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Assessment and the Removal of the selected heavy metals from hospital and dumpsite wastes in Rwanda: Case Study CHUK and Nduba dumpsite

A dissertation submitted to the Department of Chemistry, School of Science, College of Science and Technology, University of Rwanda, in partial fulfillment of the requirements for the Degree of Masters of Science in Environmental Chemistry.

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ASSESSMENT AND THE REMOVAL OF HEAVY METALS FROM HOSPITAL AND DUMPSITE WASTES IN RWANDA: CASE STUDY CHUK AND NDUBA

Jean Bosco BIZIMANA

Qualification submitted in fulfillment of the University of Rwanda's Master's degree criteria for the School of Science, College of Science and Technology.

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ABSTRACT

Around the world environmental resources are contaminated by hospital and dumpsite wastes that are poorly managed. This study's objective was to evaluate and get removed of the chosen heavy metals from hospital and dumpsite wastes in Rwanda mainly in University Teaching Hospital of Kigali (CHUK) and Nduba Municipal Solid Wastes (MSW) dumping site. Various samples such as leachate, soil, ash and hospital wastewater samples were taken from CHUK and Nduba dumpsite. Using polyethylene (PE) bottles and bags, sampling was carried out during the dry and rainy seasons. The heavy metals were examined using MP-AES, or Microwave Plasma Atomic Emission Spectroscopy. The outcomes also demonstrated the CHUK waste's exposure to heavy metals. Wastewater samples revealed (Zn:4.835±0.60mg/L, Mn:1.894±0.40mg/L, Pb:0.343±0.06mg/L, Cd:0.123±0.03mg/L, Cu:0.502±0.05mg/L), and ash samples are the most concentrated samples with heavy metal (Zn:1280±12.7mg/Kg, Cd: 5.2±1.2mg/Kg, Cu:3570±204.3mg/Kg, Mn:116±19.4mg/Kg, Pb:25.2mg/Kg) Due to the in one of the wells near the CHUK and Nduba MSW dumping site, a very little amount of the heavy metals in question was found, more research is required, including hydro geochemical analysis of the area. It has been demonstrated that sawdust has a nice structure suitable for water filtration techniques. There are a number of factors that affect how heavy metals adsorb into sawdust biochar, although present research has focused on dose and contact time. According to this study, the rates of adsorption for lead, zinc, manganese, cadmium, and copper increased from 45 to 80%, 35 to 90%, 30 to 70%, 45 to 79%, and 15 to 71%, for hospital wastewater respectively, in addition percentage removal of lead, zinc, manganese, cadmium, and copper in leachates were 27 to 78%, 30 to 76%, 39 to 77%, 41 to 80%, 34 to 76% respectively. One of the most effective methods for addressing the wastewater issue is sawdust, which offers important benefits to consider.

***Keywords*:** Nduba MSW, heavy metals, environment, dumpsite, ash, soil, CHUK, leachate, saw dust, adsorptions, solid waste.

CERTIFICATION

This is to certify that BIZIMANA Jean Bosco, a student at the university, finished the master's thesis.

Supervisors: Dr. Gratien HABARUREMA

Signature

Dr. Jean Nepo HAKIZIMANA

Signature

DECLARATION AND COPYRIGHT

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I, Jean Bosco BIZIMANA hereby declare that, this master dissertation entitled *"Assessment and the Removal of the selected heavy metals from hospital and dumpsite wastes in Rwanda: Case Study CHUK and Nduba dumpsite*" is my own original work. It is submitted at the University of Rwanda for partial fulfilment for the award of the Degree of Masters in Environmental Chemistry of the University of Rwanda. This dissertation has never been submitted and will not be submitted elsewhere for any other award of a degree or academic certificate.

Student:

Jean Bosco BIZIMANA **Date: September /2024** **Signature: ……………………**

Supervisor(s):

We supervisors of this master dissertation, confirm for its originality and that it has been submitted for examination with our approval.

Dr. Gratien HABARUREMA **Date: September / 2024** **Signature:**

Dr. Jean Nepo HAKIZIMANA **Date**: **September/ 2024** **Signature:**

DEDICATION

To my all-powerful God

For my parents

To my siblings and family

To my dear friends and family

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LIST OF ABBREVIATIONS AND ACRONYMS

Cd: Cadmium

CHUK: University Teaching Hospital of Kigali

Cu: Copper

HW: Hospital waste

Jan: January

Mar: March

Mn: Manganese

MW: Municipal waste

Nov: November

Pb: Lead

SDBC**:** Sawdust biochar

TDS: Solids dissolved in total

TSS: Total solids in suspension

WW: Wastewater

Zn: Zinc

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1. Background

Heavy metals, inorganic pollutants, pesticides, and other persistent organic contaminants are just a few examples of the many environmental pollutants that can build up in the environment and then enter the body of a person, having a variety of harmful effects [1]. Different waste types provide obstacles for both environmental deterioration and human health [2, 3]. Without taking into account the potential risks of alleged harmful heavy metal contamination from the wastes, landfills are used as manure to promote crops in Rwandan urban communities [1, 4]. People who live adjacent to such places use the water bases nearby as a local water supply [4,5,7]. Toxic heavy metals that leach from the dumpsite frequently contaminate this water. It is well known that heavy metals accumulate in plants before being transferred to people through the food chain [6, 7]. Additionally, according to a study by Jiao and Kaifeng [5, 8] Both organic and inorganic wastes release leachate at the moment of disposal. This leachate, due of its harmful chemical composition could pollute surface soil and groundwater. Due to the lack of designed liners, leachate collection systems, and leachate treatment plants at several dumping sites in Rwanda [4,6,9], there may be a considerable danger of groundwater pollution in areas close to these sites.

Hospital Wastes (HW) are also mostly clinical and medical wastes, such as recognizable human body parts, medications, surplus microbiological stocks, human tissues, sharps, and old bandages and dressings [5]. If not controlled, these lead to sickness, contaminated soil, groundwater, surface water, and air. Hazardous waste from hospitals includes waste that can cause life-threatening infections, physical harm, and negative effects on the environment and public health [2,6,9]. Therefore, it is necessary to realize that HW must be handled and disposed of in a secure manner. The primary method of hospital waste management is typically waste incineration [10]. In many nations, especially developing nations like Rwanda, this strategy is the most widely used for disposing of medical waste [2,9]. High levels of heavy metal in the food chain are mostly caused by improper handling of ash leftovers from burning processes [10]. Then, their presence in the environment at large concentrations has a negative impact on the ecosystem and community health [4, 6]. Three times from medium and small incinerators, ash samples were taken. Metal concentrations of Cd, Cr, Cu, Pb, Fe, and Zn were calculated using Microwave Plasma Atomic Emission Spectroscopy (MP-AES). [2,8, 9].

The majority of solutions that have been suggested in scientific studies have been disregarded for the treatment of wastewaters because of financial limitations [11]. The best material for the purification process has been chosen after comparisons between a number of alternative materials for this goal. Of all the materials examined, sawdust exhibits the highest potential and was used to remove heavy metals in leachate and hospital wastewater.

1.2. Problem statement

The management of hospital and city wastes is a source of worry since poor collection and disposal practices have a negative influence on the environment, degrade the urban environment, and endanger the health of the general population living in cities. Because these wastes might harm water sources, land, air, and vegetation are all sources of nourishment, various studies have shown that people who live close to hospitals and dumpsites are most affected [2,9,13,14].

Numerous environmental issues have persisted as a result of the city's large population growth without adequate urban planning [14,15]. Among these issues is because of their current inability to do so, metropolitan authorities are unable to effectively manage significant volumes of solid garbage that are produced [4]. As a result, there is waste disposed of in an unmanaged and unsupervised manner, resulting in contamination and eventual heavy metal pollution of the environment. Due to their wide dispersion and numerous repercussions on the ecosystem, the latter scenario has become a global concern [12,15,16]. Batteries, plastic, paper, scrap metal, and other things that are known to be true sources of heavy metals make up a sizable portion of wastes that contain organic molecules [2,16]. Additionally, because heavy metals cannot biodegrade, they can accumulate in soils to hazardous amounts that are harmful to both plant and animal life [6]. Through ingesting contaminated drinking water, soil, or produce from contaminated land, traces of heavy metals may reach the human body [9,17]. Lead, mercury, cadmium, and copper are examples of metals that collectively pollute the environment and are said to be extremely poisonous [18]. These metals can cause carcinogenesis and are a key contributor to oxidative stress in cells [14, 19]. Heavy metals harm the brain and cause dermatitis, lung cancer, mental retardation, cerebral palsy, and gastrointestinal problems [20]. It has been demonstrated that several metals directly alter and create DNA adducts that damage DNA by causing chromosomal breakage [21]. This study examined the leachate generated by hospital waste from CHUK and the Nduba dumping site before determining if the environmental effects of the dumping site and hospital waste were significant. Thus, the findings aided in the discussion of appropriate waste management techniques. Sawdust as an adsorbent for the pre-treatment of hospital wastewater and leachate has been suggested because it is simple to get, inexpensive, and has a high surface area for active sites.

1.3 Research question

What percentage of specific heavy metals are present in the ash, wastewater, leachates, and hospital wastes from CHUK?

Can heavy metals be removed from hospital wastewater and leachates using sawdust biochar ?

1.4. General Objective

To quantify the level of heavy metals in the soil, ash, leachates, and waste water, as well as the community's perceptions of the health concerns associated with the Ndub a dumpsite and CHUK Hospital in Kigali, Rwanda.

1.5. Specific Objectives

i) To ascertain the amount of a specific heavy metal present in soil taken from the Nduba dumpsite

ii)To figure out the amount of a given heavy metal in samples of CHUK wastewater.
iii) To establish the level of specific heavy metal content in the leachate from the Nduba dumpin g site.

iv) To describe the CHUK incineration wastes' ash.
V) Using sawdust biochar to remove heavy metals from hospital wastewater and leachate.

2.0 LITERATURE REVIEW

2.1 Municipal Solid Waste Management Techniques

Because it is expensive and no applicable law has been implemented, waste management services are inadequate in many densely populated areas in both developing and developed nations [13, 19]. The prevalence of dumpsites inside residential areas in developing nations is a result of urban and regional planning that is subpar, not having implementation of applicable law and decrees regarding waste dumping, and a shortage of designated landfills [13, 17]. Due of this, home garbage and other refuse are released into the environment untreated. One of the reasons for the contamination of fresh water is surface run-off and leachates from dumpsites [22]. Modern population growth and industrial expansion have increased the generation of municipal, industrial, and home wastes, that are then carelessly thrown in water bodies and landfills without prior treatment [23]. One of the most significant health and environmental issues that African town governments must deal with is the management among municipal solid wastes [22, 5]. The majority of developing nations practice open dumping of solid wastes, which poses threats to the health of people and the environment [24]. Our environment the past transformed into a landfill to some extent by industrial development, neighborhood growth, and unplanned development [16, 25].

2.2 Environmental Impacts of Municipal Solid Wastes

Poor solid waste management results in ecological destruction, environmental deterioration, and serious health hazards for the community. The resulting buildup endangers the environment and puts the health of urban residents at risk [13, 22, 25]. Solid wastes can cause environmental problems such as health risks, water and soil contamination, unpleasant look, and objectionable odor. This causes the standard of our environment to degrade [22]. Most landfills are situated near populated areas and wetlands. It is hence prone to leak toxins into the air and adjacent water through dumpsite gases and leachates, respectively [26]. The majority of uncontrolled dumps are unmanaged garbage sites and are old, having expanded from tiny to big dumps over time [6, 27]. Numerous studies have demonstrated that soil samples are an effective medium for demonstrating how anthropogenic activities have caused heavy metal pollution [2, 24]. When heavy metals are present in soil, they can disrupt the ecosystem by leaking into groundwater or by posing an increased risk when ingested by plants and animals [28].

According to Wong's research [29], heavy metals may be hazardous to humans, animals, and crops when polluted soil is employed for crop production [1]. According to a recent study, agricultural lands cannot be used without risk due to the biosphere becoming contaminated with heavy metals caused by industrial, agricultural, and home activity [30]. Some landfills burn wastes out there, causing uncontrolled Ash at the locations while paying lack of focus on the effects on the environment. Some dumpsites burn waste in the open, causing uncontrolled ashes at the sites while paying no attention to the effects on the environment. Because of the risk of explosion and potential effects on the environment, especially water and soils, this directly endangers public safety. Burning garbage oxidizes the metals and removes the organic components, creating ash more abundant metals. Waste disposal facilities have the potential to release significant amounts of hazardous and persistent metals into the soil [31]. Plants absorb these metals, which then enter the food chain [32]. A plant's rate of metal uptake may vary depending on factors like the type of metal, the type of plant, the age of the plant, and the section of the plant [33]. Table 1.1 demonstrates the potential health risk that an increase in fictitiously harmful heavy metals poses to biota, including humans [22].

Table 1.1 Heavy metals effect in soil

Heavy metals	Effect of heavy metal in soil
Lead (Pb)	Organism metabolic abnormalities, Macronutrient shortage in the soil. Sabotage water balances. Cut back on soil productivity.
Cadmium(Cd)	Organism metabolic function anomalies Harm the enzymes alkaline phosphatase and protease
Zinc(Zn)	Affects soil fertility and is phototoxic Reduces the biomass of bacteria
Copper(Cu)	Decrease of the microbial biomass N

2.3. Health care waste management

The recent explosion in hospital waste disposal has caused widespread worry. A similar amount of residential solid wastes makes up 80% of the entire amount of rubbish from hospitals [34]. Radioactive wastes, medicines, hazardous wastes such Anatomical wastes, contaminated sharps, chemical wastes, infectious wastes, and pathological wastes make up the remaining 20% [35]. One of the biggest environmental concerns for local authorities is the elimination of these wastes, that have a significant likely to cause long-term health harm. Hospital wastes have undergone a variety of treatment and disposal procedures. However, in many places, the optimal method for disposing of hospital garbage has been determined to be incineration [4]. The latter methods result in ashes that can leak into groundwater and soil and are enriched with heavy metals. Abdas [22] claims that excessive amounts burned hospital waste ashes are leaking of Cd, Zn, and Pb. The concentrations of Pb (9.8 mg/L), Zn (4.2 mg/L), and Cd (1.1 mg/L) were higher than the concentration limitations for dumping of these minerals into dumpsite, studies that make use of the US EPA's leaching assessment. Then, much emphasis has been paid to an effort to stabilize the ash into a stable product that is good for the environment [29].

2.4 How heavy metals affect human health

The term "heavy metals" is now used to refer to metals with a density greater than 5 mg ml-1, which includes strontium, cobalt, aluminum, arsenic, cadmium, nickel, molybdenum, copper, vanadium, and zinc [36]. Nearly all elements, also referred to as trace elements or micronutrients, play important roles in the health of plant and animal cells. They only become dangerous when their internal concentration goes over a certain limit generally referred to as "heavy metals" [30, 37]. Municipal garbage disposal sites release heavy metals like Cd, Co, Cu, Fe, Hg, Mn, Pb, Ni, and Zn into the environment, which end up in the soil [35,38].

According to WHO guidelines, the average levels of lead, zinc, and cadmium in all of the veggies that were tested exceed the maximum permitted values, according to a report on the evaluation of heavy metals absorptions vegetables cultivated in areas Theca, Kenya [22,30]. According to EPA guidelines, the lead concentration in the veggies was observed to be higher than the 0.3 mg/kg upper limit that is considered safe for human health [2, 17]. According to Muiruri [40], there were indications of heavy metal bioaccumulation in the fish.

2.5 Some heavy metals

a) Zinc

For the proper operation of metalloenzymes such alcohol carbonic anhydrase, dehydrogenase, alkaline phosphatase, and (DNA,) (RNA) polymerase, zinc is a necessary nutrient for both humans and other animals [6]. If you consume too much zinc, you could have tachycardia, dyspeptic nausea and vomiting, vascular shock, pancreatitis, and hepatic parenchyma damage [41]. Zinc consumption is excessive, which inhibits the body's ability to absorb copper. Therefore, a surplus of zinc may have an impact on the development of copper deficiency and the availability of dietary copper [42]. Thus, dermatitis, inadequate wound healing, anorexia, growth retardation, and impaired mental function may all be symptoms of zinc deficiency [41, 42].

b) Copper

Hemoglobin production, the process of digesting carbohydrates, the metabolism of drugs and xenobiotics, the production of catecholamines, and the antioxidant defense mechanism may all depend on copper. A high quantity of copper can cause health problems such liver and kidney damage, anemia, and developmental toxicity [22]. Some enzymes, such glutathione reductase and glucose 6-phosphatase, can have copper fix to their sulfhydryl groups, which interferes with their ability to shielding cells from oxidative damage [42].

c) Manganese

All animals require Manganese for normal body function and development throughout their lives [43]. Additionally, manganese binds to and controls a variety of enzymes in the body [24]. Since the brain retains manganese for a considerably longer period of time than other tissues, it is the primary target organ for manganese toxicity [44].

d) Iron

In general, consumption of iron lowers the risk of estrogen and kidney cancers Syrian hamsters and rats, respectively [22]. For a wide range of metabolic processes, iron serves as a catalytic center. Additionally, it is a part of cytochromes necessary in place of the energy production and the immune system's enzymes [2]. The finding that some cases of iron deficiency anemia have low serum copper levels suggests that iron status affects copper metabolism [45]. A lack of iron can impair cognitive function, lower learning ability, weaken the immune system, decrease productivity at work, decrease physical fitness, increase distractibility, and lead to eating disorders like pica [46].

e) Nickel

Although its functional significance has not been clearly established, nickel is a necessary trace metal found in animals [46]. According to reports of nickel deficiencies in several animal classes, it is evident that it is needed. The effects of nickel deficiency are largely shown in the liver and consist of modified cellular structure, oxidative metabolism, and adjustments to lipid levels [32].

f) Vanadium

Vanadium generally has minimal nutritional value and is not necessary for humans [28]. As a result, no recognized dietary guidelines or intake requirements exist [47]. It has been demonstrated that vanadium compounds can imitate the effects diabetes humans [48]. As a result, their effectiveness in the treatment of diabetes mellitus has been evaluated [49]. Vanadium is accumulated and stored in the bones and is rather hazardous to animals, according to several studies [42].

g) Cobalt

Cobalt is a mineral that the body requires and that has been detected in a variety of bodily tissues, with the liver having the highest quantities [41]. Numerous studies have shown that the latter element enters the atmosphere and combustion using catalysts made from cobalt compounds and oil, paint driers, and colorants in glass, ceramics, and paints [50]. The main sources of exposure for humans are water, food, and drinking water when cobalt moves through it is related to particles in the air that will eventually fall to the ground [51].

h) Mercury

The environmental pollutant mercury is thought to cause a wide range of harmful health effects in people [52]. The most prevalent naturally occurring forms of mercury in the environment are metallic mercury, mercuric sulfide, mercuric chloride, and methylmercury [16, 52]. Each of them has a unique toxicity profile. Metallic and inorganic mercury are released into the atmosphere as a result of mining deposits of mercury-containing ores and coal-fired power plant emissions [6]. Methylmercury is an organometallic molecule that can enter the food chain and build up there [1].

I) Lead

Lead element is a toxic element that can be damaging plants [28]. The latter chemical component is also referred to as a neurotoxic and can harm a child's neurodevelopment [53]. Fetuses and breastfed newborns are exposed to lead because it is mobilized from bones and builds up in the skeleton during pregnancy and lactation [41]. On a cellular and molecular level, it has been suggested that lead may intensify carcinogenic processes [2]. Radicals, harmful compounds that result in the oxidation of biological components, may also be produced by this kind of poison [54].

2.6 Controlling heavy metal toxicity

The peculiarity of metal poisonousness is that the toxic agent may be resistant to the metabolic process [55]. Metal-containing compounds can undoubtedly be digested to speed up excretion, and metal characteristics can alter, however, the body is unable to change a harmful metal into a non-toxic metal [13]. Chelators are a common treatment for metal poisoning. They are capable of processing stable compounds with cationic metal atoms are referred to as a Chelators [42]. After then, the complexes are expelled from the body. Ethylenediaminetetraacetic acid (EDTA) is a common Chelators [2, 54].

2.7Adsorption process as a way of heavy metal removal

Various researchers are always working hard to develop techniques that are effective for removing heavy metals from water [55,57,58]. The primary methods used in the processes to remove heavy metals include minerals used for adsorption, activated carbon adsorption, electrolytic recovery, ion exchange, reverse osmosis, solvent extraction, cementation, electro deposition, ultrafiltration, and electrochemical precipitation are some of the processes that are used [56, 57]. Several methods exist to remove heavy metals from water, although the majority of them involve chemical processes have a number of shortcomings that keep them from working as intended. The bulk of these technologies are actually impracticable to employ because of their complexity, high running costs, the metal ions' poor selectivity , production of sludge , and inability to thoroughly clean water low (less than 50 ppm) heavy metal ion concentrations [58]. Many methods to eliminate excessive concentrations of heavy metal ions have been proposed in the literature over the past few decades, but only a small number of these have been authorized and put into practice due to the various factors mentioned above. Because of this, recent research has concentrated on developing better, more potent methods that can result in superior heavy metal removal results [11]. One of the important directions in the search for novel, more effective, and selective methods and materials is the study of agricultural wastes technologies [72].

2.8 Activated carbon

There are four different types of activated carbon: powder, granular, liquid, and solid, fibrous activated carbon, and fabric activated carbon. Every form is different and has its own uses. Heavy metal ions can be successfully removed from wastewater using activated carbon because of its wide increased surface area and surface reactivity [57] because it is possible to chemically modify activated carbon by changing its surface area.

2.9 Agriculture residual as adsorbent

Studies nowadays are expected to promote the use of inexpensive substitutes for activated carbon and other methods for recovering heavy metals from wastewater because Cost-related issues with activated carbon have been demonstrated [52,59]. Low-cost adsorbent can be divided into four categories: industrial wastes, natural materials, agricultural wastes, and other low-cost adsorbents [59]. Each of these categories will be briefly reviewed in relation to the capabilities of activated carbon since they are all alternatives to activated carbon that might be used to purify wastewater. Because agricultural wastes, like orange peels, are abundant in nature and have no much economic value, and if not utilized in any known processes poses a dumping issue [60]. By changing their surface or turning them into activated carbon, agricultural wastes can also be offered extra chemical benefits. The results show that certain agricultural wastes have significantly improved metal adsorption capacity, making chemical augmentation of agricultural wastes a feasible strategy for heavy metal removal from wastewater. Agricultural wastes modification comes at a high price, but research indicates that the metal removal capability that may be acquired for these wastes may be able to offset this process [58].

3.0 MATERIALS AND METHODS

3.1. Study Location

Various samples were collected from both University Teaching Hospital of Kigali (CHUK) hospital and Nduba dumping site locate in Kigali city capital city of Rwanda. CHUK is located at Nyarugenge district, Gitega sector (see Figure 3.1 a) while Nduba dumpsite is located Gasabo district Nduba sector (see Figure 3.1b). Saw dust was collected from Agakiriro Kayonza.

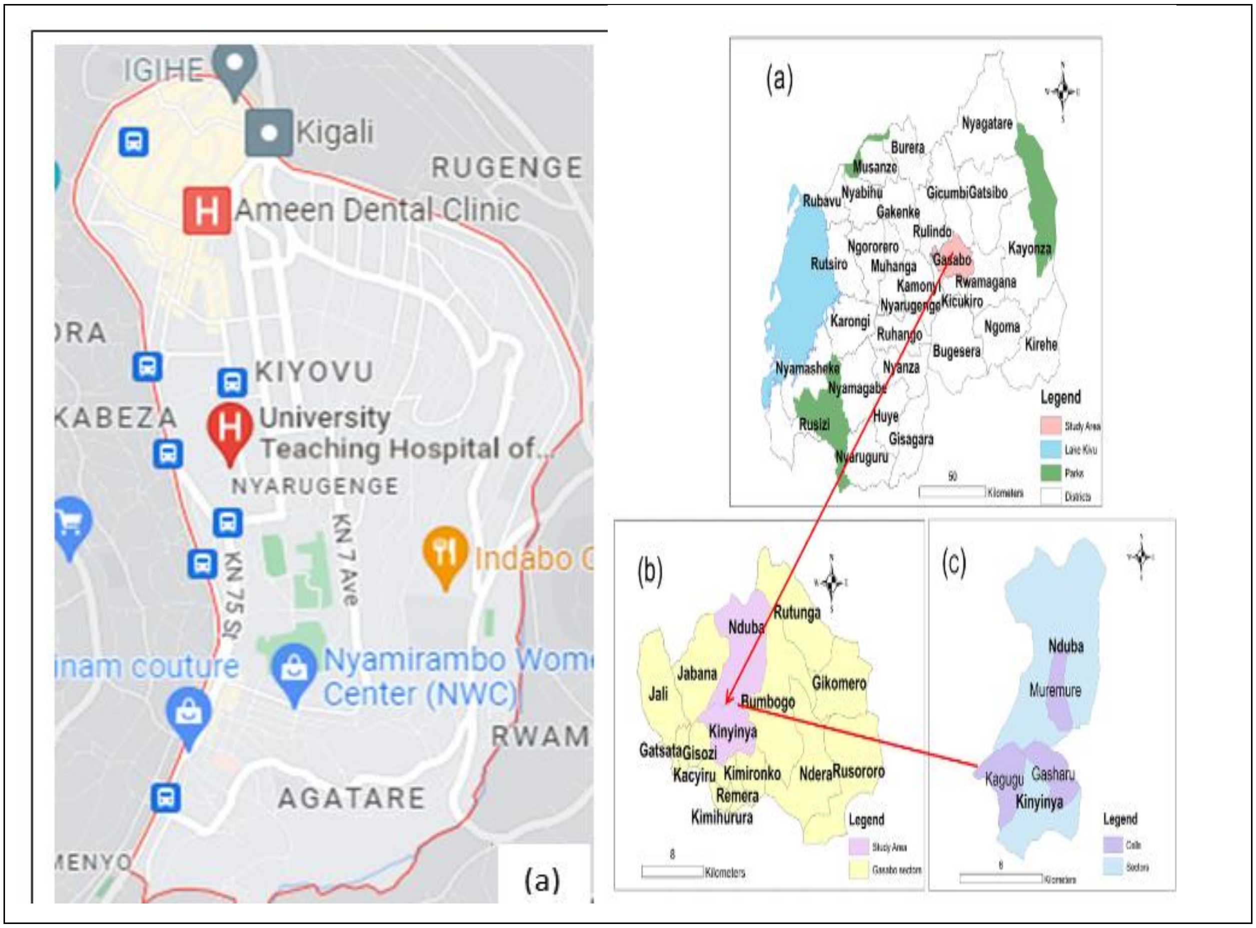

Figure 3.1 Map showing the study areas CHUK (a) and Nduba dumpsite (b).

3.2 Methods for Analysis

In soil samples, leachates, wastewater, and ash samples, the analytical approach enabled to calculate the mean heavy metal concentrations. To evaluate the environmental impact of the hospital waste and dumpsite samples of ash, water, leachate, and soil were taken and examined The levels of heavy metals in several areas were assessed using MP AES. In order to observe changes in heavy metal concentrations following a month of garbage disposal, samples were taken in the months of November (Nov), January (Jan), and March (Mar). We chose these months to compare the presence of heavy metals during periods of heavy precipitation (November and March) with periods of light precipitation (January).

3.3. Analytical procedures

3.3.1 Sampling Methods

3.3.1.1. Soil sample collection and preparation

Around Nduba dumpsite, soil samples were taken. Following air drying, crushing, sieving, and storage at room temperature for laboratory analysis, the soil samples were cleaned up and placed in clean polythene bags.

3.3.1.2. Water sample and leachate collection and preparation

The CHUK and Nduba dumpsites were used as the source for the wastewater samples that were taken utilizing the depth integrated water sampling technique. A composite sample was created by combining the samples [7,17,19]. According to established protocols, a 500 ml representative sample was taken from this and placed in white plastic bottles [3,7,32]. Leachate was gathered similarly to how wastewater was gathered earlier in this explanation.

3.3.1.3. Ash sample collection, preparation and analysis

After cooling to normal temperature, ash was removed from the bottom of the incinerator since it was more stable there. Heavy metal tests using the TCLP (Toxicity Characteristic Leaching Procedure) parameters including Cu, Zn, and Pb were used to examine the features of untreated bottom ash [1,7,22,28,32]. The addition of water and pH measurement were the first steps in the TCLP processing process. This value must stir for seven and a half hours while rotating at 300 rpm. The parameters Cu, Cd, Zn, Mn, and Pb were used to measure the results of the TCLP processing using the MP-AES method.

3.3.2. Heavy metal concentration determination

3.3.2.1 Determination of heavy metal concentration in soil samples

One gram of soil was mixed with 18 milliliters of concentrated HCl and 6 milliliters of concentrated HNO_3., and the mixture was then slightly moistened with deionized water. A heated plate was used to slowly boil the combination until only 5 to 11 ml of extract remained. The mixture was then allowed to cool for around 15 min. 18 ml of concentrated HCl and 6 ml of concentrated HNO_3 were added when there was between 5 and 11 ml of extract left in the flask. After cooling, the extract was felted through Whatman no. 42 filter paper with 50 ml of distilled water. Equation (1) was employed to estimate the concentration of heavy metals in soil and solid waste samples. [61].

$$C_s=(C_m-C_b)50/W \qquad \text{equation (1)}$$

where, the following is how metal concentrations are expressed: W = mass of air dried solid waste and soil sample digested (g), where CS = metal concentration in soil, air dried basis (mg/kg), Cm = metal concentration in digest (mg/l), Cb = metal concentration in blank (mg/l), and Cm = metal concentration in digest (mg/l).

3.3.2.2. Determination of heavy metal concentration in wastewater samples

Water samples were digested with aquaregia (HNO_3 67%: HCl 37% = 3:1) in order to evaluate the concentrations of heavy metals in all prepared samples that were gathered. a typical set of standard calibration curves with higher linear regression and better relative standard deviations for measuring heavy metals

3.3.2.3. Determination of heavy metal in leachates

For a heavy metal solubility investigation, the leachate samples from the Nduba dumping site were felted and kept concentration in leachate. Several heavy metals were examined with a drop of very concentrated nitric acid. The conserved leachate was used to evaluate the heavy metals Cd, Cu, Mn, and Pb.

3.4. Conventional solution preparation

Copper sulfate ($CuSO_4.5H_2O$), cadmium sulfate ($CdSO_4.8H_2O$), manganese sulfate ($MnSO_4.7H_2O$), and lead nitrate [$Pb(NO_3)_2$] produced using distilled water with a concentration of 1,000 ppm were used to make copper, cadmium, manganese, and lead standard solutions [2,13].

3.5 Batch heavy metals removal by activated carbon from saw dust

To get rid of any dust and other contaminants, saw dust was first washed with tap water, then given a second wash with deionized water. In order to use saw dust as activated carbon, it was then sun-dried. Second, the chemical activation step was carried out by combining 1.8 weight units of concentrated H_2SO_4 with 1 weight unit of sawdust. Following that, the sample was dried for a day at a temperature of 150˚C. The carbonized material was repeatedly rinsed with deionized water to ensure the removal of the free acid before being dried at 105°C then saw dust biochar made by heating the residuals saw dust at 450-600˚C in furnace for 4hours. Figure 3.2 showed the process to prepare saw dust biochar as adsorbent.

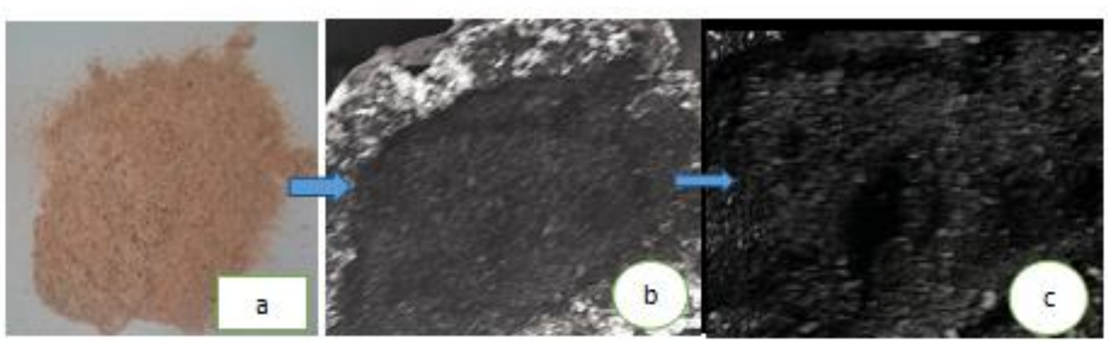

Figure 3.2 Sawdust (a), carbonized sawdust (b) and sawdust biochar (c).

This saw dust biochar substance was used in the current study to adsorb copper, cadmium, zinc, manganese. The adsorbent's particles ranged in size from 0.6 to 1 mm removed percent was calculated by this equation (2).

$$R\% = \frac{(C_0 - Ce)}{CO} 100. \qquad \text{Equation (2)}$$

Where C_o is initial concentrations, C_e concentration after treatment

3.5. Instruments

Using MP-AES, ash, leachate, soil, water waste, and heavy metal concentrations were all measured [34].

3.6. Analyzing Data

Utilizing typical descriptive statistics, the data were calculated. To calculate the means and standard deviations of the identified metals, descriptive statistics were used. The levels of heavy metals discovered in bottom ash were over USEPA's allowed limits, whereas those found in soils were in line with crucial allowed limits for heavy metals in soils [53]. The link between the metals in the soil was evaluated using Pearson correlation analysis.

4.0 RESULTS AND DISCUSSIONS

Although heavy metals are normally present in nature and necessary for life, they can become harmful when they bioaccumulation in living things [24,25,26,27,30]. In this work, as previously noted, we evaluated heavy metals from hospital wastes and a dumpsite in Rwanda. Heavy metals were examined using MP-AES. The analytical results of soils samples in March (Pb:2.080±0.047mg/Kg,Cd:2.096±0.545mg/Kg,Cu:1.352±0.569mg/Kg, Zn:16.017±0.624mg/Kg, and Mn:12.305±1.058mg/Kg) demonstrated that municipal solid wastes include heavy metals that leak into the soil and nearby farms. The results of the MSW dumping site in Nduba's leachates analysis in March (Zn:11.953±3.511mg/L, Pb:3.783±1.212mg/L, Cu:0.08±0.002mg/L, Cd:0.017±0.001mg/L, Mn; 1.574±0.121mg/L) indicated that different wastes are mixed with heavy metals containing materials. The results of the analysis in March of the CHUK wastewater were; Zn:4.835±0.60mg/L, Pb:0.343±0.06mg/L, Mn:1.894±0.40mg/L, Cu:0.502±0.05mg/L, Cd:0.123±0.03mg/L. This study in March revealed that ash samples were the most polluted samples with a high level of heavy metal; Zn:1280±12.7mg/Kg, Cd: 5.2±1.2mg/Kg, Cu:3570±204.3mg/Kg, Mn 116±19.4mg/Kg, Pb:360±25.2mg/Kg. The findings indicated that too many heavy metals were present in two different types of samples from two different research regions, including leachate from the Nduba dumpsite and ash from hospital wastes. According to numerous research, persistent heavy metals build up in the environment and contaminate food chains [1]. Additionally, the effect of adsorbent dosage on the lead, zinc, manganese, cadmium, and copper ion adsorption on activated saw dust was examined. The rates of adsorption increased for lead, zinc, manganese, cadmium, and copper from 45 to 80%, 35 to 90%, 30 to 70%, 45 to 79%, and 15 to 71% for hospital wastewater respectively, in addition percentage removal of lead, zinc, manganese, cadmium, and copper in leachates were 27 to 78%, 30 to 76%, 39 to 77%, 41 to 80%, 34 to 76% respectively .Lead, zinc, manganese, cadmium, and copper ions are adsorbed onto activated sawdust in Figures 5 and 6, depending on the amount of 3g/L adsorbent in contact with the surface for 60 to 420 minutes.

4.1. Ash chemical characteristics

Ash from hospitals (HW) is not appropriate. Lead, zinc, manganese, cadmium, and copper all experienced a rise in adsorption rates respectively. Any kind of trash that differ from conventional MSW ashes because they include comparatively high levels of heavy metals. When compared to MSW ash the levels of the toxic heavy metals Cu, Pb, Cd, and Zn in HW ashes are much greater (see table 4.1) [31,33,35,36]. The findings showed that high leaching levels of Pb, Cu, Cd, and Zn in HW ash exceeded USEPA legal values; as a result, HW ashes should be adequately cleaned before being dumped to prevent environmental pollution [23,29,34,37,39,40].

Table 4.1 Heavy concentration in ash

Parameter in mg/kg	Nov	Jan	Mar	USEPA limits
Zn	1202.5±20.1	1305±31.6	1280±12.7	NA
Cd	7.2±1.4	10.1±1.9	5.2±1.2	1.0
Cu	3000±153.5	2520±189.5	3570±204.3	5.0
Mn	86±7.8	90.5±5.7	116±19.4	5.0
Pb	307.5±12.3	375±14.2	360±25.2	5.0

According to recent laboratory chemical analysis investigations, hospital waste ashes contained significant levels metal salts, such as Potassium, aluminum and sodium with concentrations ranging from 1.8 to 315 g kg^{-1} [50]. Similar to this, the ashes had substantial concentrations of heavy metals, including silver, cadmium, manganese and copper with a wide range of 1.1-121,411 mg kg^{-1} [62]. Additionally, the findings of the TCLP revealed that practically of fly ash sample Cd, Cu, and Pb leached amounts were higher than USEPA-required values [35].

Waste from hospitals has a significantly different makeup. Rubber, metal cans cotton, glass scalpels, syringes, needles, plastics, and small metallic medical instruments are typically found in hospital waste [25,38,41,44,50,53]. It is intriguing to discover that Cu and Zn contents in these hospital waste incinerator ashes are substantially greater than those found in previous research. This may be because different raw HW materials were used. Hospital wastes frequently contain a significant amount of plastic material, and the Zn that is added to these polymers is common. For instance, medicinal applications of PVC equipment frequently contains this pair substances, also that particular class contains plastics as well large concentrations of chlorides, which causes a high rate of zinc conversion into fly ash because $ZnCl_2$ is produced, which lowers the boiling point (732 °C). Medical adhesive plaster and alloys used in the manufacture of needles and syringes both include zinc [10].

In the process of incineration, cadmium (Cd) can result in instable compound as a result, it is simple to filter out of the ash in natural settings, demonstrating that the quantities of Cd in ash were relatively low in comparison to other heavy metals [50]. In addition to having high volatility, these very volatile compounds ($CdCl_2$, $ZnCl_2$, and $PbCl_2$) can also be easily formed by a few heavy metals, such as Pb, Zn, and Cd which is why they frequently wind up in fly ash during the cremation process [62]. Pharmaceuticals, photography materials, medical equipment and other products are regularly found to contain these heavy metals in the field of medicine. Most medical instruments comprised alloys of Bi, Pb, Sn, and Cd [27]. Hospital rubber and an important source of Zn in household waste (HW) is waste plastic [63].

4.2 Physico-chemical characteristics of Hospital wastewater

4.2.1. Hospital wastewater physical characteristics

The hospital under investigation's wastewater was found to have an average pH of 7.8. The US Environmental Protection Agency accepts the indicated range (6.8–8.4) as suitable for wastewater treatment operations [27,29,45,54,60,61]. According to the Nation Sanitation Foundation (NSF) worldwide standard from 2011, which says that the range for TSS in hospital effluent must be between 100 and 300 mg/L as reported in earlier studies [46,55,64,65,70], the measured TSS of 88.5 mg/L was below range. The temperature was also lower than the Environmental Protection Agency's recommended limit, which stated that the temperature of wastewater may range from 20 to 35^{o}C [27,32,47,54,66]. The hospital under investigation had wastewater with an average pH of 7.8. The indicated range (6.9–8.3) is accepted by the Iran Environment Protection Agency and reasonable from the perspective of wastewater treatment operations (see Table 4.2).

Table 4.2 pH, TSS, TRB, Temperature in hospital wastewater

Parameters	Nov	Jan	Mar
pH	7.8	8.6	6.9
TSS(mg/L)	98.5	105.6	51.8
Turbidity (NTU)	58	70	64
Temperature	22.5	25.6	24.5

4.2.2 Hospital wastewater chemical characterization

Due to their poisonous nature and other negative impacts, a significant issue in the treatment of hospital wastewater is heavy metals [27,48,51,53]. According to the World Health Organization (WHO), 10% of hospital wastes are infectious, 5% are non-infectious, and 85% are not harmful. Hospital wastewater discharges include radioactive elements, harmful chemical species, partially metabolized medications, and other heavy metals like copper manganese, and zinc [52,65,67,70]. Zn, Pb, Mn, Cu, and Cd variations in CHUK hospital effluent are displayed in Table 4.3. The greatest discovered analyte in hospital wastes was zinc, and this may be because more hospital supplies were used that contained zinc alloys, as has been previously documented [27,35,56,57].

Table 4.3 Heavy metal concentration in hospital waste water

Parameter mg/L	Nov	Jan	Mar
Zn	3.06±0.56	2.605±0.78	4.835±0.6
Pb	0.145±0.02	0.262±0.08	0.343±0.06
Mn	2.096±0.22	2.76±0.29	1.894±0.4
Cu	0.605±0.03	0.393±0.03	0.502±0.05
Cd	0.468±0.04	0.159±0.03	0.123±0.03

Hospital wastes contain high levels of Cr, Cu, Zn, Pb, and Mn, which could have a deleterious effect on local flora and fauna inhabiting these aquatic settings. Zn and Cd are associated with the highest and lowest heavy metal concentrations in hospital wastewaters, respectively [66]. Zn > Cu > Pb > Cd was the overall order of heavy metal concentrations in wastewater (see table 4.3). Hospital wastewater discharges are merely one source of contamination, as evidenced by the high values of the probable effect level that were seen upstream of them. Indeed, a variety of human activities (such as industrial, sewage, agricultural land use, mining, etc.) are known to release heavy metals into the environment [67], and these activities may also be to blame for the high metal levels found in upstream HW water effluent discharge.

4.3. Soil chemical characteristics

Groundwater and soil contamination can arise from improper garbage disposal. Paper, food scraps, glass, ceramics, metal shavings, and ashes are all components of municipal solid waste [1,5,8]. An unhealthy ecosystem arises from an abundance of heavy metals in the soil, and this has an effect on the general health of all living creatures. Heavy metals in the soil cause changes in soil quality and fertility. Pb lasts a very long time on the soil's surface [62,63,64,68]. In addition, cadmium strongly attaches to organic matter, stifles in the ground, is taken up by plants, and finally makes its way into the food chain [48]. In addition to having a negative impact on plant production and quality, heavy metal pollution also causes changes in the makeup and activity of the soil microbial population [55,71,74]. One of the key factors in soil pollution is thought to heavy metals being present. Cu, Cd, Zn, Mn, and Pb are the main metals responsible for heavy metal contamination of the soil [42,47,59]. Numerous variables, the quantities of heavy metals in the soil close to garbage dumps depend on a variety of factors, such as the type of waste, runoff, geography, and degree of scavenging. [2,6,11]. Groundwater and soil contamination can arise from improper garbage disposal. The findings from soil samples taken at the Nduba dump site are displayed in Table 4.4.

Table 4.4 Heavy metal concertation in soil

Parameter mg/Kg	**Nov**	**Jan**	**Mar**
Zn	16.727± 1.123	14.506±1.251	16.017±0.624
Pb	1.570±0.052	2.350±0.923	2.080±0.047
Mn	13.258±2.062	11.937±2.762	12.305±1.058
Cu	0.809±0.023	1.589±0.054	1.352±0.569
Cd	1.894±0.237	2.76±0.098	2.096±0.545

Even though they are present in nature, heavy metals like lead, mercury, and cadmium are far from being benign. They can be found in a wide variety of goods, including sweets, paints, hair dyes, and even automotive and art supplies [13]. Lead-containing old paint deteriorates into dust that is safe to consume [68]. Human activities, such as the production of trash and its disposal in landfills and other disposal facilities, have been connected to heavy metal soil pollution. The concentrations of heavy metals in the soil close to rubbish dumps are influenced by the different types of waste, the terrain, run-off, and level of scavenging [66].

4.4. Physico-chemical of characteristics Leachate

4.4.1 Physico characteristics of leachate

Any polluted liquid, known as leachate, is created when water percolates through a solid waste disposal site, picking up contaminants as it goes, and then moves into subterranean areas. Another source of leachate is the high moisture content of some discarded wastes. Evaluations of a few significant pollutant parameters from the Nduba dump site at various locations are shown in table 6. It has been noted that the Nduba dump site's pH is primarily in the alkaline range and that electrical conductivity is elevated [49]. Leachates from Nduba landfills may have low pH values due to the presence of bicarbonate ions and carboxylic acids in the dumpsite. TDS ranges from 8900 to 12601mg/L. According to the study, an increase in the concentration of dissolved organic and inorganic compounds was associated with a decrease in the TDS value [69,71].

Table 4.5 pH, EC, TDS, and Temperature in leachates

Parameter	Nov	Jan	Mar
pH	6.8	8.4	7.9
Temperature	29	19	27
Ec(µs)	223000	14500	21800
TDS(mg/L)	8900	12601	11200

4.4.2 Chemical characteristics of leachate

Municipal solid wastes that contain organic material are broken down by microorganisms into leachate, which is a poisonous liquid that contaminates land and water because it contains heavy metals, organic materials, and macro-inorganic elements [22]. As a result, leachate-filled landfills in underdeveloped nations are unsuitably managed; Unchecked leachate flows, spreads, and seeps into the groundwater, damaging the ecosystem and people living there [26].

Metals such as Zn, Fe, Cu, Cr, and Ni function as micronutrients necessary for plant growth. As a result, at some concentrations, they are necessary for their correct operation and can promote development, but once they exceed certain threshold values, they are toxic to them. High metal concentrations can interrupt germination and prevent the growth of roots or shoots. Even at low concentrations, a few heavy metals, like Cd or Pb, can be hazardous toward plants [70]. Table 4.6 displayed the measured parameters in comparison to the EPA's [1,17,74] criteria for environmental protection.

Table 4.6 Heavy metal concertation in leachates

Parameter mg/L	**Nov**	**Jan**	**Mar**	**EPA stand**
Zn	11.761±2.981	12.287±4.232	11.953±3.511	5.00
Pb	2.996±1.032	3.721±1.201	3.783±1.212	0.05
Cu	0.193±0.051	0.227±0.002	0.08±0.002	-
Cd	0.005±0.001	0.008±0.002	0.017±0.001	0.01
Mn	0.967±0.052	1.356±0.123	1.574±0.121	0.05

Leachate taken from the Nduba MSW dumping site was found to have 3.5 mg/L of Pb. Pb being present in the leachate samples may indicate that lead-containing batteries, photochemical, paints, and pipes were properly disposed of at the landfill [6]. Pb batteries that had been discharged were found in the Nduba MSW dumping site. Lead in the leachate samples may have come from pipes and Pb-based paints as well as other sources. Leachate samples had lead concentrations above the 1 ppm European limit for industrial effluent that cannot be dumped into the environment.

The leachate from the MSW dumpsite in Nduba contained an average quantity of Cd of 0.01 mg/L. According to the European Directive on Industrial Waste Streams, specific water bodies only allowed to be released into those that have been authorized by authority agencies (0.02 ppm), upstream leachate concentration in Cd. Copper (Cu) average contents in the leachate samples taken from the Nduba MSW disposal site were 0.25 mg/L, respectively. Given that metal solubility often declines with rising pH [16], these low values could be the result of copper ions complexing. Since the pH of the Nduba MSW dumping site was in the range of 7.9 to 8.9, copper may have been eliminated by the precipitation and complexation processes. The primary cause of the low copper concentration is because few of the solid wastes that are discharged at Nduba MSW have copper in bioavailable forms. This is a sign of a strong leaching process at the Nduba MSW disposal site.

4.5 Removal of heavy metal from Hospital wastewater and leachate

4.5.1 Saw dust biochar characterizations

Fourier-transform infrared spectra have been produced to identify chemical groups and study their various properties in presence of metal cations. Figure 3 displays the FTIR spectrum of (a) sawdust biochar, (b)carbonized sawdust (b) pine sawdust. The significant peak at 3398.3 cm^{-1} could indicate both the presence of C-O and N-H vibrations on the surface of the sawdust as well as an overlap between -OH and -NH stretching [11]. The spectra show peaks between 500 cm^{-1} and 3400 cm^{-1}. The necessity of hydroxyl groups as a component of sawdust is demonstrated by Fourier-transform infrared spectra, underscoring the significance of sawdust in luring heavy metal ions.

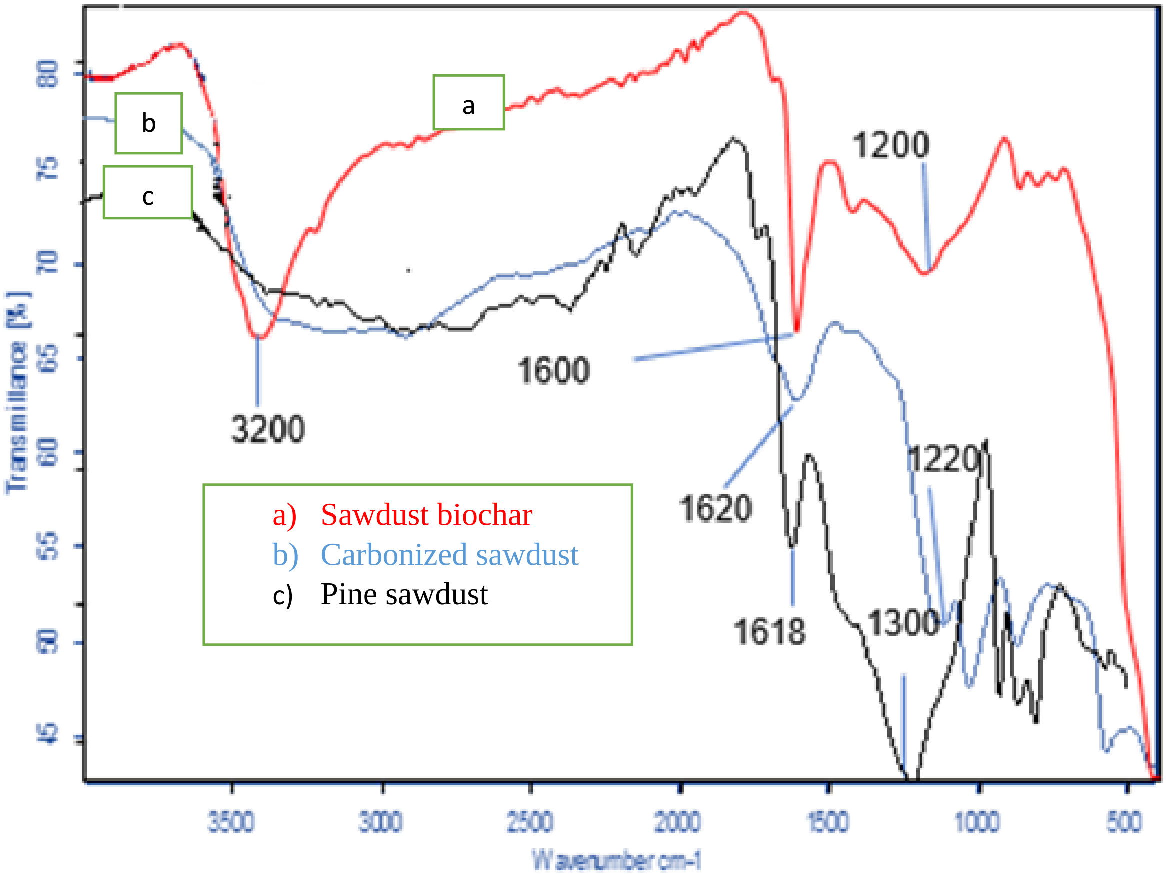

Figure 4.3 Activated saw dust characterization.

4.5.1 Adsorption mechanisms

The FTIR spectra of saw dust biochar after heavy metal adsorption are contrasted with those of synthetic biochar in order to comprehend how the heavy metal removal method works [71]. The peak shifting from 1600 to1618 cm^{-1}, 16300 to 1220 cm^{-1}, and 3200 to 2988cm^{-1}influence the formation of large surface of adsorbent to adsorb heavy metals [1,72,74]. This shows that the functional groups COO-/C==C/C==O, C==O (carboxyl/ester), and O-H have reacted with heavy metals to alter the vibration frequency of the bonds. Peaks in the SDBC at 1090 cm^{-1}, 1927 cm^{-1}, and 3400 cm^{-1} may be seen varying.

4.5.2. Efficient of saw dust in heavy metals removal

4.5.2.1. Effect of dose to remove heavy metals in wastewater.

Figures 4.4 and 4.5 depict the effects of adsorbent dosage on the adsorption of lead, zinc, manganese, cadmium, and copper ions on saw dust biochar. The rates of adsorption increased for lead, zinc, manganese, cadmium, and copper from 45 to 80%, 35 to 90%, 30 to 70%, 45 to 79%, and 15 to 71% for hospital waste water respectively, in addition lead, zinc, manganese, cadmium, and copper removed form,36 to 80%, 25 to 78%,16 to 68%, 19 to 80%, and 27 to 79% for leachate respectively. This variance in percentage removal was driven by the different types of metals and how long they could cling to the adsorbent surface.

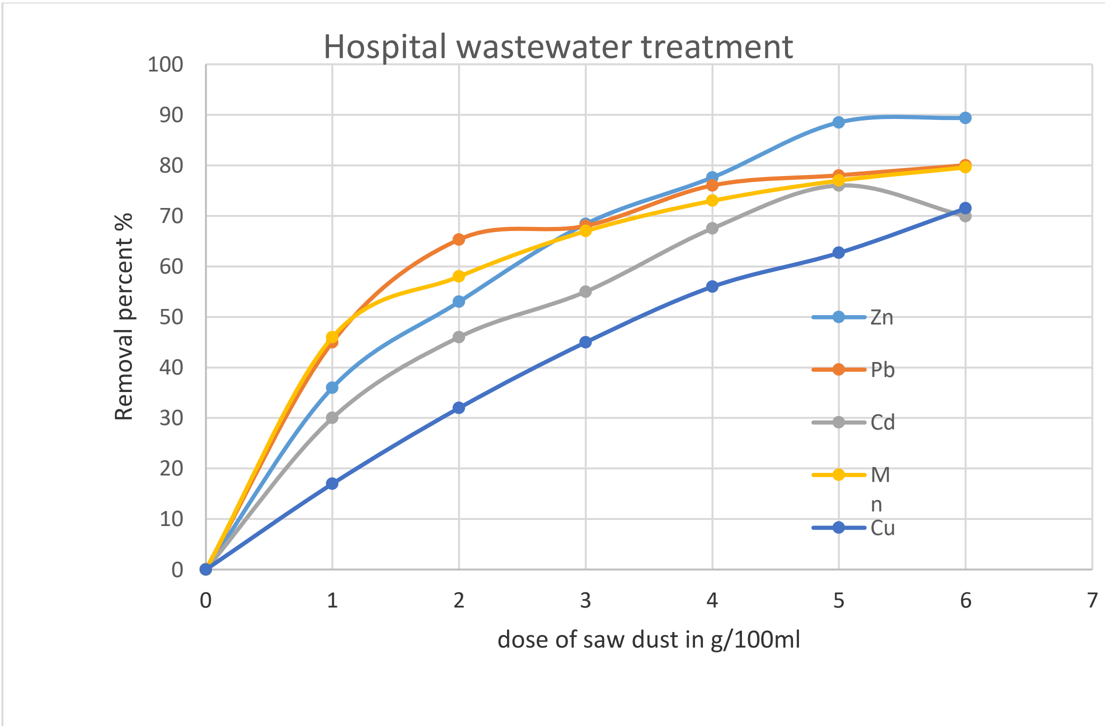

Figure 4.4 Removal of heavy metal in hospital wastewater by using saw dust biochar.

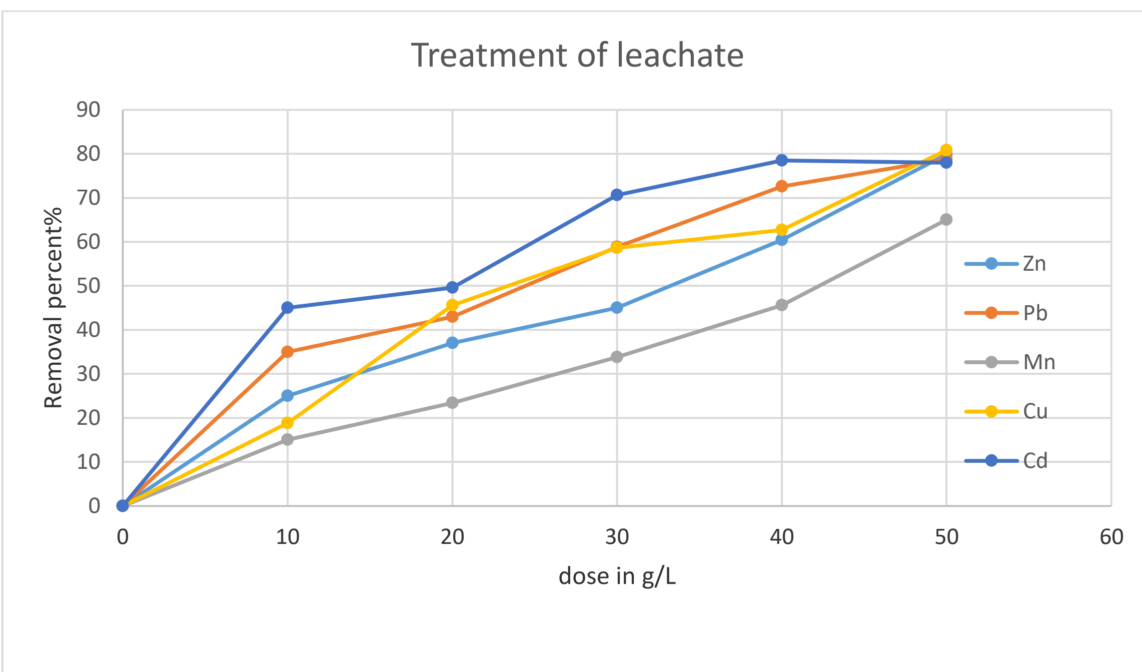

Figure 4.5 Removal of heavy metal in leachate by using sawdust biochar.

The dosage or concentration of the adsorbent is directly inversely correlated with the rate at which heavy metals are removed. The amount of heavy metals that are adsorbed into sawdust increases with the dosage of the adsorbent. The behavior of heavy metal ions exhibits similar trends, with an increase in the fraction of ions attaching to activated sawdust as sawdust weight increases [72]. There are more active sites for the heavy metal ions to deposit on when there is more sawdust in the solution., which is how this occurrence is easily explained. It's interesting to note that the process of adsorption is also influenced by the quantity of metal ions in the solution. The availability of surfaces to adsorb heavy metals and the reactivity of heavy metals on the adsorbent determine how differently metals adsorption on biochar react in figures 4 and 5.

4.5.2.2 Effect of contact time to remove heavy metals in wastewater

Figures 4.6 and 4.7 contrast the sample's variation in Cu, Cd, Pb, and Zn removal. The type of heavy metal has a bigger impact on the equilibrium contact time than the adsorbent substance. The idea that both types of adsorbents have an adequate number of binding sites available [12,15] supports this observation. The effects of 3g/L adsorbent contact duration 60 to 420 minutes on the adsorption of lead, zinc, manganese, cadmium, and copper ions on activated sawdust are shown in Figures 5 and 6. The rates of adsorption increased for lead, zinc, manganese, cadmium, and copper from 45 to 91.7%, 40 to 89%, 47.8 to 91.9%, 40 to 89%, and 52 to 89% for hospital wastewater respectively in addition percentage removal of lead, zinc, manganese, cadmium, and copper in leachates were 27 to 78%, 30 to 76%, 39 to 77%, 41 to 80%, 34 to 76% respectively

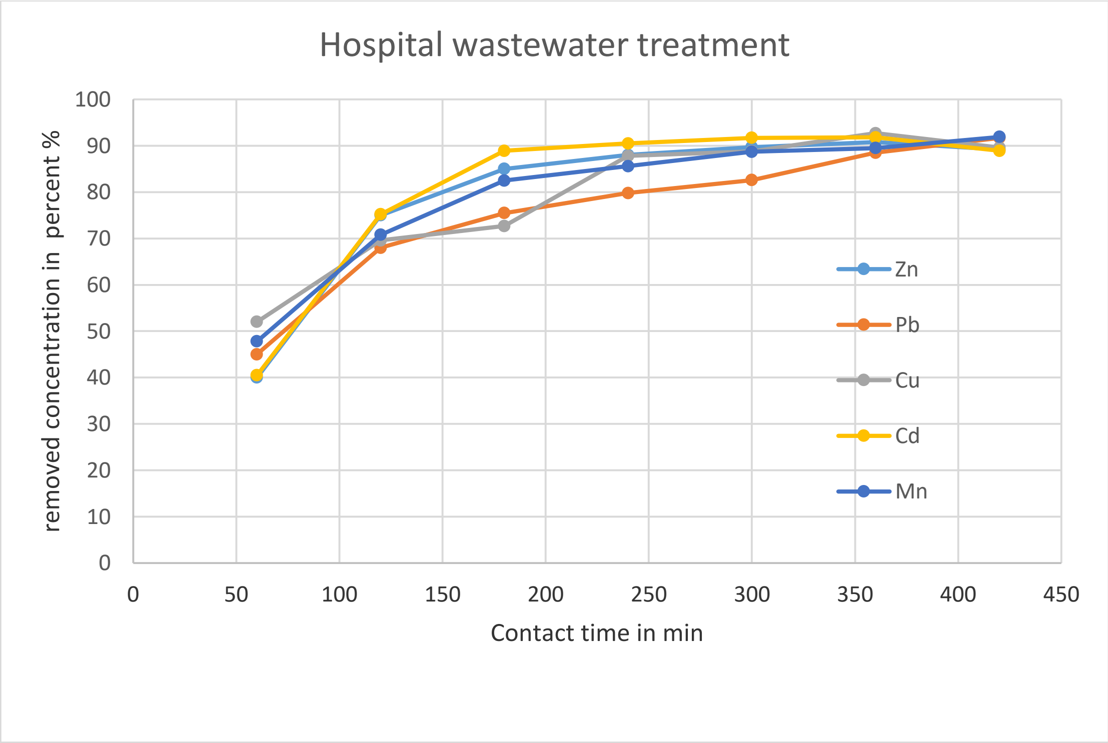

Figure 4.6 Effect of contact time to remove heavy metal in hospital wastewater by using sawdust biochar.

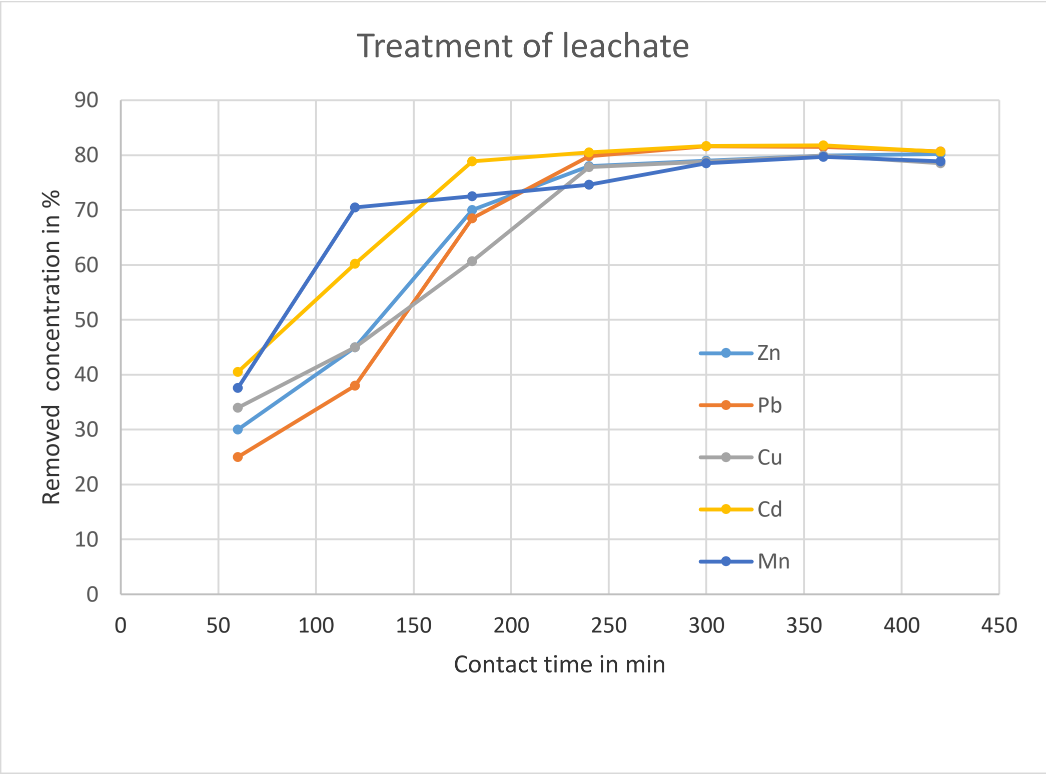

Figure 4.7 Effect of contact time in removal heavy metals in leachate.

For heavy metal ions to adhere to the sawdust, they must spend a certain length of time in the same solution as it. This period of time is referred to as the "contact time. Figure below demonstrates how the amount of Zn, Pb, Cd, Cu, and Mn that is adsorbed rises over time until equilibrium is reached at around 240 minutes, at which point it remains stable. Also noteworthy is the fact that adsorption increases quickly during the first few minutes of contact and then progressively declines till a state of equilibrium. The fact that there is a bigger surface area available for adsorption to take place on is what causes the adsorption rate to be at its peak during the earliest contact period, which is normal [58]. As time goes on, the amount of heavy metal surface area available decreases due to saturation, which causes the adsorption rate to gradually decrease until equilibrium is reached. There is no use in continuing the process once equilibrium and the required contact time have been established.

4.5.3. Heavy metal removal in Soil treatment

Phytoremediation, which makes use of hyper-accumulator plant species that are remarkably tolerant to heavy metals (HMs) present in the soil and environment [73], is a feasible and efficient approach for eliminating heavy metals from polluted environments. Hazardous metals are removed from the environment, decomposed, or detoxified by green plants. Five different phytoremediation techniques, including phytostabilization, phytodegradation, rhizofiltration, phytoextraction, and phytovolatilization, have been employed for soil decontamination. To increase the effectiveness of plants as potential candidates for HM decontamination, biotechnological efforts to adapt plants for HM phytoremediation methods are being investigated in contrast to traditional phytoremediation methods, which have substantial limitations in terms of large-scale application [1].Psidium gujava in experiences findings, Cd, Zn, Cu, Mn and Pb had average removal efficiencies of 40.95%, 30.26%, 65.48%,35.7% and 51.1%respectively.Hazardous HM properties and bioavailability to plants are affected by factors such soil pH, texture, cation exchange capability, temperature, and nutrient content [74].

5.0 CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

The environment and its constituent pieces are seriously threatened by heavy metals. because of their potential detrimental impacts on both the natural world and people's health. Heavy metals are mostly produced by processing industries, electroplating waste, painting waste, electronic devices, and obsolete batteries. When these materials are thrown away with municipal solid waste, the amount of heavy metals in dump sites increases. The purposeful leaching of these heavy metals in an acidic environment throughout the degradation process leads to leachates with high metal concentrations. Currently, one of the potential sources of groundwater contamination is leachates, and keeping an eye on the amount of heavy metals in dumps will assist determine the appropriate remediation measures. The findings of this investigation showed that significant levels of leaching of Cd, Cu, Pb and Zn in hospital wastes ash surpassed USEPA statutory norms. To prevent environmental contamination, HW ashes should be thoroughly handled before being dumped. The structure of sawdust, which consists of cellulose, lignin, and carboxyl groups, increases the ability of cations to be absorbed by the active sites, sawdust in particular has emerged as an exciting component for water purification. Using agricultural wastes to remove heavy metals from wastewater has produced astounding results and is quite inexpensive to purchase.

5.2 Recommendations

Additional study is needed to analyze other hazardous heavy metals like mercury, chromium, and iron Analysis is also required to assess how heavy metals from the dumpsite affect the vegetation and underground water in the vicinity of the Nduba dumpsite. It is possible to research organic wastes in addition to their organometallic components. Prior to disposal, waste must be pre-treated with inexpensive adsorbents to reduce the amount of hazardous environmental exposure to heavy metals.

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