was named Mn-Diatomite. The surface area measurements for Mn-diatomite showed a 2.2 fold increase, hence higher removal capacity for the heavy metals. The results of the removal showed an increase in adsorption capacity which was for Pb^{2+}about 40 mg/g, for Ni^{2+}about 34mg/g and for Cu^{2+}about 33mg/g. The filtration quality of diatomite was significantly enhanced with surface modification by manganese oxide.

1.12. Problem statement

The research concentrated on efficiency of stem bark of *Khaya senegalensis* , *Acacia seyal* , stem bark and leaves of *Azadirachta indica* and leaves of *Cymbopogon schoenanthus* as low cost adsorbent to remove (Cd, Pb, Zn and Hg) from wastewater.

1.13. Research objective

Phytochemical screening and Characterization of some local herbs and their Efficiency in removing of heavy metals ion from wastewater.

1.14. Specific objective

- To collect plant samples from different area in river Nile state.
- To study phytochemical compounds of these plants.
- To use these plants to remove of (Cd, Pb, Zn and Hg) from wastewater.

Materials and Method

2.1. Collection and Preparation of Samples

Fresh sample of the stem- bark of *KhayaSenegalensis* , *Acacia seyal* , leaves of *Cymbopogon schoenanthus* , stem bark and leaves of *Azadirachata indicia* were collected in May 2021 from the river Nile State (Shendi and Tyba) . The samples were air dried in the laboratory before powdering.

2.2. Instruments

-Atomic Absorption Spectrophotometer (AAS) Model 210 VGP.

-Milestone Direct Mercury Analyzer (DMA-80).

2.3. Glassware

Conical flasks, funnel, beakers, bottles, spatula, measuring cylinders, glass rod, dropper, and volumetric flasks**.**

2.4. Chemicals

All chemicals used in this research were of analytical grade by

lead nitrate $Pb(NO_3)_2$, zinc chloride $ZnCl_2$, Cadmium chloride $CdCl_2$, Mercury (II) Chloride $HgCl_2$, Distilled Water H_2O, chloroform $CHCl_3$, acetic anhydride concentrated sulphuric acid H_2SO4, Ferric chloride $FeCl_3$, Dragendorff's reagent (Potassium Bismuth Iodide), Lead acetate$(CH3COO)_2Pb$

glacial acetic acid CH_3COOH.

2.5. Materials

-stem bark of *kaya senegalensis*

-stem bark of *Acacia seyal*

-stem bark and leaves of *Azadirachata indicia*

-leaves of *Cymbopogon schoenanthus*

2.6. Crude Extracts preparation

The Chloroform ,Ethanol and Distilled water extracts were prepared by extracting 25g of pulverized sample with 125mL of solvent for seven days. The extracts were filtered and solvent were evaporated under room temperature for 3days. The tested Chloroform , Ethanol and Distilled water extracts ready for phytochemical screening.

2.7. Phytochemical analysis

2.7.1. Qualitative analysis

Following methods were used for qualitative analysis of samples to check for the presence of Alkaloids, glycosides, Flavonoids, Saponins, Tannins, Terpenoids and Sterols (Ahuja et al 2011).

2.7.1.1.Test for Sterols

Liebermann-Burchard test: To the chloroform solution, few drops of acetic anhydride was added and mixed well. 1 mL of concentrated sulphuric acid was added from the sides of the test tube, appearance of reddish brown ring indicates the presence of sterols (Ahuja et al 2011)..

2.7.1.2.Test for Tri-terpenes

To the chloroform solution, few drops of acetic anhydride was added and mixed well. 1 mL of concentrated sulphuric acid was added from the sides of the test tube, appearance of deep red color indicates the presence of triterpenes (Ahuja et al 2011).

2.7.1.3.Test for Tannins

a. Ferric chloride test: To extracts a few drops of 1% neutral ferric chloride solution was added, formation of blackish blue color indicates the presence of tannins (Ahuja et al 2011).

2.7.1.4.Test for Saponins

a. Foam test: Small amount of extract/ fraction was shakenwith little quantity of water, if foam produced persists for 10 minutes; it indicates the presence of saponins (Ahuja et al 2011).

2.7.1.5.Test for Alkaloids

Dragendorff's reagent(Potassium Bismuth Iodide): The acid layer was treated with few drops of Dragendorff's reagent. Formation of reddish brown precipitate indicates the presence of alkaloids (Ahuja et al 2011).

2.7.1.6.Test for Flavonoids

Lead acetate test: To the extract, a few drops of aqueous basic lead acetate solution were added. Formation of yellow precipitate indicates presence of flavonoids (Ahuja et al 2011).

2.7.1.7.Test for Glycosides

Kellar Kiliani test: The test extract was dissolved in glacial acetic acid and after cooling, 2 drops of ferric chloride solution was added. These contents were transferred to test tube containing 2 mL of sulphuric acid. A reddish brown color ring observed at the junction of two layers (Ahuja et al 2011).

2.8.Preparation of metal solution

A stock solution of metals ions(**Cd, Pb, Zn,Hg)** was prepared by dissolving 0.1g of metal ion chloride in distilled water and the volume was completed to 1000 ml to get a concentration of 100ppm, from this stock solution, 10, 5 ppm were prepared by dilution.

2.9.Removal of metals (Pb , Zn, Cd, Hg)at different concentration by AAS, DMA

The concentrations of metals were prepared in the linear range with some modification. The concentration was prepared as 5ppm and 10ppm. For specific metal analysis, standard solutions of known concentrations were used and the effect of the addition samples of extracts metal adsorptions was tested. The samples of extracts were prepared by taking approximately 2g of the samples (stem bark of *kaya senegalensis* ,stem bark of *Acacia seyal* ,stem bark and leaves of *Azadirachata indicia* And leaves of *Cymbopogon schoenanthus*)and mixing it with about 50 mL of prepared solution. All experiments were conducted at room temperature and after being allowed to stand for 10, 20 and 30 minutes the samples were analyzed using Atomic Absorption Spectrophotometer (AAS) for Pb, Zn, Cd and (DMA**)** for Hg. The concentrations of these metals adsorbed by samples were determined after and before adding the plant powder. these readings was analyzed statistically.

2.10.Data Management and analysis

Standardized data sheet developed in Ms-excel was used to computerize data related to plants code, , type of these plants and heavy metals identified, and concentration of heavy metals. The data was analyzed using SPSS version 16.

Analysis of variance (ANOVA) is statistical technique used for analyzing the difference between the means of more than two samples. ANOVA provides an analytical study for testing the differences among group means and thus generalizes the t-test beyond two means. ANOVA uses F-tests to statistically test the equality of s. The purpose of an ANOVA test is to determine the existence of a statistically significant difference among several group means. The test actually uses variances to help determine if the s are equal or not. The F test statistic can be used to determine the p value for one –way ANOVA , the p value is defined as the probability ,under the assumption of hypothesis, of obtaining result equal to or more extreme than what was actually observed. In statistical significance testing, the p-value is the probability of obtaining a test statistic result at least as extreme as the one that was actually observed, assuming that the null hypothesis is true. If the p value greater than the significance level of 0.05 ,this s that there is no difference between the samples ,and if the p value is less than the level of significance this s that there difference between the samples ,in this case ,you must LSD test to find out these differences and is called least significant difference (LSD) test . it is used to find smallest difference between two means. Inferential statistics of ANOVA was performed to assess association between the type of heavy metals and the level of accumulation in the parts of these plants .

3. Results and Discussion

from (Table3.1)bellow it is clear that the Extraction of a phytochemical from the plant material is mainly dependent on the type of solvent used. Similarly, the test applied for phytochemical analysis determines the presence or absence of a phytochemical in the sample. Phytochemical screening shows that some of the natural products tested for were not present in the plant material ,and these include Saponins in Leaves of *Cymbopogon schoenanthus*. it also showed the presence of natural products namely Tannins , Flavonoids, Saponins, Sterols, Terpenes, Alkaloids, Glycosides were present in ethanol extract of all the parts. were Sterols only present in both water and ethanol extracts of all the parts. This shows the generality of the components in medicinal plants. Biological actions are primarily due to these components in a very complicated concert of synergistic or antagonistic activities. Mixtures of such chemicals show abroad spectrum of biological effects and pharmacological properties. To a large extent, the phonological age of the plant, percentage humidity of the harvested material, place and time of harvest, and the method of extraction are possible sources of variation for the chemical composition, toxicity and bioactivity of the extracts.

Table (3.1) Preliminary phytochemical screening

The plant	Plant Constituents	Name of Extracts		
		Water	Chloroform	ethanol
stem bark of *kaya senegalensis*	Tannins	+	-	+
	Flavonoids	+	-	+
	Saponins	+	+	+
	Sterols	+	-	+
	Terpenes	-	+	+
	Alkaloids	+	+	-
	Glycosides	+	+	+
stem bark of *Acacia seyal*	Tannins	+	-	+
	Flavonoids	+	-	+
	Saponins	+	+	+
	Sterols	+	-	+
	Terpenes	-	+	+
	Alkaloids	+	+	+
	Glycosides	-	+	+
stem bark of *Azadirachata indicia*	Tannins	-	-	+
	Flavonoids	-	-	+
	Saponins	+	-	+
	Sterols	+	+	+
	Terpenes	-	+	+
	Alkaloids	-	+	+
	Glycosides	-	+	+
Leaves of *Azadirachata indicia*	Tannins	+	-	+
	Flavonoids	+	-	+
	Saponins	+	-	-
	Sterols	+	-	+
	Terpenes	-	-	+
	Alkaloids	+	+	+
	Glycosides	-	-	+
Leaves of *Cymbopogon schoenanthus*	Tannins	+	-	+
	Flavonoids	-	-	+
	Saponins	-	-	-
	Sterols	+	+	+
	Terpenes	-	+	+
	Alkaloids	+	+	+
	Glycosides	-	-	+

Table 3.2 bellow the adsorbents showed stem bark of *kaya senegalensis* , leaves of *A zadirachata*, stem bark of *A zadirachata* , *Acacia seyal* and Leaves of *Cymbopogon schoenanthus* their efficiency in the biosrption of heavy metals ,such as (Cd,Pb,Zn,Hg) where the concentration of these metals decreased from the initial concentration (5ppm,10ppm) after the process of biosorption by these biosorbents,after adding 2.0 g of the plant sample to 50 ml of the aqueous solution of the metal with out nutrient medium ,and after taking three readings over three times . it was found that the cadmium concentration decreased with increased contact time and the removal percentage increased with increased contact time From this study, it has been observed that Cd ion uptake takes place during 30 minutes of contact indicating the adsorption of Cd increased from 86.7 % to 88.42%, 87.56% to 91.28% , 30.3% to 37.88%,64.26 to71.98 and 88.64 to90.18% in the case of 5ppm, 85.69% to 89.98, 88.86%to90.9, 56.48% to 61.51%, 63.66% to 69.98% , 86.79%to88.85 % in the case of 10 ppm for stem bark of *kaya senegalensis,* stem bark of *Acacia seyal,* stem bark of *Azadirachata indicia* Leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* respectively and from with an increased time from 10 to 120 minutes. This is due to the fact that the higher contact time between the sorbent surface and the metal solutions, and increased with the lower initial concentration . also we note the removal percentage increased with increased initial concentration when adsorbed the cadmium by *stem bark of Azadirachata indicia* this because number of collisions between these metals ions and plants, thus increasing adsorption.Initial solution concentration can provide a driving force for heavy metal ions in solution to transfer from solution to the surface of adsorbent With the increase of the initial solution concentration, the driving force is also enhanced, thus much heavier metal ions can be attached onto the adsorption sites of adsorbent. the adsorption sites for heavy metal ions were limited, with the initial concentration increasing, the total heavy metal ions in solution also increased, corresponding to amounts of heavy metal ions that cannot be adsorbed by adsorbent also increased. As a result, the removal ratio declined with the initial concentration increasing, although the higher driving force can enhance the amount of adsorbed heavy metal ions (Liu et al. 2020).

Table 3.2 Effect of plants on removal of Cd ion by AAS

Adsorbents	time	C mg/l		Removal percentage%	
		5.00	10.00	R_1	R_2
stem bark of *kaya senegalensis*	10	0.665	1.431	86.7	85.69
	20	0.625	1.223	87.5	87.77
	30	0.579	1.002	88.42	89.98
stem bark of *Acacia seyal*	10	0.622	1.114	87.56	88.86
	20	0.487	1.032	90.26	89.68
	30	0.436	0.910	91.28	90.9
stem bark of *Azadirachata indicia*	10	3.485	4.352	30.3	56.48
	20	3.277	4.011	34.46	59.89
	30	3.106	3.849	37.88	61.51
Leaves of *Azadirachata indicia*	10	1.787	3.634	64.26	63.66
	20	1.428	3.113	71.44	68.87
	30	1.401	3.002	71.98	69.98
Leaves of *Cymbopogon schoenanthus*	10	0.568	1.321	88.64	86.79
	20	0.510	1.246	89.8	87.54
	30	0.491	1.115	90.18	88.85

from (Table3.3) bellow we can see that the probability value in5ppmand 10ppm equal to 0.00(p value < 0.05) accordingly , the result of the F test to find out that there is a significant difference between residual concentrations of cadmium after adsorption by some plant parts such as stem bark of *kaya senegalensis*, stem bark of *Acacia seyal* , stem bark and leaves *A zadirachata indicia* and Leaves of

Cymbopogon schoenanthus asignificant result, ing that there are statistically significant differences between the remaining concentrations to know who these differences tend to be ,we note the values of the arithmetic for the remaining concentrations where we notice that the lowest remaining concentration of cadmium from the initial concentration(5ppm) after adsorption process by these plants which are arranged in order of preference as follows *Acacia seyal* , Leaves of *Cymbopogon schoenanthus* , stem bark of *kaya senegalensis* , leaves of *A zadirachata indicia* and stem bark of *A zadirachata*. While the arrangement in the case of initial concentration as follows (10ppm) stem bark of *Acacia seyal* ,Leaves of *Cymbopogon schoenanthus* ,stem bark of *kaya senegalensis* ,leaves of *A zadirachata indicia* and stem bark of *A zadirachata indicia*.

Table 3.3: The ANOVA analysis for residual concentration of Cadmium after adsorption (F test)

Cd				
Plants	**5PPm**		**10PPm**	
	Conc(30minutes)	**Sig**	**Conc(30minutes)**	**sig**
stem bark of *kaya senegalensis*	0.579	0.000*<0.05	1.002	0.000*<0.05
stem bark of *Acacia seyal*	0.436		0.910	
stem bark of *Azadirachata indicia*	3.106		3.849	
Leaves of *Azadirachata indicia*	1.401		3.002	
Leaves of *Cymbopogon schoenanthus*	0.491		1.115	
Result	Difference		Difference	

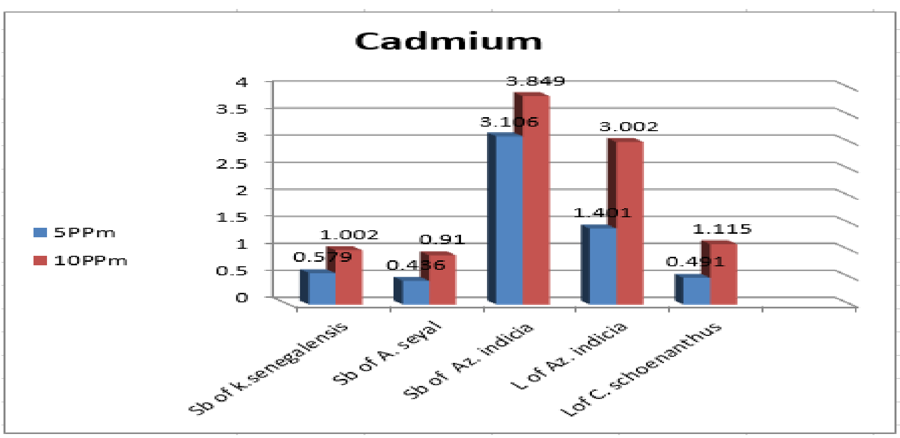

Figure 3.1: residual concentration of cadmium after adsorption by different adsorbents

From the table (3.4) we note that :

- the probability value of the residual concentrations of cadmium from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *kaya senegalensis* and stem bark of *Acacia seyal* equal .334, .296 and stem bark of *kaya senegalensis* and Leaves of *Cymbopogon schoenanthus* equal .367 , .963 in 5ppm and 10ppm respectively (p value > 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual cadmium concentrations after bisorption by these biosorbents insignificant result, meaning that there are non statistically significant differences between the remaining concentrations in 5ppm and 10ppm .
- the probability value of the residual concentrations of cadmium from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *kaya senegalensis* and stem bark of *Azadirachata indicia* equal 0.00 and stem bark of *kaya senegalensis* and Leaves of *Azadirachata indicia* equal 0.00 (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual cadmium concentrations after biosorption by these biosorbents significant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

  - the probability value of the residual concentrations of cadmium from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *acacia seyal* and stem bark of *Azadirachata indicia* and stem bark of *acacia seyal* and leaves of *Azadirachata indicia* equal 0.00 (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual cadmium concentrations after biosorption by thses biosorbents significant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of cadmium from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *acacia seyal* and Leaves of *Cymbopogon schoenanthus* equal .945, .277in 5ppm and 10ppm respectively (p value > 0.05)accordingly , the result of the LSD test to find out that there is a significant difference between the residual cadmium concentrations after adsorption by stem bark of *acacia seyal* and Leaves of *Cymbopogon schoenanthus* insignificant result, meaning that there are non statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of cadmium from initial concentrations 5ppm ,10 ppm after adsorption by stem bark *Azadirachata indicia* and leaves of *Azadirachata indicia* equal 0.00 and .001 respectively and stem bark *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* equal 0.00 (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual cadmium concentrations after biosorption by these biosorbents result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of cadmium from initial concentrations 5ppm ,10 ppm after adsorption by leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* equal 0.00 (p value< 0.05)accordingly , the result of the LSD test to find out that there is a significant difference between the residual cadmium concentrations after adsorption by leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* significant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm.

Table 3.4: LSD (least significant difference) test in F test

adsorbents	Difference	5 ppm		10 ppm	
		Sig	Result	sig	result
stem bark of *kaya senegalensis*	stem bark of *Acacia seyal*	.334	Not Difference	.296	Not Difference
	stem bark of *Azadirachata indicia*	.000*	Difference	.000*	Difference
	Leaves of *Azadirachata indicia*	.000*	Difference	.000*	Difference
	Leaves of *Cymbopogon schoenanthus*	.367	Not Difference	.963	Not Difference
stem bark of *Acacia seyal*	stem bark of *kaya senegalensis*	.334	Not Difference	.296	Not Difference
	stem bark of *Azadirachata indicia*	.000*	Difference	.000*	Difference
	Leaves of *Azadirachata indicia*	.000*	Difference	.000*	Difference
	Leaves of *Cymbopogon schoenanthus*	.945	Not Difference	.277	Not Difference
stem bark of *Azadirachata indicia*	stem bark of *kaya senegalensis*	.000*	Difference	.000*	Difference
	stem bark of *Acacia seyal*	.000*	Difference	.000*	Difference
	Leaves of *Azadirachata indicia*	.000*	Difference	.001*	Difference
	Leaves of *Cymbopogon schoenanthus*	.000*	Difference	.000*	Difference
Leaves of *Azadirachata indicia*	stem bark of *kaya senegalensis*	.000*	Difference	.000*	Difference
	stem bark of *Acacia seyal*	.000*	Difference	.000*	Difference
	stem bark of *Azadirachata indicia*	.000*	Difference	.001*	Difference
	Leaves of *Cymbopogon schoenanthus*	.000*	Difference	.000*	Difference
Leaves of *Cymbopogon schoenanthus*	stem bark of *kaya senegalensis*	.367	Not Difference	.963	Not Difference
	stem bark of *Acacia seyal*	.945	Not Difference	.277	Not Difference
	stem bark of *Azadirachata indicia*	.000*	Difference	.000*	Difference
	Leaves of *Azadirachata indicia*	.000*	Difference	.000*	Difference

Table 3.5bellow it was found that the lead concentration decreased with increased contact time and the removal percentage increased with increased contact time and increased with the lower initial concentration . it has been observed that Pb ion uptake takes place during 30 minutes of contact indicating the adsorption of Pb increased from **94.32**% to **97.98**%, **97.64** % to **98**% , **95.48**% to **96.3**%,**96.9**to **97.72**and **88.74**to**94.36**% in the case of 5ppm, **92.68**% to **96.95**, **93.57**%to**95.91**, **89.89**% to **96.03**%, **93.49**% to **94.8**% , **86.4**%to**91.74**% in the case of 10 ppm for stem bark of *kaya*

senegalensis, stem bark of *Acacia seyal*, stem bark of *Azadirachata indicia* Leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* respectively with an increased time from 10 to 30 minutes, This is due to the fact that the higher contact time between the sorbent surface and the metal solutions. the removal percentage increased with an increases in the initial concentration when adsorbed to these biosorbents . similar results have been reported by Jalija et al (2019)and Amuda et al (2007)

Table 3.5: Effect of plants on removal of Pb ion by AAS

adsorbents	time	C mg/l		Removal percentage%	
		5.00	10.00	R_1	R_2
stem bark of *kaya senegalensis*	10	0.284	0.732	94.32	92.68
	20	0.103	0.339	97.94	96.61
	30	0.101	0.305	97.98	96.95
stem bark of *Acacia seyal*	10	0.118	0.643	97.64	93.57
	20	0.112	0.438	97.76	95.62
	30	0.100	0.409	98	95.91
stem bark of *Azadirachata indicia*	10	0.226	1.011	95.48	89.89
	20	0.211	0.439	95.78	95.61
	30	0.185	0.397	96.3	96.03
Leaves of *Azadirachata indicia*	10	0.155	0.651	96.9	93.49
	20	0.133	0.534	97.34	94.66
	30	0.114	0.520	97.72	94.8
Leaves of *Cymbopogon schoenanthus*	10	0.563	1.360	88.74	86.4
	20	0.435	0.837	91.3	91.63
	30	0.282	0.826	94.36	91.74

From table (3.6) bellow we can see that the probability value in the case of concentration (5ppm) is equal to 0.004 (p value < 0.05) and the case of concentration (10ppm) equal 0.108(p value > 0.05) accordingly , the result of the F test to find out that there is a significant difference between the residual concentrations from initial concentration (5ppm) of lead after adsorption by some plant parts such as stem bark of *kaya senegalensis*, stem bark of *Acacia seyal* , stem bark and leaves *A zadirachata indicia* and Leaves of *Cymbopogon schoenanthus* asignificant result, meaning that there are statistically significant differences between the remaining concentrations to know who these differences tend to be ,we note the values of the arithmetic for the remaining concentrations where we notice that the lowest remaining concentration of lead from the initial concentration after adsorption process by these plants which are arranged in order of preference as follows stem bark of *Acacia seyal* , Leaves of *Cymbopogon schoenanthus* , stem bark of *kaya senegalensis* , leaves of *A zadirachata* and stem bark of *A zadirachata*. and the result of the F test to find out that there is a significant difference between the residual concentrations from initial concentration (10ppm) of lead after adsorption by these plants insignificant result, meaning that there are non statistically significant differences between the remaining concentrations. Therefore, there is no preference between these samples of plant when they adsorption of lead .

Table 3.6: The ANOVA analysis for residual concentration of Lead after adsorption (F test)

Pb				
Plants	**5PPm**		**10PPm**	
	Conc (30 minutes)	**Sig**	**Conc (30 minutes)**	**Sig**
stem bark of *kaya senegalensis*	0.101	0.004*<0.05	0.305	0.108>0.05
stem bark of *Acacia seyal*	0.100		0.409	
stem bark of *Azadirachata indicia*	0.185		0.397	
Leaves of *Azadirachata indicia*	0.114		0.520	
Leaves of *Cymbopogon schoenanthus*	0.282		0.826	
Result	Difference		Not Difference	

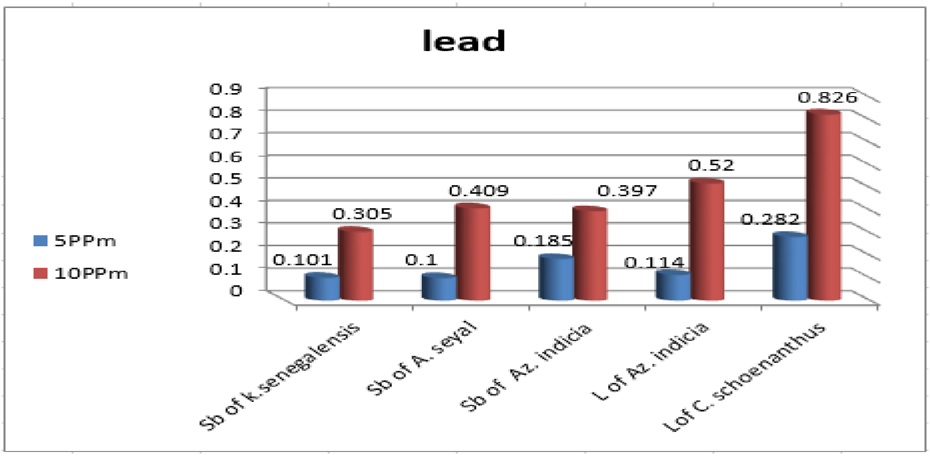

Figure 3.2: residual concentration of Lead after adsorption by different adsorbents

From the table(3.7) bellow ,we note that :

- the probability value of the residual concentrations of lead from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *kaya senegalensis* and stem bark of *Acacia seyal* equal .437 , .850, stem bark of *kaya senegalensis* and stem bark of *Azadirachata indicia* equal .508, .442 and stem bark of *kaya senegalensis* and Leaves of *Azadirachata indicia* equal .669 , .588 respectively (p value > 0.05)accordingly , the result of the LSD test to find out that there is a significant difference between the residual lead concentrations after biosorption by these biosorbents insignificant result, meaning that there are non statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of lead from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *kaya senegalensis* and Leaves of *Cymbopogon schoenanthus* equal .002, .019 respectively (p value < 0.05)accordingly , the result of the LSD test to find out that there is a significant difference between the residual lead concentrations after adsorption by stem bark of *kaya senegalensis* and Leaves of *Cymbopogon schoenanthus* asignificant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of lead from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *acacia seyal* and stem bark of *Azadirachata indicia* equal .166 , .558 and stem bark of *acacia seyal* and leaves of *Azadirachata indicia* equal .720 , .722 respectively (p value > 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual lead concentrations after biosorption by these biosorbents insignificant result, meaning that there are non statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of lead from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *acacia seyal* and Leaves of *Cymbopogon schoenanthus* equal .001 , .026 respectively (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual lead concentrations after adsorption by stem bark of *acacia seyal* and Leaves of *Cymbopogon schoenanthus* asignificant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of lead from initial concentrations 5ppm ,10 ppm after adsorption by stem bark *Azadirachata indicia* and leaves of *Azadirachata indicia* equal .286 , .814 respectively (p value > 0.05) accordingly , the result of the LSD test to find out that there is asignificant difference between the residual lead concentrations after adsorption by stem bark of *Azadirachata indicia* and leaves of *Azadirachata indicia* insignificant result, meaning that there are non statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of lead from initial concentrations 5ppm ,10 ppm after adsorption by stem bark *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* equal .007, (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual lead concentrations after adsorption by stem bark of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* asignificant result , meaning that there are statistically significant differences between the remaining concentrations statistically significant differences in 5ppm and10ppm .

- the probability value of the residual concentrations of lead from initial concentrations 5ppm ,10 ppm after adsorption by leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* equal .001, .049 respectively (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual lead concentrations after adsorption by leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* asignificant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm.

Table 3.7: LSD (least significant difference) test in F test

adsorbents	Difference	5 ppm		10 ppm	
		sig	Result	Sig	result
stem bark of *kaya senegalensis*	stem bark of *Acacia seyal*	.437	Not Difference	.850	Not Difference
	stem bark of *Azadirachata indicia*	.508	Not Difference	.442	Not Difference
	Leaves of *Azadirachata indicia*	.669	Not Difference	.588	Not Difference
	Leaves of *Cymbopogon schoenanthus*	.002	Difference	.019	Difference
stem bark of *Acacia seyal*	stem bark of *kaya senegalensis*	.437	Not Difference	.850	Not Difference
	stem bark of *Azadirachata indicia*	.166	Not Difference	.558	Not Difference
	Leaves of *Azadirachata indicia*	.720	Not Difference	.722	Not Difference
	Leaves of *Cymbopogon schoenanthus*	.001	Difference	.026	Difference
stem bark of *Azadirachata indicia*	stem bark of *kaya senegalensis*	.508	Not Difference	.442	Not Difference
	stem bark of *Acacia seyal*	.166	Not Difference	.558	Not Difference
	Leaves of *Azadirachata indicia*	.286	Not Difference	.814	Not Difference
	Leaves of *Cymbopogon schoenanthus*	.007	Difference	.007	Difference
Leaves of *Azadirachata indicia*	stem bark of *kaya senegalensis*	.669	Not Difference	.588	Not Difference
	stem bark of *Acacia seyal*	.720	Not Difference	.722	Not Difference
	stem bark of *Azadirachata indicia*	.286	Not Difference	.814	Not Difference
	Leaves of *Cymbopogon schoenanthus*	.001	Difference	.049	Difference
Leaves of *Cymbopogon schoenanthus*	stem bark of *kaya senegalensis*	.002	Difference	.019	Difference
	stem bark of *Acacia seyal*	.001	Difference	.026	Difference
	stem bark of *Azadirachata indicia*	.007	Difference	.007	Difference
	Leaves of *Azadirachata indicia*	.001	Difference	.049	Difference

Table 3.8 bellow it was found that the lead concentration decreased with increased contact time and the removal percentage increased with increased contact time and increased with the lower initial concentration . it has been observed that Pb ion uptake takes place during 30 minutes of contact indicating the adsorption of Pb increased from **94.32**% to **97.98**%, **97.64** % to **98**% , **95.48**% to **96.3**%,**96.9**to **97.72**and **88.74**to**94.36**% in the case of 5ppm, **92.68**% to **96.95**, **93.57**%to**95.91**, **89.89**% to **96.03**%, **93.49**% to **94.8**% , **86.4**%to**91.74**% in the case of 10 ppm for stem bark of *kaya senegalensis*, stem bark of *Acacia seyal*, stem bark of *Azadirachata indicia* Leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* respectively with

an increased time from 10 to 30 minutes. This is due to the fact that the higher contact time between the sorbent surface and the metal solutions. This finding is in agreement with previous studies and can be attributed to the driving force that overcomes all mass transfer resistance of metal between the aqueous and solid phases (Peng et al(2010), Mourabet et al (2012), Aksu et al(2005), Malkoc et al(2007)). it can be assumed that increasing initial metal concentration increases the number of collisions between these metals ions and plants, thus increasing biosorption.

Table 3.8: Effect of plants on removal of Zn ion by AAS

adsorbents	time	C mg/l		Removal percentage%	
		5.00	10.00	R_1	R_2
stem bark of *kaya senegalensis*	10	2.572	2.817	48.56	71.83
	20	2.457	2.719	50.86	72.81
	30	2.347	2.481	53.06	75.19
stem bark of *Acacia seyal*	10	2.724	2.787	45.52	72.13
	20	2.606	2.696	47.88	73.04
	30	2.478	2.561	50.44	74.39
stem bark of *Azadirachata indicia*	10	2.668	2.807	46.64	71.93
	20	2.544	2.702	49.12	72.98
	30	2.516	2.474	47.7	75.26
Leaves of *Azadirachata indicia*	10	2.554	2.740	48.92	72.6
	20	2.468	2.636	50.64	73.64
	30	2.327	2.606	53.46	73.94
Leaves of *Cymbopogon schoenanthus*	10	2.725	2.801	45.5	71.99
	20	2.628	2.681	47.44	73.19
	30	2.523	2.572	49.54	74.28

From table (3.9) bellow we can see that the probability value in 5ppm ,10ppm equal .211 , .999 respectively (p value > 0.05) accordingly , the result of the F test to find out that there is a significant difference between the residual concentrations of zinc after adsorption by some plant parts such as stem bark of *kaya senegalensis*, stem bark of *Acacia seyal* , stem bark and leaves *A zadirachata indicia* and Leaves of *Cymbopogon schoenanthus* insignificant result, ing that there are non statistically significant differences between the remaining concentrations .Therefore, there is no preference between these samples of plant when they adsorption of zinc ,so it is not necessary to test for LSD as long as there is no difference between samples .

Table 3.9: The ANOVA analysis for residual concentration of zinc after adsorption (F test)

Zn				
Plants	5PPm		10PPm	
	Conc (30 minutes|)	Sig	Conc (30 minutes)	Sig
stem bark of *kaya senegalensis*	2.347	0.211>0.05	2.481	0.999>0.05
stem bark of *Acacia seyal*	2.478		2.561	
stem bark of *Azadirachata indicia*	2.516		2.474	
Leaves of *Azadirachata indicia*	2.327		2.606	
Leaves of *Cymbopogon schoenanthus*	2.523		2.572	
Result	Not Difference		Not Difference	

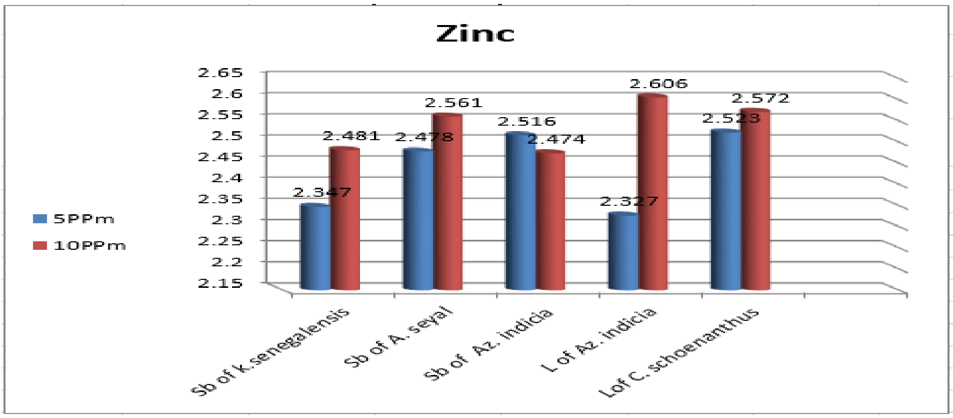

Figure 3.3: residual concentration of Zinc after adsorption by different adsorbents

Table 3.10 bellow the results also showed an increase in the removal percentage with increasing initial concentration of mercury,except in the case of its adsorption by Leaves of *Cymbopogon schoenanthus*(table3.10). similar results have been reported by Rahbar et al (2014). The adsorption of these metals onto these plants was tested at initial concentrations 5and 10 ppm The removal percentage increased with increasing the initial metals concentration This finding is in agreement with previous studies and can be attributed to the driving force that overcomes all mass transfer resistance of metal between the aqueous and solid phases (Peng et al(2010), Mourabet et al (2012), Aksu et al(2005), Malkoc et al(2007).

Table 3.10: Effect of plants on removal of Hg ion by DMA

adsorbents	time	C mg/l		Removal percentage%	
		5.00	10.00	R_1	R_2
stem bark of *kaya senegalensis*	10	1.5331	1.5444	69.34	84.56
	20	1.1922	1.485	76.16	85.15
	30	1.1507	1.1712	76.99	88.29
stem bark of *Acacia seyal*	10	1.8528	2.6817	62.94	73.18
	20	1.8204	1.8277	63.59	81.72
	30	1.5825	1.7613	68.35	82.39
stem bark of *Azadirachata indicia*	10	1.8147	2.0166	63.71	79.83
	20	1.7070	1.7960	65.86	82.04
	30	1.5923	1.6818	68.15	83.18
Leaves of *Azadirachata indicia*	10	1.4321	1.8709	71.36	81.29
	20	0.726	1.8184	85.48	81.82
	30	0.4178	1.2108	91.64	87.89
Leaves of *Cymbopogon schoenanthus*	10	2.5234	3.4173	49.53	65.83
	20	2.4906	3.1221	50.19	68.78
	30	2.4622	3.1129	50.76	68.87

From table (3.11) bellow we can see that the probability value in 5ppm and 10ppm equal to 0.00 (p value < 0.05) accordingly , the result of the F test to find out that there is a significant difference between the residual concentrations of mercury after adsorption by some plant parts such as stem bark of *kaya senegalensis*, stem bark of *Acacia seyal* , stem bark and leaves *A zadirachata indicia* and Leaves of *Cymbopogon schoenanthus* asignificant result, meaning that there are statistically significant differences between the remaining concentrations to know who these differences tend to be ,we note the values of the arithmetic for the remaining concentrations where we notice that the lowest remaining concentration of mercury from the initial concentration(5ppm,10ppm) after adsorption process by these plants which are arranged in order of preference as follows stem bark of kaya senegalensis , leaves of *A zadirachata indicia*, stem bark of *A zadirachata indicia* , *Acacia seyal* and Leaves of *Cymbopogon schoenanthus* .

Table 3.11. The ANOVA analysis for residual concentration of Hg after adsorption (F test)

Hg				
Plants	**5PPm**		**10PPm**	
	Conc (30 minutes)	**Sig**	**Conc (30 minutes)**	**Sig**
stem bark of kaya senegalensis	1.1507	0.000*<0.05	1.1712	0.000*<0.05
stem bark of Acacia seyal	1.5825		1.7613	
stem bark of Azadirachata indicia	1.5923		1.6818	
Leaves of Azadirachata indicia	0.4178		1.2108	
Leaves of Cymbopogon schoenanthus	2.4622		3.1129	
Result	Difference		Difference	

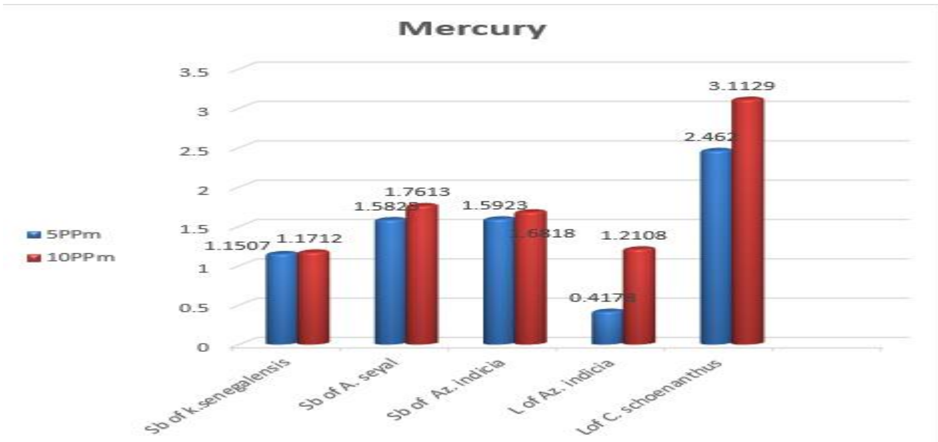

Figure 3.4: residual concentration of mercury after adsorption by different adsorbents

From the table (3.12) bellow ,we note that :

- the probability value of the residual concentrations of mercury from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *kaya senegalensis* and stem bark of *Acacia seyal* equal .000, stem bark of *kaya senegalensis* and stem bark of *Azadirachata indicia* equal.000,.002 , stem bark of *kaya senegalensis* and Leaves of Azadirachata indicia equal .000 ,.003 and stem bark of *kaya senegalensis* and Leaves of *Cymbopogon schoenanthus* equal .000 (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual mercury concentrations after biosorption by these biosorbents asignificant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

  - the probability value of the residual concentrations of mercury from initial concentrations 5ppm ,10 ppm after adsorption by stem bark of *acacia seyal* and stem bark of *Azadirachata indicia* equal .070,.80 respectively (p value > 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual mercury concentrations after adsorption by stem bark of *acacia seyal* and stem bark of *Azadirachata indicia* insignificant result, meaning that there are non statistically significant differences between the remaining concentrations in 5ppm and 10ppm .

- the probability value of the residual concentrations of mercury from initial concentrations 5ppm ,10 ppm after biosorption by stem bark of *acacia seyal* and leaves of *Azadirachata indicia* equal .000 , .03 and stem bark of *acacia seyal* and Leaves of *Cymbopogon schoenanthus* equal .000 respectively (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual mercury concentrations after biosorption by these biosorbents result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm,10ppm.

- the probability value of the residual concentrations of mercury from initial concentrations 5ppm ,10 ppm after adsorption by stem bark *Azadirachata indicia* and leaves of *Azadirachata indicia* equal.000 ,.04 and stem bark *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* equal .000 respectively (p value < 0.05) accordingly, the result of the LSD test to find out that there is asignificant difference between the residual mercury concentrations after biosorption by stem bark of *Azadirachata indicia* and leaves of *Azadirachata indicia* asignificant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm,10ppm.

- the probability value of the residual concentrations of mercury from initial concentrations 5ppm ,10 ppm after adsorption by leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* equal .000 (p value < 0.05) accordingly , the result of the LSD test to find out that there is a significant difference between the residual mercury concentrations after adsorption by leaves of *Azadirachata indicia* and Leaves of *Cymbopogon schoenanthus* asignificant result, meaning that there are statistically significant differences between the remaining concentrations in 5ppm and 10ppm.

Table 3.12: LSD (least significant difference) test in F test

Plants		5 ppm		10 ppm	
		Sig	Result	sig	result
stem bark of *kaya senegalensis*	stem bark of *Acacia seyal*	.000*	Difference	.000*	Difference
	stem bark of *Azadirachata indicia*	.000*	Difference	.002*	Difference
	Leaves of *Azadirachata indicia*	.000*	Difference	.003*	Difference
	Leaves of *Cymbopogon schoenanthus*	.000*	Difference	.000*	Difference
stem bark of *Acacia seyal*	stem bark of *kaya senegalensis*	.000*	Difference	.000*	Difference
	stem bark of *Azadirachata indicia*	.070	Not Difference	.80	Not Difference
	Leaves of *Azadirachata indicia*	.000*	Difference	.03*	Difference
	Leaves of *Cymbopogon schoenanthus*	.000*	Difference	.000*	Difference
stem bark of *Azadirachata indicia*	stem bark of *kaya senegalensis*	.000*	Difference	.002*	Difference
	stem bark of *Acacia seyal*	.070	Not Difference	.80	Not Difference
	Leaves of *Azadirachata indicia*	.000*	Difference	.04*	Difference
	Leaves of *Cymbopogon schoenanthus*	.000*	Difference	.000*	Difference
Leaves of *Azadirachata indicia*	stem bark of *kaya senegalensis*	.000*	Difference	.003*	Difference
	stem bark of *Acacia seyal*	.000*	Difference	.03*	Difference
	stem bark of *Azadirachata indicia*	.000*	Difference	.04*	Difference
	Leaves of *Cymbopogon schoenanthus*	.000*	Difference	.000*	Difference
Leaves of *Cymbopogon schoenanthus*	stem bark of *kaya senegalensis*	.000*	Difference	.000*	Difference
	stem bark of *Acacia seyal*	.000*	Difference	.000*	Difference
	stem bark of *Azadirachata indicia*	.000*	Difference	.000*	Difference
	Leaves of *Azadirachata indicia*	.000*	Difference	.000*	Difference

In this study, The mechanism of bio sorption may be through intracellular uptake are important for detoxification of these heavy metals by the application of medicinal planta. The phytochemical compounds (Flavonoids) of these plants are reactive towards dissolved metals. Thus the investigation presents the applicability of by stem bark of *kaya senegalensis*, stem bark of *Acacia seyal*, , Leaves of *Azadirachata indicia*, stem bark of *Azadirachata indicia*, Leaves of *Cymbopogon schoenanthus* in order to remove covalent these heavy metals from aqueous medium.

3.1 Conclusion

Our present study shows that a good number of organic compounds are present in the stem bark of K.senegalensis, Acacia seyal , leaves of Cymbopogon , stem bark and leaves of Azadirachata indicia and that these compounds account to a great extent for the claimed and reported ethno medicinal and bioactive potentials of the plant. Parts of these plants have also been used as adsorbents for heavy metals from polluted water. biosorption is a process that has been developed immensely as environmental issues rise. biosorption has been used to remove many pollutants from water and wastewater. Whether, sea water or industrial waste water, purifying drinking water, or as a polishing phase at the end of sewage treatment. These pollutants include heavy metals, which is the focus of this work. Heavy metals are toxic and hazardous to humans, marine life and the water body in which it is contained. The metals studies in this work include cadmium, lead, zinc, and, mercury due to their abundance in water, in addition to their toxicity. The adsorbents used was of K. Senegalensis , Acacia seyal , leaves of Cymbopogon , stem bark and leaves of Azadirachata indicia due to their availability. The effect of concentration of heavy metals on removal efficiency was studied. As concentration of metal increases, the removal percentage decreased , in the other cases it increases with increasing concentration. cadmium gave a maximum percentage removal at the two concentrations 5,10 ppm and lead respectively by Acacia seyal followed by zinc by K. Senegalensis, and mercury with leaves of Azadirachata indicia .

3.2.Recommendation for future work

Future researches can be conducted to study:

1. The effect of temperature, pH on removal efficiency of heavy metal can be studied as they were kept constant in this study.
2. Studying the adsorption efficiency of other metal by parts of these plants.

3. Studying isotherm adsorption
4. Evaluation of efficiency of other adsorbents available is recommended.

Reference

A

- A.Farhadi, A.Ameri and S.Tamjidi, Application of Agricultural Wastes as a Low-cost Adsorbent for Removal of Heavy Metals and Dyes from Wastewater :*Phys. Chem. Res*., June2021,Vol. 9, No. 2, 211-226.
- ABM Helaluddin, Reem Saadi Khalid, Mohamed Alaama and Syed Atif Abbas , Main Analytical Techniques Used for Elemental Analysis in Various Matrices: *Trop J Pharm Res*, February 2016; 15(2): 427.
- Ahmad Eid, Nidal Jaradat, Nagib Elmarzugi , A Review of chemical constituentsand traditional usage of Neem plant (Azadirachta Indica): *Palestinian Medical and Pharmaceutical Journal (PMPJ)*,2017; 2(2): 75-81.
- Alazaiza M.Y.D., Albahnasawi A., Al Maskari O., Al Maskari T., Abujazar M.S.S., Abu Amr S.S., and Nassani D.E. , Role of natural coagulants in the removal of heavy metals from different wastewaters: principal mechanisms, applications, challenges, and pro spects, *Global NEST Journal*, 2022, 24(4), 594-606.
- Ali Esmail Al-Snafi ,The chemical constituents and pharmacological activities of Cymbopagon schoenanthus: A review:*Chemistry Research Journal,* 2016, 1(5):53-61.
- Alina Pohl, Removal of Heavy Metal Ions from Water and Wastewaters by Sulfur-Containing Precipitation Agents: Water Air Soil Pollut ,2020, 231: 503.
- Amit Kumar Pathak,Water Pollution and Treatment. *International Journal of Environmental Engineering and Management*, , 2013,ISSN 2231-1319, Volume 4, Number 3 (2013), pp. 191-19.
- Andreas Kubier, Richard T. Wilkin, Thomas Pichler, Cadmium in soils and groundwater: A review : *Applied Geochemistry 108* ,2019, 104388.

- Arshid Bashir ,Lateef Ahmad Malik,Sozia Ahad, Taniya Manzoor, Mudasir Ahmad Bhat, G. N. Dar, Altaf Hussain Pandith , Removal of heavy metal ions from aqueous system by ion‑exchange and biosorption methods: *Environmental Chemistry Letters* ,2019, 17:729–754.
- Atif,B.A.M,Chemical profile, Antiprofilerative, Antimicrobial and Antioxidants Activities of Four Aromatic plants Growing in Sudan ph.D. thesis ,University of Khartoum ,Sudan ,(2019).

B

- B.C. Qi, C. Aldrich, Biosorption of heavy metals from aqueous solutions with tobacco dust:*Bioresource Technology 99* ,2008, 5595–5601.

C

- Celestine Uzoma Aguoru, Christopher Gbokaiji Bashayi and Innocent Okonkwo Ogbonna , Phytochemical profile of stem bark extracts of Khaya senegalensis by Gas Chromatography-Mass Spectrometry (GC-MS) analysis: *Journal of Pharmacognosy and Phytotherapy* ,March 2017,Vol. 9(3), pp. 35-43.
- Chaudhry FN and Malik MF,Factors Affecting Water Pollution: A Review: *J Ecosyst Ecography 2017*, 7:1DOI: 10.4172/2157-7625.1000225.

D

- Dhia Eldin.Elhag, Heba Omer Osman,Ali Aboel Dahab, Investigation of Mercury Content in Cosmetic Products by Using Direct Mercury Analyzer: *Am. J. PharmTech Res*. 2015, 5(5) ISSN: 2249-3387.

E

- Edris Ali,Md. Sadequl Islam,Md. Ismail Hossen,Mst. Minara Khatun,Md. Ariful Islam,Extract of neem (Azadirachta indica) leaf exhibits bactericidal effect against multidrug resistant pathogenic bacteria of poultry: *Veterinary Medicine and Sciencepublished by John Wiley & Sons Ltd*. 2021;7:1921–1927.

F

- Faegheh Kordbacheh& Golnaz Heidari, Water Pollutants and Approaches for TheirRemoval:*MaterChem.Horizons*,2023,2(2),139-153.

H

- H. Heumasse, S B A Omar and E B Demmallino ,Mercury (Hg) contamination on water, sediment and macrozoobenthos in Waelata River, Wamsait Village Waelata Sub-district, Buru District, Maluku Province: *Journal of Physic*s: Conference Series 1341 ,2019, doi:10.1088/1742-6596.
- Hina Khatoon and Jai Prakash Narayan Rai,agricultural waste materials as biosorbents for the removal of heavy metals and synthetic dyes– areview:*Oct. Jour. Env. Res*, 2016, Vol 4(3): 208-229.
- Hoda Abd El-Azim and Fekry A. Mourad, Removal of Heavy Metals Cd (II), Fe (III) and Ni (II), from Aqueous Solutions by Natural (Clinoptilolite) Zeolites and Application to Industrial Wastewater: *AJEE*, 2018,7(1): 1-13; Article no.AJEE.41004.

I

- Ikram Mohamed Eltayeb, Itmad Awad Elhassan, Jihad Hasab Elrasoul, Eiman Salah Eldin, comparative study of chemical composition of acacia seyal STEM, stem wood and stem bark dry distillates used by sudaneses women as cosmetic and medicine: *Int J Pharm Pharm Sci*, Vol 9, Issue 11, 218-224.
- Isiuku Beniah Obinnaa and Enyoh Christian Ebere 2019.Water pollution by heavy metal and organic pollutants: Brief review of sources, effects and progress on remediation with aquatic plants:*Analytical Methods in Environmental Chemistry Journal*, 2017 , Vol 2 (2019) 5-38.
- Isiuku Beniah Obinnaa and Enyoh Christian Ebere,A Review:Water pollution by heavy metal and organic pollutants: Brief review of sources, effects and progress

on remediation with aquatic plants, *Analytical Methods in Environmental Chemistry Journal*, 2019 , Vol 2 ,5-38.

J

- J.Muhamed Ali , Optimization Studies on the Removal of Metal Ions Using Modified Cation Exchange Resin: *International Journal of Innovative Research in Science, Engineering and Technology*, December 2015,Vol. 4, Special Issue 13.
- Jitin Ahuja*, J. Suresh, A. Deep, Madhuri, Pratyusha, Ravi, Phytochemical Screening of Aerial Parts of Artemisia parviflora Roxb.: A medicinal plant :*Der Pharmacia Lettre*, 2011, 3 (6):116-124.
- Junaid R Shaikh and MK Pati, Qualitative tests for preliminary phytochemical screen ing: An overview : *International Journal of Chemical Studies* ,2020, 8(2): 603-608.
- Jyoti Singh, Priyanka Yadav, Ashok Kumar Pal and Vishal Mishra :*Water Pollutants: Origin and Status,* 2021.

K

- K. Harshala and N. D. Wagh , Use of Agricultural Waste-Based Biosorbents for the Removal of Heavy Metals from Aqueous Solution: *Nature Environment and Pollution Technology*, 2022, Vol. 21, No. 3.
- Khushboo Chaudhry, Priti kumari , Madhu Agarwal,Heavy Metal Sources Impacts & Removal Technologies: *International Journal of Engineering Research & Technology*, 2014, *(IJERT)*ISSN: 2278-0181 .
- Krupa Unadkat and Punita Parikhm, A Review on Heavy Metal Absorption Capacity of Aquatic Plants: Sources, Impact and Remediation Technique: *IJAPRR International Peer Reviewed Refereed Journal*, Dec, 2017 ,Vol. IV, Issue XII, p.n. 23-30, Page 23.

L

- Lovell Agwaramgbo, Nichole Lathan, Shelby Edwards, ShaKayla Nunez, Assessing Lead Removal from Contaminated Water Using Solid Biomaterials: Charcoal, Coffee, Tea, Fishbone, and Caffeine : *Journal of Environmental Protection*, 2013, 4, 741-745.
- Luiz DruDe De LacerDa & OLaf MaLM, Mercury Contamination in aquatic ecosystems: an analysis of the Critical areas*: estudos avançados*, 2008, 22 (63).

M

- Magdalena Zabochnicka-Świątek ,Małgorzata Krzywonos , Potentials of Biosorption and Bioaccumulation Processes for Heavy Metal Removal: *Pol. J. Environ. Stud*, 2014, Vol. 23, No. 2, 551-561.
- Mahamudul Hasan, Laboni Begum, Shahadat Hosain, Pinku Poddar, Alauddin Chowdhury and Farhad Ali , Study on Heavy Metals (Zinc and Lead) in Drinking Water of Tannery Area, Adjacent Areas and Outside Village Areas: *journal J Environ Anal Toxicol*, 2017, 7:2DOI: 10.4172/2161-0525.
- Mahipal Singh Sankhla , Rajeev Kumar and Lalit Prasad , Zinc Impurity in Drinking Water and Its Toxic Effect on Human Health: *Indian Internet Journal of Forensic Medicine & Toxicology* ,October-December 2019, Vol. 17, No. 4, 84-87 DOI : 10.5958/0974-4487.
- Makut, M. D., Gyar, S. D., Pennap, G. R. I. and Anthony, P , Phytochemical screening and antimicrobial activity of the ethanolic and methanolic extracts of the leaf and bark of Khaya senegalensis: *African Journal of Biotechnology*, 2 May, 2008, Vol. 7 (9), pp. 1216-1219.
- Mamta Saxena, Jyoti Saxena, Rajeev Nema, Dharmendra Singh and Abhishek Gupta , Phytochemistry of Medicinal Plants: *Journal of Pharmacognosy and Phytochemistry*,2013, Vol. 1 No. 6.

- Manal Larakeb , Leila Youcef and Samia Achour, Removal of Zinc from water by adsorption on different adsorbent: *JNTM*, 2016,Vol. 06, N°01 ,19-25.
- Marwa Alaqarbeh, Adsorption Phenomena: Definition, Mechanisms, and Adsorption Types, RHAZES: *Green and Applied Chemistry*, 2021, Vol. 13, pp.43~51.
- Mika Sillanpää, Mohamed Chaker Ncibi, Anu Matilainen, Mikko Vepsäläinen, Removal of natural organic matter in drinking water treatment by coagulationChemosphere 190 ,2018, 54-71.
- Mochammad Sholehhudin, R. Azizah, Arif Sumantri ,Shaharuddin Mohd Sham, Zainul Amiruddin Zakaria, Mohd Talib Latif , Analysis of Heavy Metals (Cadmium, Chromium, Lead, Manganese, and Zinc) in Well Water in East Java Province, Indonesia: *Mal J Med Health Sci* , April 2021,17(2): 146-153.
- Mohammad Al-Shannag, Zakaria Al-Qodah, Khalid Bani-Melhem, Mohammed Rasool Qtaishat,Malek Alkasrawi, Heavy metal ions removal from metal plating wastewater using electrocoagulation: Kinetic study and process performance: *Chemical Engineering Journal* 260 ,2015,749–756.
- Monika Yadav, Gurudatta Singh, and R.N. Jadeja ,Physical and Chemical MethodsforHeavyMetalRemoval:https://www.researchgate.net/publication/35143898,April 2021,DOI: 10.1002/9781119693635.ch15.
- Muhammad Zaim Anaqi Zaimee, Mohd Sani Sarjadi and Md Lutfor Rahman, Heavy Metals Removal from Water by Efficient Adsorbents: Water 2021, 13, 2659. https://doi.org/10.3390/w13192659.

N

- Nour T. Abdel-Ghani and Ghadir A. El-Chaghaby, Biosorption for Metal Ions Removal from Aqueous Solutions: Areview of recent studies: *International*

Journal of Latest Research in Science and Technology, January-February 2014, Volume 3, Issue1: Page No.24-42 .

O

- Orwa C, A Mutua, Kindt R , Jamnadass R, S Anthony, Agroforestree Database:a tree reference and selection guide version 4.0,2009 , *http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp*.

P

- P. Moslehi and P. Nahid, Heavy Metal Removal from Water and Waste Water using Raw and Modified Diatomite: *IJE Transactions B: Applications* , August 2007 , Vol. 20, No. 2, 141.
- Parimal Chandra Bhomick, Aola Supong, Dipak Sinha, Organic pollutants in water and its remediation using biowaste activated carbon as greener adsorbent: *Int J Hydro*.2017;1(3):91–92.

R

- Ramandeep Singh Gambhir, Vinod Kapoor, Ashutosh Nirola, Raman Sohi and Vikram Bansal, J Hum Ecol .Water Pollution:Impact of Pollutants and New Promising Techniques in Purification Process, 2012 , 37(2): 103-109 .
- Roger Arnold , Khaya senegalensis – current use from its natural range and its potential in Sri Lanka and elsewhere in Asia :*Prospects for high value hardwood , Prospects for high-value hardwood timber plantations in the 'dry' tropics of northern Australia, Mareeba, 19th– 21st October 2004*.

S

- S. F. Mohd Noor, N. Ahmad, M. A. Khattak, A. Mukhtar, S. Badshah, R. U. Khan , Removal of Heavy Metal from Wastewater: A Review of Current Treatment Processes :*Journal of Advanced Research in Materials Science*, 2019 ,Volume 58, Issue 1 ,1-9.

- S. Thangamalathi and V. Anuradha, Role of Inorganic Pollutants in Freshwater Ecosystem A Review: *Int. J. Adv. Res. Biol. Sci*, 2018, 5(11): 39-49.
- Salaudeen Abdulwasiu Olawale ,Biosorption of heavy metals from aqueous solutions: an insight and review :*International Journal of Ground Sediment and Water*, 2021, Vol. 14 .
- Salman H. Abbas, Ibrahim M. Ismail, Tarek M. Mostafa, Abbas H. Sulaymon, Biosorption of Heavy Metals: A Review: *Journal of Chemical Science and Technology* , Oct. 2014, Vol. 3 Iss. 4, PP. 74-102.
- Sameer Mohapatro, Sandeep Rout, Ajay Kumar Prusty and Yagyavalkya Sharma, Phytochemical Properties and Biological Importance of Neem (Azadirachta indica)- An Overview : *International Virtual Conference On"Agricultural and Biological Science Research*,January2021,ISBN: 978-93-89817-54-6.
- Sara, S. Awad; Ali, A. Rabah; Hassan,. Ali, Tarig, E. Mahmoud , Acacia Seyal Gums in Sudan: A review: *Available online at* www.ejournals.uofk.edu , 2016 ,Vol. 6 pp. 94-98.
- Seema Tiwari, Seema Tiwari, H.L.Tiwari , Effects of Lead on Environment: *International Journal of Emerging Research in Management andTechnology*,2013,ISSN: 2278-9359 ,Volume-2, Issue-6.
- Shaymaa A. Gouda and Ayat Taha, Biosorption of Heavy Metals as a New Alternative Method for Wastewater Treatment :*Egyptian Journal of Aquatic Biology & Fisheries*, 2023, Vol. 27(2): 135 – 153 .
- Soisungwan Satarug,Jason R. Baker, Supanee Urbenjapol,Melissa Haswell-Elkins, Paul E.B. Reilly,David J. Williams, Michael R. Moore , A global perspective on cadmium pollution and toxicity in non-occupationally exposed population: *Toxicology Letters* 137 ,2003, 65 – 83.

T

- Tae-Young Kim, Sun-Kyu Park, Sung-Yong Cho, Hwan-Beom Kim, Yong Kang,Sang-Done Kim and Seung-Jai Kim , Adsorption of Heavy Metals by Brewery Biomass: *Korean J. Chem. Eng*, 2005,22(1), 91-98 .
- Tamirat Dula Chaemiso ,Tariku Nefo , Removal Methods of Heavy Metals from Laboratory Wastewater: *Journal of Natural Sciences Research*, 2019, ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) DOI: 10.7176/JNSR,Vol.9, No.2.
- Tatyana A. Lytaeva, Aleksandr E. Isakov , Environmental Impact of the Stored Dust-like Zinc and Iron Containing Wastes: *Journal of Ecological Engineering*, 2017,Vol. 18(3).

V

- Vinay Kumar, Munish Sharma, Sonica Sondhi, Komalpreet Kaur, Deepak Sharma, Shivali Sharma and Divya Utreja, Removal of Inorganic Pollutants from Wastewater: *InnovativeTechnologies and Toxicity Assessment: Sustainability* ,2023, 15, 16376.

W

- W.S. Wan Ngah , M.A.K.M. Hanafiah , Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents: A review : *Bioresource Technology* 99 ,2008, 3935–3948.

X

- Xiaofeng Liu, Xin Xu, Xiaoqiang Dong, Jounboum Park, Competitive Adsorption of Heavy Metal Ions from Aqueous Solutions onto Activated Carbon and Agricultural Waste Materials: Pol. *J. Environ. Stud* ,2020, Vol. 29, No. 1 , 749-761.

Y

- Y. Bai, B. Bartkiewicz , Removal of Cadmium from Wastewater Using Ion Exchange Resin Amberjet 1200H Columns : *Polish J. of Environ. Stud*,2009, Vol. 18, No. 6 , 1191-1195.
- Yassir Barkouch, El Khadiri Mohy Eddine, Alain Pineau, A New Approach to Understanding Well Water Contamination by Heavy Metals at a Mining Extract Region in Marrakech, *Morocco, Pol. J. Environ. Stud*,2016, Vol. 25, No. 3 ,1347-1351.