REMOVAL OF ZINC (Zn) FROM TEXTILE WASTEWATER BY USING SAWDUST AS AN ADSORBENT

By

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THESIS DECLARATION

I declare that this thesis entitled "**Removal of Zinc (Zn) from Textile Wastewater By Using Sawdust As An Adsorbent**" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Student

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LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
ppm	Parts per million
TSS	Total Suspended Solids
BET	Brunaeuer-Emmett-Teller
SEM	Scanning Electron Microscope
Zn	Zinc

LIST OF SYMBOLS

°C	Degree Celsius
µm	Micrometer
mm	Millimeter
cm	Centimeter
mL	Milliliter
g	Gram
%	Percentage

REMOVAL OF ZINC (Zn) FROM TEXTILE WASTEWATER BY USING SAWDUST AS AN ADSORBENT

ABSTRACT

Zinc is one of the heavy metals commonly found in the textile wastewater. This heavy metal is toxic and will cause many problems to human and environment. Sawdust was used in this research to remove this heavy metal from the textile wastewater. The investigation was carried out by studying the effect of various experimental parameters, such as types of sawdust (raw and carbonized), adsorbent dosage (5g and 15g), and size adsorbent particle (150µm and 600µm) by using fixed bed column experiment. The results showed the raw sawdust remove more Zn compares to carbonized sawdust, 15g of adsorbent dosage remove more Zn compare to 5g of adsorbent dosage, and 150µm of adsorbent particle size remove more Zn compares to 600µm of adsorbent particle size. However, the carbonized sawdust with the size of particle 600µm and 15g of dosage has the most efficient of Zn removal based on colour changes and the time taken for wastewater completely through the adsorbent. This type of adsorbent removes 85.19% of Zn from the textile wastewater. The data was analyzed using a Mann–Whitney U test to determine the best adsorbent for this research. Thus, this study indicates that sawdust could be employed as a potential adsorbent for the Zn removal from the textile wastewater.

PENYINGKIRAN ZINK (Zn) DARI AIR SISA TEKSTIL DENGAN MENGGUNAKAN HABUK KAYU SEBAGAI PENJERAP.

ABSTRAK

Zink merupakan salah satu logam berat yang kebiasaannya dijumpai di dalam air sisa tekstil. Logam berat ini akan menyebabkan banyak masalah kepada manusia dan juga alam sekitar. Habuk kayu telah diguna di dalam kajian ini untuk menyingkirkan logam berat ini dari air sisa tekstil. Kajian telah dijalankan dengan mengkaji pelbagai kesan parameter eksperimen, seperti jenis habuk kayu (mentah dan arang), dos penjerap (5g dan 15g) dan saiz penjerap (150µm dan 600µm) dengan menggunakan ekperimen *fixed bed column*. Hasil kajian menunjukkan habuk kayu mentah menyingkirkan lebih banyak Zn berbanding arang habuk kayu, 15g dos penjerap menyingkirkan lebih banyak Zn berbanding 5g dos penjerap, dan saiz penjerap 150µm menyingkirkan lebih banyak Zn berbanding saiz penjerap 600µm. Walau bagaimanapun, arang habuk kayu dengan saiz penjerap 600µm dan 15g dos penjerap adalah yang paling efisien untuk menyingkirkan Zn berdasarkan perubahan warna dan masa yang diambil oleh air sisa tekstil untuk sepenuhnya melalui penjerap. Penjerap jenis ini menghapuskan 85.19% Zn daripada air sisa tekstil. Setiap data telah dianalisis dengan menggunakan ujian *Mann-Whitney U* untuk menentukan penjerap yang terbaik dalam kajian ini. Oleh itu, kajian ini membuktikan bahawa habuk kayu berpotensi digunakan sebagai penyerap untuk menyingkirkan Zn daripanda air sisa tekstil.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Earth is known as the "Blue Planet" because 71% of the Earth's surface is covered with water (Mullen, 2012). Earth also the only planet that has water in abundance on its surface. Water is one of the most precious gifts of nature, without which no life could survive on earth. Water has the central role in mediating global-scale ecosystem processes, linking atmosphere, lithosphere, and biosphere by moving substances between them and enabling chemical reactions to occur. The majority of fresh water is actually found underground as soil moisture and in aquifers. Groundwater can feed the streams, which is why a river can keep flowing even when there has been no precipitation. Humans can use both ground and surface water (Mullen, 2012). Water on earth moves continually through water cycle via several processes such as evaporation, transpiration, condensation, precipitation, and runoff. The amount of water on earth is immense and 97% consist of the ocean which in unfit for human consumption, 2% is in the form of ice caps while the rest exist as fresh water.

Due to increasing of the world population, unsustainable consumption, and aggravated development, the water sources and supplies are currently being tremendous polluted (Xian, 2013). Specifically, the following sectors namely agriculture, industrial and domestic respectively consumes 70%, 22% and 8% of available fresh water and thus results in the generation of large quantity of wastewater (Gupta & Suhas, 2009). Textile industries that produce wastewater are one of the main source of pollution worldwide (Norerni, 2013). The wastewater from the textile industry includes a large variety of dyes and chemical additions that can pollute the environment. The challenge for the textile industry not only to manage the effluent but also to control their chemical composition. Dyeing and finishing processes are the main sources of pollution in textile wastewater. These processes demand a lot of chemicals and dyestuffs, which generally are organic compounds of complex structure. The dyes from textile wastewater are highly resistant to light, pH and microbial attack that makes them remain in the environment for a longer period of time. Commercially, there are more than 100 000 types of dyes such as acid, reactive, disperse, vat, metal complex, mordant, direct, basic, and sulphur dyes in which their production exceeds 150 metric tons per year (Wong *et al*., 2013). According to Ramachandra, Ahalya, and Kanamadi (2010), they have found that a lot of heavy metals are widely discharged in the wastewater. The effluents produced by the textiles industry also containing high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), suspended solids, toxic compounds and the color that was perceived by human eyes at very low concentration. The wastewater disposal may cause damage to the quality of the receiving water bodies, the aquatic ecosystem and the biodiversity of the aquatic environment.

The wastewater treatment is needed in view of the wastewater from the textile industry that has become the popular issue in ASEAN country, and people are in need the best quality of water for their daily life. There are many technologies have been developing for purification and treatment of wastewater. The examples are chemical precipitation (Aguinaldo, 2009), solvent extraction (Juang *et al*., 2009), oxidation (Anam Asghar *et al*., 2015), dialysis or electrodialysis (Deghles & Kurt, 2016), reverse osmosis (Senthil & Senthilmurugan, 2016), ion-exchange (Bochenek *et al*., 2011), evaporation (Green *et al*., 2006), cementation (Konsowa, 2010), dilution (Ort, 2009), adsorption (Altmanna *et al*., 2016), and other treatments which are available in the industry. By the way, the selection of the technologies must be considered carefully according to several factors such as available space for construction treatment facilities, the ability of process equipment, limitation of waste disposal, desired final water quality and costs of capital and operating.

Wood is a well-known raw material for the manufacturing of several products such as houses, furniture, and paper and as fuel for district heating and electricity in cold climate countries (Kaczala *et al*., 2014). The waste from the cutting, grinding, drilling, sanding, or otherwise pulverizing wood or any other material with a saw or other tool is called as sawdust. Sawdust refers to the tiny-sized and powdery wood waste produced by the sawing of wood. The sawdust which is of no profitable use and can cause serious environmental problems if disposed of inadequately (Couto *et al*., 2011). Based on the previous research by Parihar and Malaviy (2013), the sawdust can be used to treat the textile wastewater. Since the sawdust does not involve large financial input, it was selected in this study to treat the textile wastewater.

1.2 Problem Statement

The textile industry is one of the industries that has an important role which affecting the water quality. The pollutant from textile wastewater will cost many problems to human and environment. Zinc (Zn) normally found in textile wastewater, a lustrous bluish-white metal and a reactive metal that will combine with oxygen and other non-metals (Lenntech, 2008). Zn can cause a lot of trouble to human and environment. The abundance of sawdust as a by-product also can cause many problems to human beings. The contact with the sawdust can cause conjunctivitis, hay fever, asthma, coughing, hypersensitivity pneumonia and other respiratory diseases (McCann & Babin, 1995). In addition, chronic exposure to sawdust affects the worker's lung functions at sawmills factory and stimulates their allergic responses (Deshpande & Afshan, 2014). Inadequate management of these waste will cause many problems not only to human but also to the environment. Both are the waste that needs to be manage and control very carefully because they can lead to a lot of trouble. This research will help to reduce the risk caused by the waste.

1.3 Objectives

The main objectives of this study are:

- To determine the concentration of Zn in the textile wastewater.
- To produce an adsorbent from the sawdust using fixed bed column experiments.
- To analyze the effectiveness between raw sawdust and carbonized sawdust an adsorbent to remove Zn in the textile wastewater.

CHAPTER 2

LITERATURE REVIEW

2.1 Textile Wastewater

The textile industry is one of the most complex industries among manufacturing industry. There are many complicated processes consisting of bleaching, dyeing, printing and stiffening of textile products. The chemicals used throughout the production of textiles in the textile manufacturers will lead to the creation of textile wastewater. A large amount of water will be used in the textile industry and at the end it will become wastewater. Textile printing and dyeing processes include pre-treatment, dyeing and printing, finishing. The main pollutants are organic matters which come from the pre-treatment process of pulp, cotton gum, cellulose, hemicellulose, and alkali, as well as additives and dyes using in dyeing and printing processes (Zongping Wang *et al*., 2011). On the other side, dyeing process will contribute to the largest portion of the total wastewater from dye preparation, spent dye bath and washing processes. Improper and uncontrolled of discharging wastewater will causing a lot of environmental problems. Controlling the pollution and build up the best treatment are the key factor in the human future. Untreated textile wastewater discharge into the environment will give severe impact to natural water bodies and the surrounding area.

Wastewater treatment is one of the major problems faced by textile manufacturers (Paul, 2008). The high concentration of COD and colour from the dyestuff in the final effluent are kind of example of troubles faced by the textile manufacturers. Then, the release of dyes into the environment constitutes only a small proportion of water pollution, but dyes are visible in small quantities due to their brilliance (Robinson et al., 2001). The colour interferes with the transmission of sunlight into a stream and therefore reduces photosynthetic action (Kadirvelu et al., 2000) and decolourization efficiency was largely influenced by the type of dye, pH, temperature, and flocculants concentration (Simphiwe *et al*., 2012). In addition, the discharge of colored waste is not only damaging the aesthetic nature of receiving streams but also it may be toxic to the aquatic life.

Moreover, dyes also contained a large degree of heavy metal that will affect the aquatic life and living organisms due to their non-degradability and toxicity (Gopalakrishnan & Jeyadoss, 2011). Due to their flexibility in aquatic ecosystems and their toxicity to higher life forms, heavy metals in surface and groundwater supplies have been prioritized as major inorganic contaminants in the environment. These metals can either be detected in their elemental state, which implies that they are not subject to further biodegradative processes or bound in various salt complexes. In either instance, metal ions cannot be mineralized (Ramachandra et al., 2010).

The heavy metals in the textile wastewater such as chromium will have a cumulative effect and have high potentials for entering into the food chain and endanger living organisms. Even if the concentration of heavy metals present in water is low or undetectable quantities, their recalcitrance and consequence persistence in water bodies imply that through a natural process such as biomagnifications, the concentration may become elevated to such an extent that they begin exhibiting toxic characteristics (Gopalakrishnan & Jeyadoss, 2011). The problem of heavy metals pollution in water and aquatic organisms including fish, needs continuous monitoring and surveillance as these elements do not degrade and tend to biomagnify in man through the food chain. Therefore, there is an essential to eliminate the heavy metals from the aquatic ecosystems (Ramachandra *et al*., 2010).

2.1.1 Zinc (Zn)

Zinc are found in group IIB of the periodic table. It is brittle and crystalline at ordinary temperatures, but it becomes ductile and malleable when heated between 110°C and 150°C. It is a fairly reactive metal that will combine with oxygen and other non-metals and will react with dilute acids to release hydrogen (Lenntech, 2008). This metal has a common origin in textile effluents. The high concentration in the effluent ultimately leading to contaminate the soil and groundwater (Muneer *et al*., 2010). This metal is essential to maintaining the metabolism of human body. However, at higher concentration of Zn, it can lead to poisoning (Ranjana *et al*., 2014).

Zn can cause eminent health problems, such as stomach cramps, skin irritations, vomiting, nausea, and anemia. High levels of Zn can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis. Extensive exposure to Zn chloride can cause respiratory disorders. Furthermore, Zn can be a danger to unborn and newborn children. When their mothers have absorbed large concentrations of Zn the children may be exposed to it through blood or milk of their mothers (Lenntech, 2008).

Zn may also escalation the acidity of waters. Some fish can accumulate Zn in their bodies when they live in zinc-contaminated waterways. When Zn enters the bodies of these fish it is able to biomagnify up the food chain. Another than that, Zn also can be found in soils. When the soils of farmland are polluted with Zn, animals will absorb concentrations that are damaging to their health. Water-soluble Zn that is located in soils can contaminate groundwater. Moreover, Zn not only is a threat to cattle but also to plant species. Plants often have a Zn uptake that their systems cannot handle, due to the gathering of zinc in soils. On Zn-rich soils, only a partial number of plants has a chance of survival. That is why there is slight plant diversity near Zn disposing of factories. Due to the effects upon plants Zn is a serious threat to the productions of farmlands. Despite this Zn-containing manures are still applied. Finally, Zn can disturb the activity in soils, as it negatively impacts the activity of microorganisms and earthworms. The breakdown of organic matter may seriously delay because of this metal (Lenntech, 2008).

2.2 Treatment of Textile Wastewater

The textile industry has been recognized as one of the industries that produced high discharged rate of wastewater with a high load of contaminants to the environment considering both volume and composition. Owing to their high BOD, COD, high coloration, selected heavy metals, in the wastewater have greatly polluted the environment especially aquatic organisms (Zongping Wang *et al*., 2011). Untreated dyes wastewater produced from dyestuff and dyeing industries are hard to biodegrade due to their complex chemical structures which containing significant BOD, COD and total suspended solids (TSS) content plus non-biodegradable nature organic dyestuffs (Syafalni *et al*., 2012). In addition, increasing demand for water supply had caused polluted water to be recovered and reused. Thus, several methods such as activated carbon, sorption, chemical coagulation, ion exchange, electrolysis and chemical treatment have been developed for removing dye from wastewater prior to release into the environment (Geçgel *et al*., 2013). The treatment for textile wastewater can be divided into three major methods which are biological, chemical and physical.

2.2.1 Biological Methods

The biological method, it utilized naturally occurring microorganisms to remove pollutants, basically to oxidized organic waste. There are many types of biological methods used in the industry to treat textile wastewater and it can be divided into aerobic and anaerobic. Besides, biological methods are commonly economy and simple to apply and are currently used to remove organics and color from textile wastewater.

2.2.1.1 Aerobic Biological Treatment

Aerobic Biological Treatment processes are used bacteria and oxygen to remove dissolved organic load (COD/BOD) from the wastewater. Actually, these processes use natural microbial colonies and molecular oxygen to decompose organic substances in the wastewater. The microbes feed on undesired biological substances in the water, creating aggregates or “flocks” of organic substances and microorganisms that settle to the bottom of the container. This sludge is stable and usually can be disposed of easily. Aerobic treatment is typically part of a multistage water treatment process. The technology is not confined to use as an intermediate stage, but can also be used for finishing water and to augment other types of treatments. In the aerobic process, the decomposition rate is more rapid than the anaerobic process and it is not accompanied by unpleasant odors, whereas in the anaerobic process, longer detention period is required and gives unpleasant odors (Durai & Rajasimman, 2011).

2.2.1.2 Anaerobic Biological Treatment

The treatment process that utilizes anaerobic microorganisms to biologically degrade organic constituents in wastewater. This treatment involves a series of bacterial reactions, the slowest which will determine the speed of the total treatment. The Anaerobic Biological Treatment processes are used to stabilize biological sludge prior to dewatering and/or final disposed. Plus, these treatment processes are used to treat a variety of industrial wastes (Roberts Alley, 2007). Anaerobic systems are very expensive to install but do not require the large energy requirements of the anaerobic system and generate the only relatively small volume of sludge (Cooper, 1995).

2.2.2 Chemical Methods

Generally, chemical methods are used when a pollutant in wastewater must be altered or manipulated chemically in order to reduce the pollutant's concentration in the effluent. In chemical method, it normally includes coagulation and flocculation, chemical oxidation/reduction and metals precipitation. Among all the chemical methods, chemical oxidation is the most common technique used to treat textile wastewater (Paul, 2008).

2.2.2.1 Coagulation and Flocculation

Coagulation is always considered along with flocculation and is used to remove particles which cannot be removed by sedimentation or filtration alone (Evans, 2010). Coagulation and flocculation are the methods used for aggregating suspended solids into larger and perhaps denser particles that will settle more quietly or become more filterable. Coagulation is the addition of chemicals to water to destroy or reduce repulsive forces and induce particle agglomeration. On the other hand, flocculation is the physical process of promoting particle contact to facilitate the agglomeration to larger settleable floc. These processes are usually accomplished by using two different tanks in series (Roberts Alley, 2007).

2.2.2.2 Chemical Oxidation/Reduction

Oxidation-reduction reactions are fundamental parts of wastewater treatment. All forms of chemical wastewater treatment as well as biological wastewater treatment incorporate redox reactions. Redox reactions consist of two parts. The first part is oxidation reaction. The oxidation of a substance occurs when it loses or donates electrons which are an increase in oxidation state. The second part is reduction reaction. The reduction of a substance occurs when a substance gains or accepts electron which is a decrease in oxidation state (Roberts Alley, 2007).

2.2.2.3 Metals Precipitation

This treatment usually involves reducing the metal concentration from an initially high level to a target level of concentration of the heavy metals established by a regulatory requirement. One practical approach is the conversation of soluble metal ions to insoluble metal salts, with subsequent removal of solids by gravity settling, filtration, centrifugation, or similar solids-liquids separation techniques (Roberts Alley, 2007). Metals that found in wastewater will be cations or anions where cations are positively charged and cations are negatively charged. The most common precipitating salts for metal cations are hydroxides, sulfides, and carbonates while chromate and permanganate are examples of metallic anions.

2.2.3 Physical Methods

Finally, the physical methods. This method basically can be used prior to chemical or biological treatment to remove constituent which might cause problems with subsequent treatment. There are three main types of physical methods used to treat textile wastewater, which are nanofiltration, reverse osmosis, and adsorption. Adsorption has been suggested as the best among all three physical method is due to its sludge free clean operation and complete removal of dye even from dilute solutions. Absorption is a process that may be chemical (reactive) or physical (non-reactive) and these processes are being widely used by various researchers for the removal of dye due to its simplicity, inexpensiveness and efficiency (Gao *et al*., 2013).

2.2.3.1 Nano Filtration

This technique requires the effluent to be circulated significantly more rapidly than for reverse osmosis. Plus, this technique sometimes was called as loose reverse osmosis, when the pressure of the operation often similar. Furthermore, Nanofiltration will retain most pollutants inside the membrane but allows waste and some small molecule salts and organics to pass through. Nanofiltration units have very high capital costs and higher running costs than reverse osmosis units of comparable size. They can, however, generate a smaller volume of concentrated than reverse osmosis unit but the permeate will have much higher concentrations of inorganic salts (Cooper, 1995).

2.2.3.2 Reverse Osmosis

The Reverse Osmosis can remove up approximately 98% of the impurities in the water with a relative molecular mass. Even with this high degree of efficiency, permeate may still contain a residual salt concentration that is too high for recycling to the front end of the factory. The membranes in these units have to be cleaned on a regular basis and may be attacked by the dye materials or other constituents of the effluent. Then, it may change their surface characteristic, resulting in either a poorer-quality permeate or premature membrane failure. This treatment, in general, is associated with high capital costs and relatively high running costs (Cooper, 1995).

2.2.3.3 Adsorption

Adsorption is the formation of a layer of gas, liquid, or solid on the surface of a solid. The process of adsorption involves separation of a substance from fluid phase (gas or liquid) by accumulation or concentration onto the surface of a solid phase (Ronald, 2005). Basically, Adsorption will use low-cost adsorbents could be technically feasible and economically viable sustainable technology for the treatment of wastewater streams. Low-cost adsorbents are nothing but materials that require little processing, are abundant in nature or is a byproduct or waste material from another industry (Ramachandra *et al*., 2010). With regards to its simplicity and high-efficiency characteristics, adsorption is looked upon as a better technology. Adsorption processes have been and actually are the most applied in industries, and consequently the most studied (Chiarle *et al*., 2000).

2.3 Sawdust

Sawdust is referred to the tiny size and powdery wood waste produced by the cutting, grinding, drilling, sanding, or otherwise pulverizing of wood. The size of sawdust particles depends on the types of wood from which the sawdust is obtained and also on the size of the saw teeth. Moreover, sawdust being essentially a lignocellulosic material, is not easily deteriorated but rather stable on recalcitrant in the environment, and rarely produces odor during its long-term biodegradation process (Maharani *et al*., 2010).

These material are cheap, renewable and abundantly available (Couto *et al*., 2011). The wasted sawdust provides a practical and sustainable source for development of better quality low-cost activated carbon for efficient abatement of toxic metal ions and organic chemicals from industrial and municipal wastewater at reduced cost (Mukosha *et al*., 2013) Sawdust is considered as one of the best material among agricultural and industrial wastes because of its cheap and quite abundant (Obiora-Okafo *et al*., 2014).

Due to sawdust lignocellulosic composition. It is mainly composed of cellulose (45–50%) and lignin (23–30%), both with a capacity for binding metal cations due to hydroxyl, carboxylic and phenolic groups present in their structures (Ahmad *et al*., 2011).

2.3.1 Sawdust as an Adsorbent

Due to its cost and easy to get it, the sawdust has been used in many types of research to treat the textile wastewater. The sawdust can successfully remove dyes, for example, are Methylene Blue, Malachite Green and Congo Red Dye (Hamdaoui, 2006; Shafiqul Alam *et al*., 2015; Singh *et al*., 2015). Moreover, sawdust also effectively in order to remove heavy such as Copper, Cadmium, Nickel, Lead and Zinc (Ageena, 2010; Marin & Ayele, 2003).

2.4 Fixed Bed Column Experiment

This study will be conducted in Fixed Bed Column Experiment, which is usually limited to the treatment of small quantities of wastewater. The sorption capacity parameter obtained from a batch experiment is useful in providing information about the effectiveness of sorbate–sorbent system. However, in the practical operation of full-scale adsorption processes, continuous flow fixed bed columns are often preferred. In such systems, the concentration profiles in the liquid and adsorbent phases vary in both space and time. As a result, design and optimization of fixed bed columns are difficult to carry out a priori without a quantitative modeling approach. The solute concentration in the effluent is free of the target solute until breakthrough of solute occurs (Hamdaoui, 2006). The effluent can be treated in two situations which are downflow column or up flow column (Mutammimul Ula, 2012).

The advantages of fixed bed column experiment will give an accurate prediction for adsorption process (within an acceptable size of error from real wastewater systems) (Al-Degs *et al*., 2009). Plus, this experiment is a simple operation and can be scaled-up from laboratory process. Furthermore, fixed bed column experiment always brings the effluent constantly in contact with the absorbent thus providing the needed concentration slope between the adsorbent and effluent for adsorption (Mutammimul Ula, 2012).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

The wastewater used for this study were the textile wastewater, which was generated and released by the textile workshop. The sawdust used in this study are from the wood workshop. Both wastes were collected at University Malaysia Kelantan Bachok Campus, Kelantan (Coordinates 6.003342, 102.401786).

3.2 Preparation of Raw Material

The materials that are used in this research are sawdust. The sawdust was taken at a wood workshop at University Malaysia Kelantan Bachok Campus, Kelantan. Mostly sawdust in this wood workshop is from rubber wood. The sawdust was washed with distilled water and dried at 80°C for 24 hours. The sawdust was grinded and then sieved into two different sizes (150µm and 600µm) (Vinodhini & Das, 2010). Then it will be store in tight lid container at room temperature.

3.3 Preparation of Adsorbent

3.3.1 Raw Sawdust

The sieved sawdust with the size of particle 150µm and 600µm were weighed into two dosages, 5g, and 15g. Then, it will be store in tight lid container (Raffiea *et al*., 2012).

3.3.2 Carbonized Sawdust

Then, the raw sawdust that was being carbonized in a furnace at 500°C for 1 hour (Geçgel *et al*., 2013). Later, the carbonized sawdust with the size of particle 150µm and 600µm were weighed into two dosages, 5g and 15g then stored in tight lid container (Raffiea *et al*., 2012).

3.4 Wastewater Analysis

The textile wastewater will be taken from the drainage of the textile workshop at University Malaysia Kelantan Bachok Campus. The initial concentration of zinc in the textile wastewater will be analyze using Colorimeter DR900.

3.5 Fixed Bed Column Experiment Setup

The fixed bed column experiment was made by the column that made up from a plastic material which holds by the retort stand. Then, the bottom of the column was used nylon filter mesh size less than 150µm to hold the sawdust in the column. The height of the column is 25cm with the diameter 5cm. The surface area of the bed column is 17.67 cm^2. The flow rate of the textile wastewater is 37.5 mL/Min that control by using the burette.

3.6 Wastewater Treatment

The fixed bed column experiments were conducted at room temperature (Evans, 2010) and it was used to remove the Zn in textile wastewater. The column internal diameter was 5cm and its length was 25cm was put with absorbent (raw and carbonized) and then packed in a vertical column. About 100mL of textile wastewater was pass through the column that has a different mass of adsorbent (5g and 15g) and different size of the adsorbent particle (150µm and 600µm) (Vinodhini & Das, 2010). Then, Zn reduction was recorded. The effectiveness of the adsorbent in adsorption process was determined using plotted graph by Mann–Whitney U test. The percentage of Zn removal was calculated as follows using the Zn values obtain from Colorimeter DR900. (Selvanathan *et al*., 2015).

$$\% \, removal = \left(\frac{C_o - C_t}{C_o}\right) \times 100\% \tag{1}$$

Where C_o is the Zn value before the wastewater treated, while C_t is the Zn value after the wastewater treated.

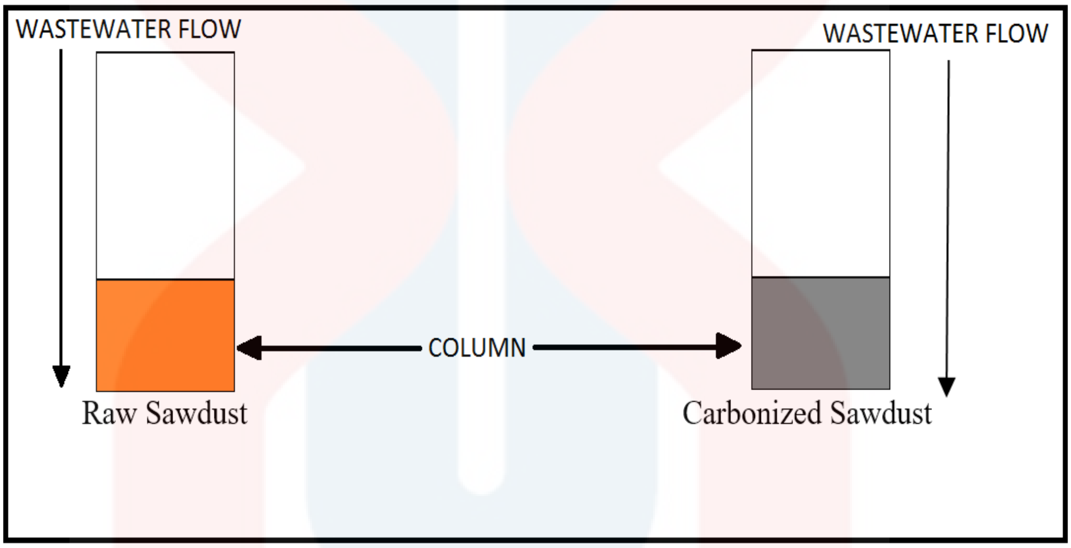
The parameters affecting the efficiency of Zn reduction like surface area, the volume of wastewater, pH value, temperature, the dosage of absorbent, the size of adsorbent particle and flow rate have been given in Table 3.1.

Table 3.1 Adsorption Parameters

No	PARAMETERS	CONDITION/AMOUNT
1	Surface Area Of Adsorbent In Column (cm^2)	17.67
2	Wastewater Volume (ml)	100
3	Size Particle (µm)	150 and 600
4	Adsorbent Weight (g)	5 and 15
5	Types Of Sawdust	Raw and Carbonized
6	Flow Rate (ml/min)	37.5

3.7 Effect of Type of Sawdust

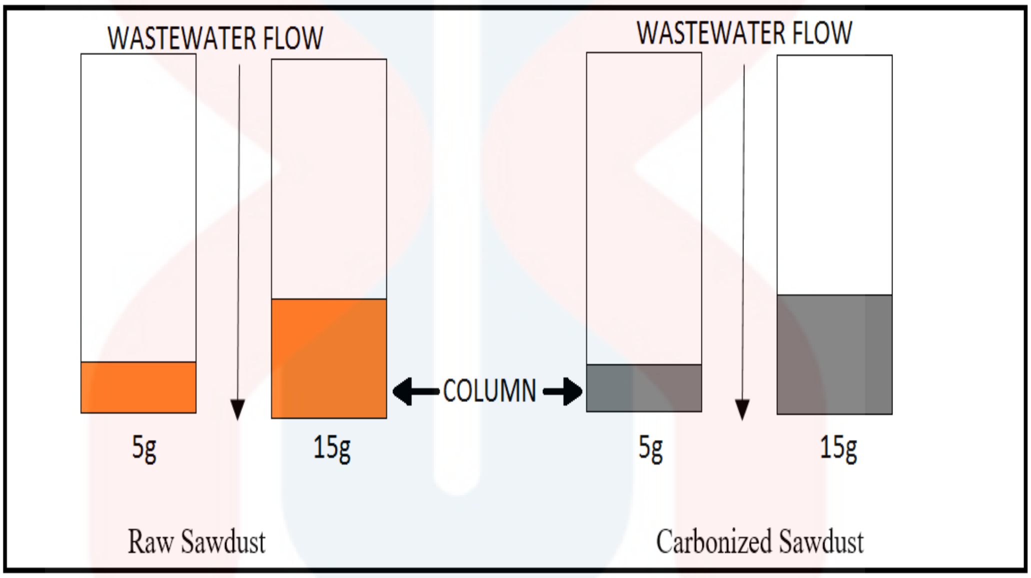
100mL of textile wastewater were put into the column with raw and carbonized sawdust as shown in Figures 3.1. The dosage of adsorbent was at 5g then repeated with 15g. The adsorbent particle size was at 150µm then repeated with 600µm. Then, other parameters such as surface area and volume of wastewater are also constant.



Figures 3.1 Effect of Types of Sawdust

3.8 Effect of Adsorbent Dosage

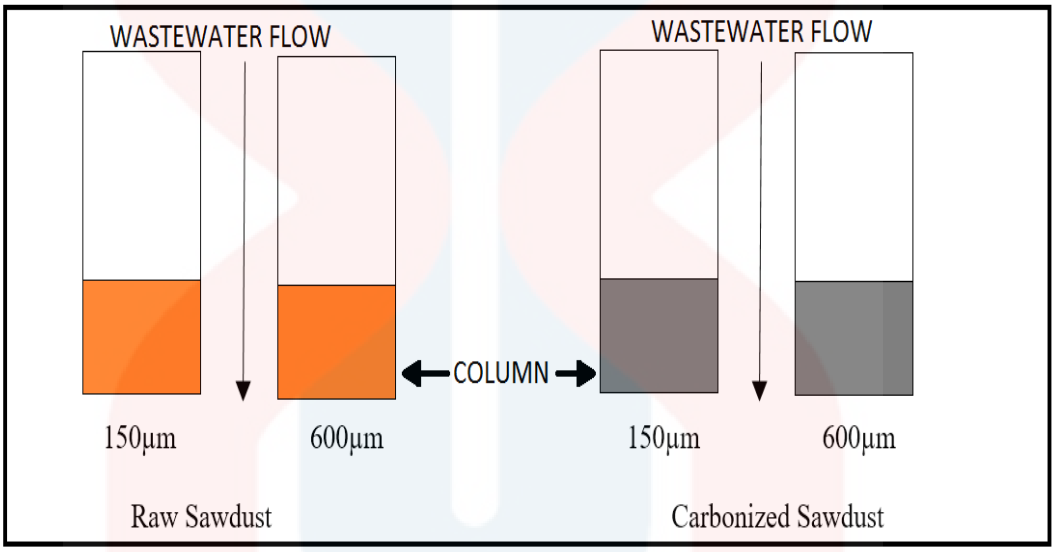
About 100mL of textile wastewater were put into the column with 5g and 15g of sawdust (raw and carbonized) as shown in Figures 3.2. The size of the adsorbent particle was at 5g then repeat with 15g. Then, other parameters such as surface area, the volume of wastewater, and size of the adsorbent particle were constant.



Figures 3.2 Effect of Adsorbent Dosage

3.9 Effect of Adsorbent Particle Size

Once again, 100mL of textile wastewater were put into the column with two different of the size of the adsorbent particle; 150µm and 600µm (2 values) as shown in Figures 3.3. The adsorbent dosage was at 5g then repeated with 15g. Other parameters were put into constant value.



Figures 3.3 Effect of Adsorbent Particle

3.10 Statistical Analysis

Mann-Whitney U test is the alternative test to the independent sample t-test. It is a non-parametric test that is used to compare two population means that come from the same population, it is also used to test whether two population means are equal or not. It is used for equal sample sizes and is used to test the median of two populations. Usually, the Mann-Whitney U test is used when the data is ordinal.

The test will help to identify the different between the means of two types of sawdust (raw and carbonized), two different of adsorbent dosage and two different of adsorbent particle size. There will have several factors that will affect the means of the sawdust which are surface area, pore structure, acidity (pH), temperature, time and the nature of the material.

CHAPTER 4

RESULT AND DISCUSSION

4.1 The concentration of zinc in textile wastewater

Textile wastewater was obtained from the drainage at UMK Bachok Campus. Then, the concentration of zinc in textile wastewater are determined by using Colorimeter DR900. The concentration of Zn in the textile wastewater before treatment are 0.54 mg/L.

4.2 The Sawdust As Adsorbent Using Fixed Bed Column Experiments

The adsorbent was made from sawdust which was taken at UMK Bachok Campus. The sawdust was grinded then sieved into two sizes, 150µm, and 600µm. Then, carbonized it in the furnace before weighing it into two dosages, 5g, and 15g. After filled the column with the adsorbent the height of raw and carbonized sawdust and also the time taken for textile wastewater completely through the adsorbent were taken and shown in Table 4.1 and Table 4.2.

Table 4.1 Raw Sawdust Data

SIZE (µm)	600		150	
DOSAGE (g)	5	15	5	15
HEIGHT (cm)	4.1	11.5	3.5	10
TIME TAKEN (Min)	7	14	142	660

Table 4.2 Carbonized Sawdust Data

SIZE (µm)	600		150	
DOSAGE (g)	5	15	5	15
HEIGHT (cm)	4.7	17.5	4.3	13.5
TIME TAKEN (Min)	9	10	42	62

The highest height of bed (adsorbent) are from carbonized sawdust with 15g of dosage and 600µm of the size particle. The fastest time taken for the textile wastewater to completely through the adsorbent are from raw sawdust with the size of particle 600µm and 5g of dosage for about 7 minutes while for the slowest to complete the experiment are from raw sawdust with 150µm and 15g with the time of 660 minutes.

4.3 Effect of Operational Variables on Zinc Removal

This research was carried out by studying the effects of three (3) parameters, types of sawdust as adsorbent (raw and carbonized), adsorbent dosage (5g and 15g), and adsorbent particle size (150µm and 600µm) in order to remove the Zn in textiles wastewater. The percentage removal for types of sawdust as an adsorbent, adsorbent dosage, and adsorbent size were calculated and the result was attached in Appendix A.

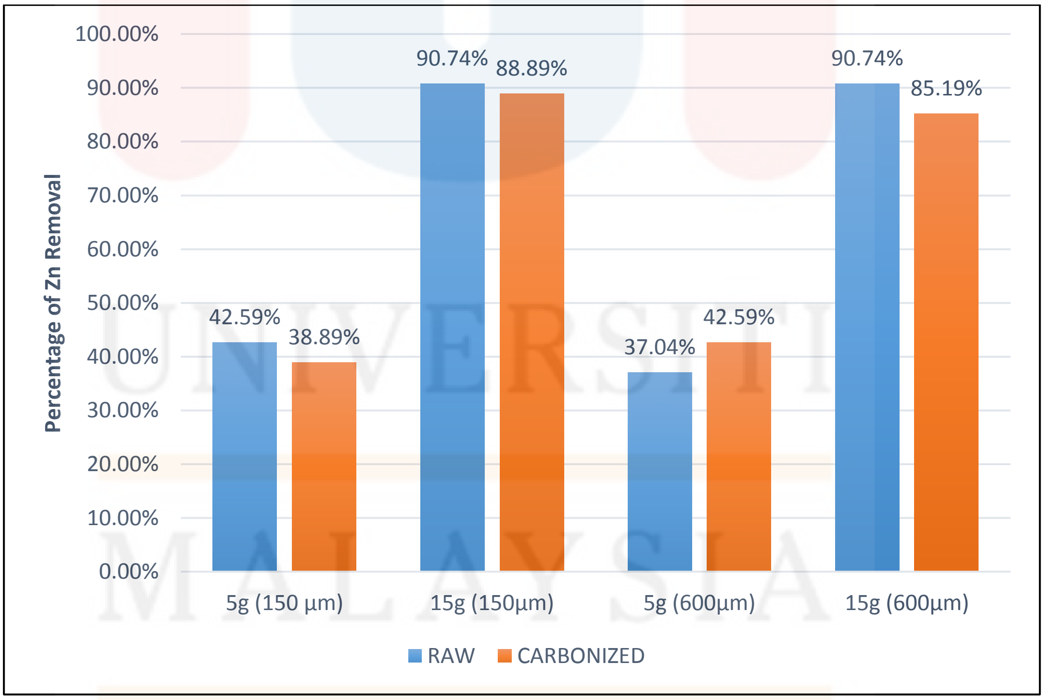


Figure 4.1 Zn Removal from Textile Wastewater

4.3.1 Effect of Types of Sawdust

The main parameter that being control in this research are the types of sawdust. There were two types of sawdust which are raw and carbonized. The adsorbent (raw and carbonized) were sieved into two sizes (150µm and 600µm) and two dosages (5g and 15g). The value of Zn in the textile wastewater before treatment are 0.54 mg/L. Another data are shown in Appendix A.

In this research, the types of sawdust do not affect the removal of Zn in the textile wastewater. This can be seen clearly in Figure 4.1 that there is no big difference of removal Zn from textile wastewater between using raw and carbonized sawdust. The highest percentage difference of Zn removal between this adsorbent is about 5.55% of the size of particle 600µm with 5g and 15g of dosage. Due to the differences in this research, the types of sawdust are not effective to removed the Zn from the textile wastewater.

4.3.2 Effect of Adsorbent Dosage

The adsorbent dosage is an important parameter, which influences the extent of Zn from the textile wastewater. The adsorbent (raw sawdust) were sieved into two sizes which were 150µm and 600µm. To study the effect of adsorbent dosages, two dosages (5g and 15g) were used as an adsorbent in this study. Then repeated with carbonized sawdust. The value of Zn in the textile wastewater are 0.54 mg/L and the another data are shown in Appendix A.

In Figure 4.1 shown that the adsorbent dosage is influenced the effectively of Zn removal from the textile wastewater. More than 35% the heavy metal are removed by the dosage of 5g while for 15g more than 85% heavy metal. The highest of removal of Zn are from the raw sawdust (150µm & 600µm) with the dosage of 15g which is 90.74%. Then, the carbonized sawdust showed the 15g dosage remove more Zn compares to 5g dosage which is 88.89% for 150 µm and 85.19% for 600 µm. So, the dosage of adsorbent has affected the percentage of Zn removal in this research.

4.3.3 Effect of Adsorbent Particle Size

The adsorbent was sieve into two sizes, 150µm, and 600µm to test the effect of adsorbent particle size. The raw sawdust which has been grinded earlier was sieved into the sizes mention above. Then, repeated with the carbonized sawdust. The value of Zn in the textile wastewater are 0.54 mg/L. The height of absorbance, time was taken and percentage of zinc removal are shown in Appendix A.

Through this research, the adsorbent particle size does not affect the Zn removal from textile wastewater. This can be seen obviously in Figure 4.1 that there is no big difference of removal Zn from textile wastewater between using the size of 150µm and 600µm. The highest difference percentage of Zn removal from textile wastewater are 5.55% from raw sawdust with 5g of dosage. Thus, the size of the adsorbent particle does not influence the effectiveness of Zn removal from textile wastewater in this research.

4.4 Statistical Analysis

In this research, Mann–Whitney *U* test is carried out to compare the mean between two related groups. The first two group are mean of raw sawdust and carbonized sawdust, then the mean of adsorbent dosage between 5g and 15g and last is the mean between 150μm and 600μm of adsorbent particle size. Thus, the Mann–Whitney *U* test conducted in this research provides a clear view of the efficiency of adsorbent to remove Zn from the textile wastewater.

The mean of Zn removal from textile wastewater based on types of sawdust (raw and carbonized), adsorbent dosage (5g and 15g) and adsorbent size of particle (150μm and 600μm) show the mean of raw sawdust was remove more Zn compare to the mean of carbonized sawdust, the mean of 15g of adsorbent dosage was remove more Zn compare to the mean of 5g of adsorbent dosage and the mean of 150μm adsorbent particle size was remove more Zn compare to the mean of 600μm adsorbent particle size. This can be supported by Appendix H, Appendix I and Appendix J which shows the difference in the mean in "Rank" table for all the treatment.

In "Test Statistics" table from Appendix H, Appendix I and Appendix J show that the types of sawdust and adsorbent particle size the corresponding *U*-value are 0.436 and 0.583. It can be concluded that this result is not significant because *U*-value is more than 0.05. While, for the adsorbent dosage the corresponding *U*-value is 0.000. It can be concluded that this result is significant because *U*-value is lower than 0.05. This proves that the adsorbent dosage is effective in order to remove Zn from textile wastewater compare to types of sawdust and adsorbent particle size.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the result and discussion in this research, it shows that sawdust could be employed as a potential adsorbent for the Zn removal from the textile wastewater. The sawdust has successfully removed the Zn from textile effluents in this research.

The results showed the raw sawdust remove more Zn compares to carbonized sawdust, 15g of adsorbent dosage remove more Zn compare to 5g of adsorbent dosage, and 150µm of adsorbent particle size remove more Zn compares to 600µm of adsorbent particle size.

However, in this research, the carbonized sawdust with the size of particle 600µm and 15g of dosage has the most efficient of Zn removal based on colour changes and the time taken for wastewater completely through the adsorbent.

5.2 Recommendations

First of all, several techniques can be implemented for further study in the physical characterization of sawdust such as Scanning Electron Microscope (SEM) and Brunauer-Emmett-Teller (BET). For SEM, the surface morphology of sawdust can be ascertained by high-resolution imaging of surfaces. For BET theory, it aims to interpret the specific surface area of sawdust by physical adsorption of gas molecules on a solid surface. Through this techniques, the adsorption properties like porosity can be evaluated and studied.

Improvement for this treatment also can be done by activating the sawdust (raw and carbonized) using base activation sodium hydroxide (NaOH) or acid activation, phosphoric acids (H_3PO_4). By doing this activation either base activation or acid activation, the surface area of the sawdust will be increase then improve the ability of zinc removal from the textile wastewater.

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APPENDIX A

Raw Sawdust

Table A1 Raw Sawdust Data

SIZE (µm)	600		150	
DOSAGE (g)	5	15	5	15
HEIGHT (cm)	4.1	11.5	3.5	10
TIME TAKEN (Min)	7	14	142	660
ZINC	0.34	0.05	0.31	0.05
% REMOVAL	37.04	90.74	42.59	90.74

Carbonized Sawdust

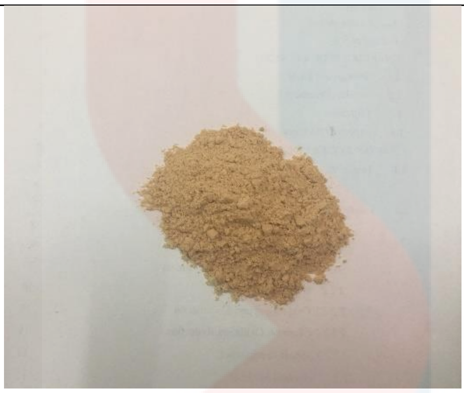
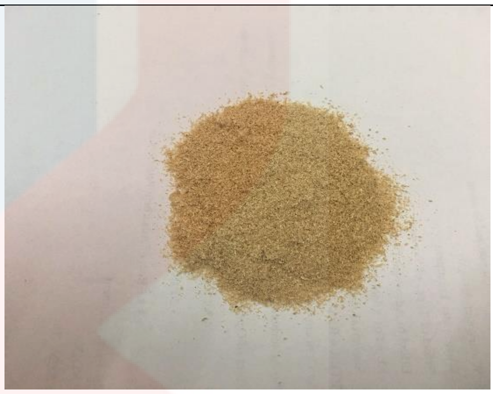
Table A2 Carbonized Data

SIZE (µm)	600		150	
DOSAGE (g)	5	15	5	15
HEIGHT (cm)	4.7	17.5	4.3	13.5
TIME TAKEN (Min)	9	10	42	62
ZINC	0.31	0.08	0.33	0.06
% REMOVAL	42.59	85.19	38.89	88.89

APPENDIX B

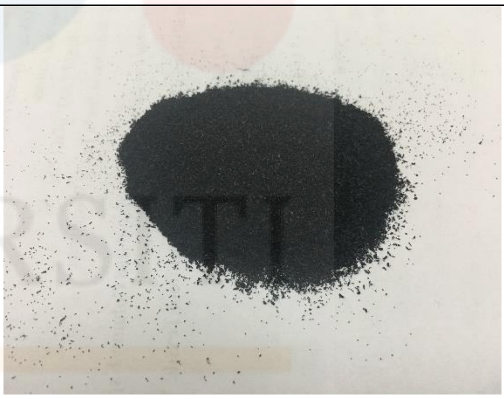
Raw Sawdust

Table B1 Raw Sawdust

150µm	600µm
	

Carbonized Sawdust

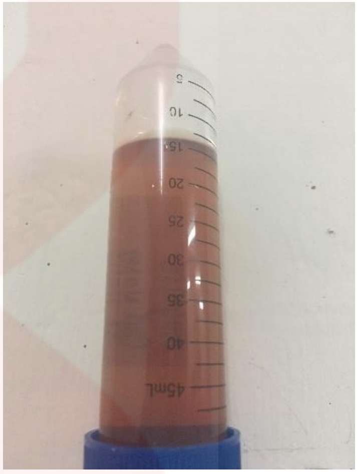
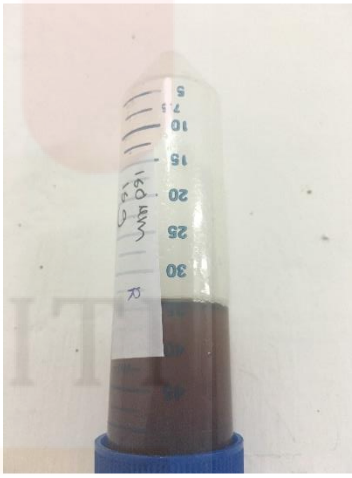
Table B2 Carbonized Sawdust

150µm	600µm
	

APPENDIX C

Raw Sawdust (150µm)

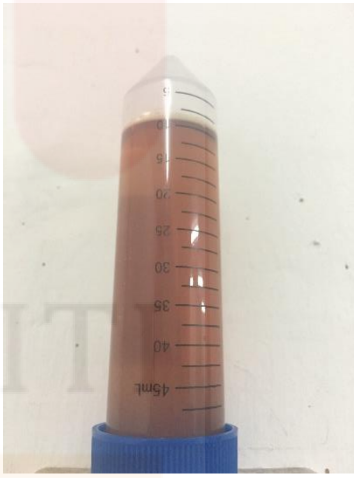
Table C1 Raw Sawdust (150µm)

	Before	After
5g		
15g		

APPENDIX D

Raw Sawdust (600µm)

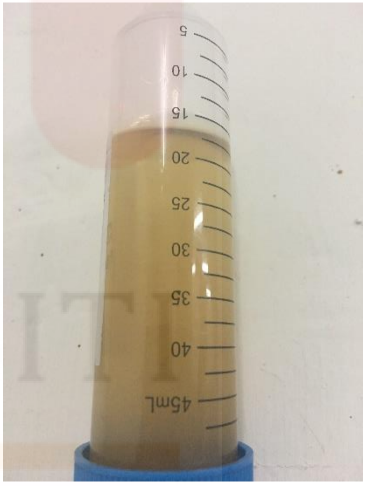
Table D1 Raw Sawdust (600µm)

	Before	After
5g		
15g		

APPENDIX E

Carbonized Sawdust (150μm)

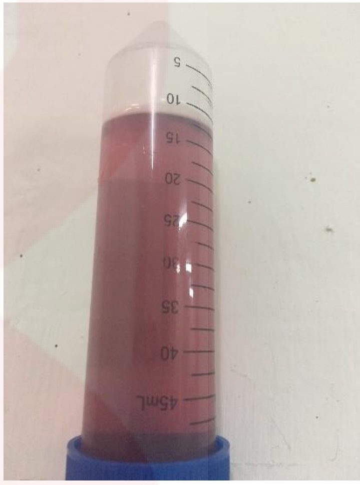
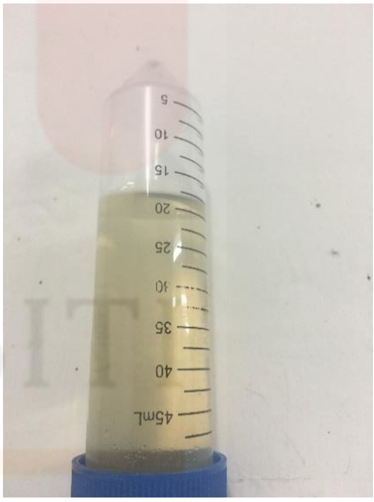
Table E1 Carbonized Sawdust (150μm)

	Before	After
5g		
15g		

APPENDIX F

Carbonized Sawdust (600µm)

Table F1 Carbonized Sawdust (600µm)

	Before	After
5g		
15g		

APPENDIX G

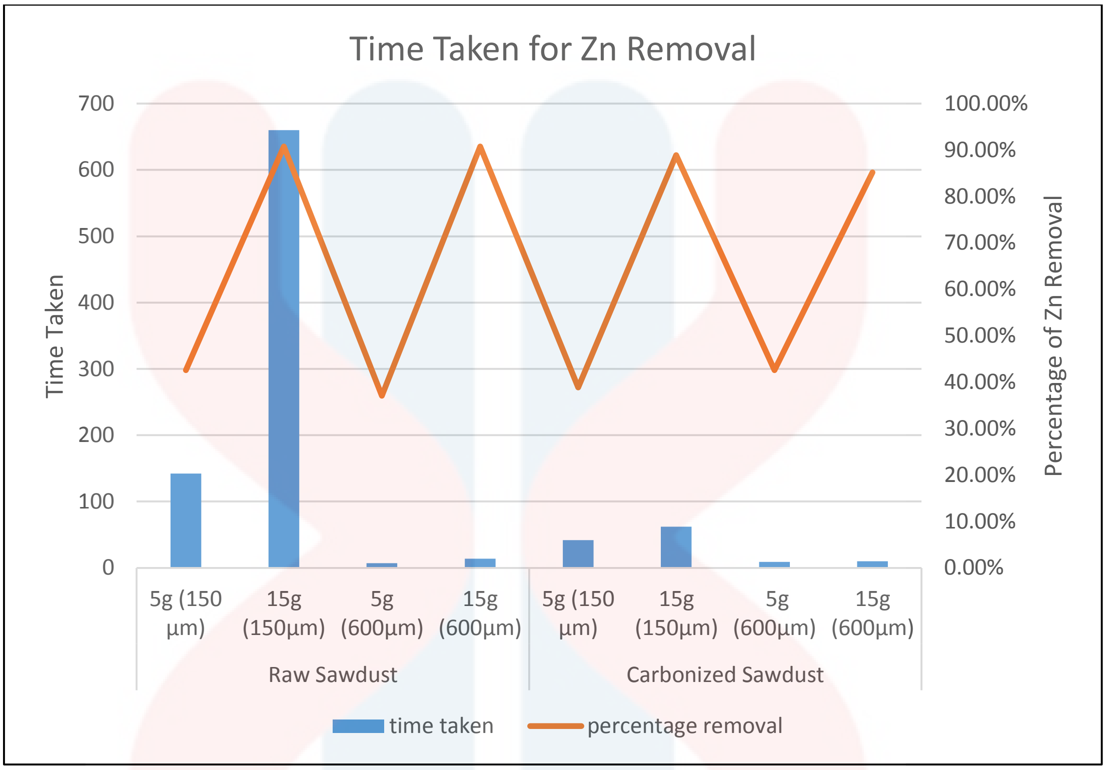


Figure G1 Percentage of Zn Removal based on Time Taken

APPENDIX H

Mann–Whitney *U* Test for Type of Sawdust

Table H1 Mann–Whitney *U* Test for Type of Sawdust

Ranks

	Type_of_Sawdust	N	Mean Rank	Sum of Ranks
Percentage_of_Zn_Removal	Raw	12	13.63	163.50
	Carbonized	12	11.38	136.50
	Total	24		

Test Statistics

	Percentage_of_Zn_Removal
Mann-Whitney U	58.500
Wilcoxon W	136.500
Z	-.780
Asymp. Sig. (2-tailed)	.436
Exact Sig. [2*(1-tailed Sig.)]	.443[b]

a. Grouping Variable: Type_of_Sawdust
b. Not corrected for ties.

APPENDIX I

Mann–Whitney *U* Test for Adsorbent Dosage

Table I1 Mann–Whitney *U* Test for Adsorbent Dosage

Ranks

	Adsorbent_Dosage	N	Mean Rank	Sum of Ranks
Percentage_of_Zn_Removal	5g	12	6.50	78.00
	15g	12	18.50	222.00
	Total	24		

Test Statistics

	Percentage_of_Zn_Removal
Mann-Whitney U	.000
Wilcoxon W	78.000
Z	-4.158
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

a. Grouping Variable: Adsorbent_Dosage
b. Not corrected for ties.

APPENDIX J

Mann–Whitney *U* Test for Adsorbent Particle Size

Table J1 Mann–Whitney *U* Test for Adsorbent Particle Size

Ranks

	Adsorbent_Particle_Size	N	Mean Rank	Sum of Ranks
Percentage_of_Zn_Removal	150µm	12	13.29	159.50
	600µm	12	11.71	140.50
	Total	24		

Test Statistics

	Percentage_of_Zn_Removal
Mann-Whitney U	62.500
Wilcoxon W	140.500
Z	-.549
Asymp. Sig. (2-tailed)	.583
Exact Sig. [2*(1-tailed Sig.)]	.590[b]

a. Grouping Variable: Adsorbent_Particle_Size
b. Not corrected for ties.