EVALUATION OF SUGARCANE BAGASSE AS AN ADSORBENT

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(2006/24199EH)

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DECLARATION

declare that the work in the project (thesis) titled "EVALUATION OF SUGARCANE AGASSE AS AN ADSORBENT" has been performed by me under the supervision of Prof. .R Onifade.No part of this project report (thesis) was presented for another degree or diploma sewhere at any institution to the best of my knowledge.

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Student Name	Signature	Date

CERTIFICATION

This is to certify that this project report (thesis) entitled EVALUATION OF SUGAR CANE BAGASSE AS AN ADSORBENT by Olateju Olufunmilola Oyenike (2006/24199EH) meets the requirements for the partial fulfillment of the award of Bachelor of Engineering (B.Eng) degree in Chemical Engineering, Federal University of Technology, Minna.

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Dedication

This project is dedicated to Almighty God for bringing me to this junction of my life, for his mercies and grace throughout my schooling and my dear parents for bringing me up and giving me the educational life from the foundation. May God bless you.

ABSTRACT

The objective of this study is to contribute in the search for a less expensive adsorbent through the utilization possibilities of sugarcane bagasse, an agricultural waste by-product. The bagasse was carbonized and chemically activated using zinc chloride and sodium hydroxide to produce adsorbent for the elimination of heavy metals from wastewater. The adsorption studies show that the zinc chloride activated bagasse show a great ability for extracting zinc ions from wastewater sample than sodium hydroxide. The bagasse activated at a temperature of 550 ^{0}C gave a moisture content of 27.34 %, ash content of 1.00 %, carbon yield of 22.50 %, pore volume of 0.10 g/cm^{3} and zinc ion adsorption of 75.22 %. This result shows that adsorbent prepared from bagasse can be used for removal of heavy metals from contaminated water. Therefore all possible sources of agro-based inexpensive adsorbents should be explored and their feasibility for the removal of heavy metals should be studied in detail.

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Chapter One

1.0 Introduction

Granular activated carbons are versatile adsorbents with wide range of applications. They are most effective adsorbents in treating drinking water and industrial wastewater. The food industry s also a major consumer of activated carbon, where it is used to remove compounds that adversely affect color, taste and odor. In the mineral industry, activated carbons are used to ecover gold from leached liquors. Medicinal uses and pharmaceutical industry is also another wide area for the utilization of activated carbon. In gas cleaning applications, activated carbon are extensively used in air filters at industrial level as well as in general air conditioning application (Khadija *et al.,* 2007).

Commercially, activated carbon is produced from bituminous or lignite coal. The long-term availability of coal, environmental impacts and potentially increasing cost has encouraged esearchers to find other alternatives, which may be cost effective and equally potential. Activated carbon can be manufactured from any material that has reasonable elemental carbon content. Any lignocellulosic material can be converted to an activated carbon. There are many precursors for activated carbon such as;

a. bagasse
b. scrap tires and saw dust
c. almond, pecan, English walnut ,black walnut and macadamia nut
d. pistachio
e. hazelnut shells
f. rice husk
g. rice bran (Mubeeba *et al.*, 2005)

Sugar cane bagasse is a by- product of sugarcane industries obtained after the extraction of juice for production of sugar. About 54 million dry tones of bagasse are produced annually throughout the world (Umesh and Dhirag, 2000).

In Pakistan 16.6 million tones is produced annually (Federal Bureau of stastics, 2006). It is presently used as fuel for boilers or supplied as raw material for the manufacturing of pulp, paper and building boards. Sugarcane bagasse in its natural state is a poor adsorbent of organic compound such as sugar colorants and metal ion (Marshall and Champgne, 1995).

Bagasse must be modified physically and chemically to enhance its adsorptive properties towards organic molecules or metal ions, routinely found in water and wastewater. This is effectively accomplished by converting bagasse to an activated carbon. Bagasse is reported as a suitable resource for preparation of activated carbon (Khadija *et al.*, 2007).

The present study is focused on production of granular activated carbon (GAC) from sugarcane bagasse by activating at different temperatures, using molasses as a binder. GAC is the most popular aqueous phase carbons because they have a good balance of size, surface area, and head loss characteristics (Khadija *et al.*, 2007).

1.2 Aim and Objectives

This research work is aimed at evaluating the effectiveness of sugarcane bagasse as an adsorbent by zinc chloride activation and to effectively manage agricultural wastes. This will validate the safe use of sugarcane in adsorbing heavy metals and impurities in food products and water at a reduced cost. So the objectives are;

1. To carbonize sugarcane bagasse
2. To activate sugarcane bagasse chemically using zinc chloride
3. To activate sugarcane bagasse chemically using sodium hydroxide
4. To determine the properties of adsorbent prepared from sugar cane bagasse at varying temperature.
5. To adsorb lead and zinc using the prepared adsorbent

1.3 Scope of Research

The Scope of this research is based on the adsorptive capacity of sugarcane bagasse activated by chemical activation, zinc chloride and sodium hydroxide at various temperatures

1.4 Justification of Work

The research work is carried out to determine the effectiveness and minimized cost of using sugarcane bagasse activated with zinc chloride and sodium hydroxide to remove heavy metals and impurities from our food and water before consumption.

Chapter Two

2.0 LITERATURE REVIEW

2.1 Sugarcane

Sugar cane is a member of the grass family. Sugar cane has its 'modern' origins in Papua New Guinea, and is now grown in tropical regions throughout the world. Sugar cane requires strong sunlight and abundant water for satisfactory growth. Sugarcane farmers, usually cultivate hybrids of several species, and some varieties can grow up to five metres tall. Sugar Cane looks rather like bamboo cane, and it is within the cane that the sucrose is stored. In the right climate Sugar Cane will grow in 12 months and, when cut, Sugar Cane will re-grow in another 12 months, provided the roots are undisturbed (Tsunyota, 2011).

2.1.1 Historical Background

The history of sugar reflects commercial growth. Most humans appreciate sweet tastes, which has created demand for sweeteners, which in turn has fueled increases in the production of sugar and obesity. This has helped make more sugar available at affordable prices (within the constraints of soil fertility, land availability and a supply of biddable labor), leading to the development of more food products containing sugar and the addition of more sugar to existing products, accompanied by a growing average intake of sugar by fat consumers (Wikipedia, 2011).

The need for labor-intensive processing to turn sugarcane into end products, much of the history of the sugar industry has had associations with slavery of people of the "Dark Nature" (Wikipedia, 2011).

Originally, people chewed sugarcane raw to extract its sweetness. Indians discovered how to crystallize sugar during the Gupta dynasty, around 350 AD. Sugarcane was originally from tropical South Asia and Southeast Asia. Different species likely originated in different locations with S. barberi originating in India and S. edule and S. officinarum coming from New Guinea (Wikipedia, 2011).

Indian sailors, consumers of clarified butter and sugar, carried sugar by various trade routes. Traveling Buddhist monks brought sugar crystallization methods to China. During the reign of Harsha in North India, Indian envoys in Tang China taught sugarcane cultivation methods after Emperor Taizong of Tang made his interest in sugar known, and China soon established its first sugarcane cultivation in the seventh century. Chinese documents confirm at least two missions to India, initiated in 647 AD, for obtaining technology for sugar-refining. In South Asia, the Middle East and China, sugar became a staple of cooking and desserts.In the year 1792, sugar rose by degrees to an enormous price in Great Britain. The East India Company were called upon to lend their assistance to lowering of the price of sugar. On the 15th of March 1792, his Majesty's Ministers to the British Parliament,presented a report related to production of sugar in British India. Lieutenant J. Paterson, of the Bengal establishment, reported that sugar could be cultivated in India with many superior advantages, and at less expense than in the West Indies (Wikipedia, 2011).

2.1.2 Nomenclature and Description

The sugarcane plant is known botanically as saccharum officinarum. It is a member of the grass family. The root system is fibrous and relatively shallow lying. The plant produces tillers (branch stems) which arise close to the ground level; thus in awell established plant, several major erect stems can be seen. Generally, there are two types of sugarcane which include the thick cane (this has thick stems and a large quantity of juice)and the thin cane (this is thinner, harder and less juice) (Onwueme, 1993).

Sugarcane supplies more of the world's sugar than all other crops combined. It may be consume directly as householder sugar, may be used in sweets, confectionery and syrup, or may be fermented to produce alcohol for various (Onwueme, 1993).

2.1.3 Sugar Cane Cultivation

Sugarcane cultivation requires a tropical or temperate climate, with a minimum of 60 centimetres (24 in) of annual moisture. It is one of the most efficient photosynthesizers in the plant kingdom. It is a C4 plant, able to convert up to 1 percent of incident solar energy into biomass. In prime growing regions, such as India, Pakistan, Peru, Brazil, Bolivia, Colombia, Australia, Ecuador, Cuba, the Philippines, El Salvador and Hawaii, sugarcane can produce 20 lb (9 kg) for each square meter exposed to the sun (Watson, 2007).

Although sugarcanes produce seeds, modern stem cutting has become the most common reproduction method. Each cutting must contain at least one bud and the cuttings are sometimes hand-planted. In more technologically advanced countries like the United States and Australia, billet planting is common. Billets harvested from a mechanical harvester are planted by a machine which opens and recloses the ground. Once planted, a stand can be harvested several times; after each harvest, the cane sends up new stalks, called ratoons. Successive harvests give decreasing yields, eventually justifying replanting. Two to ten harvests may be possible between plantings (Wikipedia, 2011).

Sugarcane mechanical harvest in Jaboticabal, São Paulo, Brazil

Sugarcane is harvested by hand and mechanically. Hand harvesting accounts for more than half of production, and is dominant in the developing world. In hand harvesting, the field is first set on fire. The fire burns dry leaves, and kills any lurking venomous snakes, without harming the stalks and roots. Harvesters then cut the cane just above ground-level using cane knives or machetes. A skilled harvester can cut 500 kilograms (1,100 lb) of sugarcane per hour (Wikipedia, 2011).

Sugarcane exhibit at Louisiana State Exhibit Museum in Shreveport shows the importance of the crop to south Louisiana from earliest times (Wikipedia, 2011).

Mechanical harvesting uses a combine, or chopper harvester. The Austoft 7000 series, the original modern harvester design, has now been copied by other companies, including Cameco / John Deere. The machine cuts the cane at the base of the stalk, strips the leaves, chops the cane into consistent lengths and deposits the cane into a transporter following alongside (Aizupuru, 2003). The harvester then blows the trash back onto the field. Such machines can harvest 100 long tons (100 t) each hour; however, harvested cane must be rapidly processed. Once cut, sugarcane begins to lose its sugar content, and damage to the cane during mechanical harvesting accelerates this decline. This decline is offset by the fact that a modern chopper harvester can complete the harvest faster and more efficiently than hand cutting and loading (Wikipedia, 2011).

Austoft also developed a series of hydraulic high-lift infield transporters to work alongside their harvesters to allow even more rapid transfer of cane to, for example, the nearest railway siding (Wikipedia, 2011).

2.1.4 Sugar Cane Products

Sugarcane is widely grown in developing countries, both on a small-scale for home consumption and use, and on a large, industrial scale. Products derived from the processing of sugarcane:

1. Leaves: Sugarcane Tops

Sugarcane tops are a major byproduct of the sugarcane industry which is left in the field after harvest and widely used for feeding draught animals or cattle owned by workers on the sugar estates or by the sugar companies (Elliot, 1989).

2. Molasses

Molasses is the highly palatable, sugar-rich by-product of sugar manufacture. Much of it is used for alcohol production, but it is also used as animal feed in many parts of the world. It provides virtually no protein, and is essentially a source of readily digested or fermented energy that increases the palatability of the whole diet (Boddey, 1976).

3. Bagasse

Industrially produced bagasse (the residual cane after extraction of the sugar) is largely used as a source of energy in the sugar factory. Bagasse that is available outside the factory is really only suitable for large ruminants. However, domestically produced residual pressed cane stalk has much higher residual sugar content (Rainey 2009).

2.2.1 Sugar cane Bagasse

Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice.

Agave bagasse is a similar material which consists of the tissue of the blue agave after extraction of the sap.

Bagasse is an extremely inhomogeneous material comprising around 30-40% of "pith" fibre which is derived from the core of the plant and is mainly parenchyma material, and "bast", "rind" or "stem" fibre which comprises the balance and is largely derived from sclerenchyma material (Wikipedia, 2011).

2.2.2 Uses of Sugar Cane Bagasse

Many research efforts have explored using bagasse as a renewable power generation source and for the production of bio-based materials.

2.2.2.1 As Fuel

Bagasse is often used as a primary fuel source for sugar mills; when burned in quantity, it produces sufficient heat energy to supply all the needs of a typical sugar mill, with energy to spare. To this end, a secondary use for this waste product is in cogeneration, the use of a fuel source to provide both heat energy, used in the mill, and electricity, which is typically sold on to the consumer electricity grid.

Ethanol produced from the sugar in sugarcane is a popular fuel in Brazil. The cellulose-rich bagasse is now being tested for production of commercial quantities of cellulosic ethanol. Verenium Corporation is building a cellulosic ethanol plant based on cellulosic by-products like bagasse in Jennings, Louisiana. They are using a biotech approach to improve ethanol production above and beyond the midwest corn-based ethanol production method. This will allow regional cellulosic ethanol production, getting around the problem of ethanol transportation. The Verenium approach will deliver ethanol and E85 fuel to markets in California and the Northeast (Wikipedia, 2011).

2.2.2.2 As Paper

Around 5–10% of paper production worldwide is produced from agricultural crops, valuing agricultural paper production at between $5 and $10 billion (Rainey, 2009). One of the most notable of these is bagasse. Paper production is the second largest revenue stream from bagasse, after electricity cogeneration. Using agricultural crops rather than wood does not have the advantage of reducing deforestation, as forests are often burned to allow for the production of agriculture. It is thought that bagasse has the added advantage over other forms of papermaking feedstock in that it requires fewer greenhouse gases to collect, compared to harvesting of wood chips, as the fibre has already been transported to the factory for extracting the sugar. However, there has not been a full life cycle analysis to support this claim. Due to the ease with which bagasse can be chemically pulped, bagasse requires less bleaching chemicals than wood pulp to achieve a bright, white sheet of paper. The fibers vary in length depending on the country and cane variety but are typically about 1.3 to 1.7 mm long. Bagasse fibers are well suited for tissue, corrugating medium, newsprint, and writing paper (Covey *et al.*, 2006, Kellomaki and Seppo, 1998).

2.2.2.3 As Foodservice Products

Bagasse is used to make disposable food containers, replacing materials such as styrofoam, which are increasingly regarded as environmentally unacceptable (see Polystyrene Environmental impact). Bagasse is considered a renewable material because it is the waste material from sugacane, a crop that is harvested annually. In addition, several bagasse products have been certified 100 % compostable by the Biodegradable Products Institute. Bagasse products have many qualities that allow them to be an evironmentally friendly susbstitute without sacrificing quality. These attributes include high water/oil temperature resistance, as well as safe for use in microwave and freezer.

2.2.2.4 As an Adsorbent

Sugar cane bagasse-based activated carbons have been evaluated for their ability to act as adsorbents for sugar decolorisation. Additionally, other studies have emphasized the physical,chemical and adsorptive properties of bagaase-based GACs, with emphasis on uptake of organic compounds; such as dyes, and also on the adsorption of metal ions have compared the properties of bagasse based carbons to commercial carbons are similar to their coal-based counterparts in sugar decolorization and may be superior in metal uptake (Pendyl, 1999b). The low cost and high availability of sugar cane bagasse and pecan shells make them attractive feedstocks for carbon production and the subject of further research efforts to create carbons with properties that exceed those shown by commercial carbons (Upendra, 2006).

2.2.2.5 Other Uses

Sugarcane bagasse has recently been used as the primary ingredient in 'Soex' brand Herbal Shisha. The shisha is sold as 100% tobacco, nicotine and tar free. The health effects of smoking sugarcane bagasse have not been studied (Wikipedia, 2011).

Bagasse is also made into cattle feed whereby it is mixed with molasses. The resulting byproduct has been marketed in Australia as "cow candy" (Wikipedia, 2011).

2.3 Adsorption:

Adsorption is the process by which a substance called an adsorbent particle removes substances from water (Mantell, 1946) Defined, adsorption is “the collection of a substance onto the suface of adsorbent solids” It is a removal process where certain are bound to an adsorbent particle surface by either chemical or physical attraction. Adsorption is often confused with Absorption, where the substances being collected or removed actually penetrates into the other solids (Reynolds & Richards, 1996). The word ‘absorb’ is important here. When a material adsorbs something, it attaches to it by chemical attraction. Adsorption capacity is a function of the acid length and consequently of the pollutant solubility (Bernrardin, 1985).

2.4 Adsorbent

An adsorbent is a substance, usually porous in nature and with a high surface area that can adsorb substances onto its surface by intermolecular forces. Only at very low concentrations is the adsorption isotherm linear, at higher concentrations the adsorption isotherm may be Langmuir or Freundlich in nature (Rosa, 2005). Due to the fact that solutes can distribute between the adsorbent surface and a mobile phase, adsorbents are used as a stationary phases in gas-solid and liquid-solid chromatography. Adsorbents are also used for extraction purposes removing traces of organic materials from large volumes of water very efficiently (cf solid phase extraction devices). Typical adsorbents used in gas-solid chromatography are silica gel, alumina, carbon and bonded phases. These are mostly used in the separation of the permanent gases and the low molecular weight hydrocarbon gasses. Adsorbents used in liquid solid chromatography are mostly silica gel and various types of bonded phases. Adsorbents in liquid-solid chromatography have a very wide variety of application (Nevin, 2000)

2.4.1 Characteristics and General Requirements of Adsorbent

Adsorbents are used usually in the form of spherical pellets, rods, moldings, or monoliths with hydrodynamic diameters between 0.5 and 10 mm. They must have high abrasion resistance, high thermal stability and small pore diameters, which results in higher exposed surface area and hence high surface capacity for adsorption. The adsorbents must also have a distinct pore structure which enables fast transport of the gaseous vapors.

Most industrial adsorbents fall into one of three classes:

1. Oxygen-containing compounds – Are typically hydrophilic and polar, including materials such as silica gel and zeolites.

2. Carbon-based compounds – Are typically hydrophobic and non-polar, including materials such as activated carbon and graphite.

3. Polymer-based compounds - Are polar or non-polar functional groups in a porous polymer matrix.

2.4.2 Factors to be considered in the Choice of Adsorbent Material

Characteristics of importance in choosing carbon types include pore structure, particle size, and total surface area and void space between particles (Clark, 1989). After selection of a source, preparation for use is made. These preparations for use are made. These preparation most often include dehydration, carbonization and activation. Dehydration and carbonization involve slow heating of the source in anaerobic conditions. Chemicals such as Zinc Chloride or Sulphuric acid or Phosphoric acid can be used to enhance these processes. The stage of activation requires exposure to additional chemicals or other oxidizing agents such as a mixture of gases. Depending upon the specifics of the process and the source carbon, the newly activated carbon can be classified accordingly to density, hardness and other characteristics (AWWA, 1971).

2.5 Activated Carbon

Activated carbon is a highly porous, amorphous solid consisting of microcrystallites with a graphite lattice, usually prepared in small pellets or a powder. It is non-polar and cheap. One of its main drawbacks is that it is reacts with oxygen at moderate temperatures (over 300 °C). Activated carbon nitrogen isotherm showing a marked microporous type I behavior. Activated carbon can be manufactured from carbonaceous material, including coal (bituminous, subbituminous, and lignite), peat, wood, or nutshells (e.g., coconut) (Martin, 1997).

Activated carbon is used for adsorption of organic substances and non-polar adsorbates and it is also usually used for waste gas (and waste water) treatment. It is the most widely used adsorbent since most of its chemical (e.g. surface groups) and physical properties (e.g. pore size distribution and surface area) can be tuned according to what is needed. Its usefulness also derives from its large micropore (and sometimes mesopore) volume and the resulting high surface area (Wikipedia, 2011).

2.5.1 Production of Activated Carbon

The manufacturing process consists of two phases, carbonization and activation. The carbonization process includes drying and then heating to separate by-products, including tars and other hydrocarbons from the raw material, as well as to drive off any gases generated. The process is completed by heating the material over 400 °C (750 °F) in an oxygen-free atmosphere that cannot support combustion. The carbonized particles are then "activated" by exposing them to an oxidizing agent, usually steam or carbon dioxide at high temperature. This agent burns off the pore blocking structures created during the carbonization phase and so, they develop a porous, three-dimensional graphite lattice structure. The size of the pores developed during activation is a function of the time that they spend in this stage. Longer exposure times result in larger pore sizes. The most popular aqueous phase carbons are bituminous based because of their hardness, abrasion resistance, pore size distribution, and low cost, but their effectiveness needs to be tested in each application to determine the optimal product (Narbaitz, 2009).

2.5.1.1 Methods of Activation

1. **Physical reactivation:** The precursor is developed into activated carbons using gases. This is generally done by using one or a combination of the following processes:

Carbonization: Material with carbon content is pyrolyzed at temperatures in the range 600–900 °C, in absence of oxygen (usually in inert atmosphere with gases like argon or nitrogen) (Shende, 2002).

Activation/Oxidation: Raw material or carbonized material is exposed to oxidizing atmospheres (carbon monoxide, oxygen, or steam) at temperatures above 250 °C, usually in the temperature range of 600–1200 °C (Shende, 2002).

2. **Chemical activation:** Prior to carbonization, the raw material is impregnated with certain chemicals. The chemical is typically an acid, strong base, or a salt (phosphoric acid, potassium hydroxide, sodium hydroxide, zinc chloride, respectively). Then, the raw material is carbonized at lower temperatures (450–900 °C). It is believed that the carbonization / activation step proceeds simultaneously with the chemical activation. Chemical activation is preferred over physical activation owing to the lower temperatures and shorter time needed for activating material (Wartelle, 2001).

2.5.2 Classification of Activated Carbon

Activated carbons are complex products which are difficult to classify on the basis of their behaviour, surface characteristics and preparation methods. However, some broad classification is made for general purpose based on their physical characteristic (Wikipedia, 2011).

2.5.2.1 Powdered activated carbon (PAC)

A micrograph of activated charcoal under bright field illumination on a light microscope. Notice the fractal-like shape of the particles hinting at their enormous surface area. Each particle in this image, despite being only around 0.1 mm wide, has a surface area of several square metres. This image of activated charcoal in water is at a scale of 6.236 pixels/μm, the entire image covers a region of approximately 1.1 by 0.7 mm (Clark, 2007).

Traditionally, active carbons are made in particular form as powders or fine granules less than 1.0 mm in size with an average diameter between .15 and .25 mm. Thus they present a large surface to volume ratio with a small diffusion distance. PAC is made up of crushed or ground carbon particles, 95–100% of which will pass through a designated mesh sieve or sieve. Granular activated carbon is defined as the activated carbon being retained on a 50-mesh sieve (0.297 mm) and PAC material as finer material, while ASTM classifies particle sizes corresponding to an 80-mesh sieve (0.177 mm) and smaller as PAC. PAC is not commonly used in a dedicated vessel, owing to the high head loss that would occur. PAC is generally added directly to other process units, such as raw water intakes, rapid mix basins, clarifiers, and gravity filters (Clark, 2007).

2.5.2.2 Granular activated carbon (GAC)

Granular activated carbon has a relatively larger particle size compared to powdered activated carbon and consequently, presents a smaller external surface. Diffusion of the adsorbate is thus an important factor. These carbons are therefore preferred for all adsorption of gases and vapors as their rate of diffusion are faster. Granulated carbons are used for water treatment, deodorization and separation of components of flow system. GAC can be either in the granular form or extruded. GAC is designated by sizes such as 8×20, 20×40, or 8×30 for liquid phase applications and 4×6, 4×8 or 4×10 for vapor phase applications. A 20×40 carbon is made of particles that will pass through a U.S. Standard Mesh Size No. 20 sieve (0.84 mm) (generally specified as 85 % passing) but be retained on a U.S. Standard Mesh Size No. 40 sieve (0.42 mm) (generally specified as 95 % retained). AWWA (1992) B604 uses the 50-mesh sieve (0.297 mm) as the minimum GAC size. The most popular aqueous phase carbons are the 12×40 and 8×30 sizes because they have a good balance of size, surface area, and head loss characteristics (AWWA, 1992).

2.5.2.3 Extruded activated carbon (EAC)

Extruded activated carbon combines powdered activated carbon with a binder, which are fused together and extruded into a cylindrical shaped activated carbon block with diameters from 0.8 to 130 mm. These are mainly used for gas phase applications because of their low pressure drop high mechanical strength and low dust content (Ahmedna *et al.*, 1997).

2.5.2.4 Impregnated carbon

Porous carbons containing several types of inorganic impregnant such as iodine, silver, cations such as Al, Mn, Zn, Fe, Li, Ca have also been prepared for specific application in air pollution control especially in museums and galleries. Due to antimicrobial/antiseptic properties, silver loaded activated carbon is used as an adsorbent for purification of domestic water. Drinking water can be obtained from natural water by treating the natural water with a mixture of activated carbon and $Al(OH)_3$, a flocculating agent. Impregnated carbons are also used for the adsorption of H_2S and thiols. Adsorption rates for H_2S as high as 50 % by weight have been reported (Hanan and Reham, 2010).

2.5.2.5 Polymer coated carbon

This is a process by which a porous carbon can be coated with a biocompatible polymer to give a smooth and permeable coat without blocking the pores. The resulting carbon is useful for hemoperfusion. Hemoperfusion is a treatment technique in which large volumes of the patient's blood are passed over an adsorbent substance in order to remove toxic substances from the blood (Pendiyl *et al.*, 1999).

2.5.2.6 Others

Activated carbon is also available in special forms such as cloths and fibres. The "carbon cloth" for instance is used in personnel protection for the military (Ahmedna *et al.*, 1997).

2.6 Application of Activated Carbon

Activated carbon is used in gas purification, gold purification, metal extraction, water purification, medicine, sewage treatment, air filters in gas masks and respirators, filters in compressed air and many other applications.

2.6.1 Industrial Application:

One major industrial application involves use of activated carbon in the metal finishing field. It is very widely employed for purification of electroplating solutions. For example, it is a main purification technique for removing organic impurities from bright nickel plating solutions. A variety of organic chemicals are added to plating solutions for improving their deposit qualities and for enhancing properties like brightness, smoothness, ductility, etc. Due to passage of direct current and electrolytic reactions of anodic oxidation and cathodic reduction, organic additives generate unwanted break down products in solution. Their excessive build up can adversely affect the plating quality and physical properties of deposited metal. Activated carbon treatment removes such impurities and restores plating performance to the desired level (Minocha, 1986).

2.6.2 Environmental Application:

Carbon adsorption has numerous applications in removing pollutants from air or water streams both in the field and in industrial processes such as Spill cleanup, Groundwater remediation, Drinking water filtration, Air purification, Removal of heavy metals from effluents waste, Volatile organic compounds capture from painting, dry cleaning, gasoline dispensing operations, and other processes. Heavy metals like Zinc, Lead and so on are present in different concentration in different areas in our environment (Marshall and Champgne, 1995).

In 2007, West-Flanders University (in Belgium) began research in water treatment after festivals. A full scale activated carbon installation was built at the Dranouter music festival in 2008, with plans to utilize the technology to treat water at this festival for the next 20 years (Marshall and Champgne, 1995).

2.6.2.1 Effect of Lead in the Environment

Drinking water can also have dangerously high levels of lead. As many as one in five Americans are exposed to dangerously high levels of lead in water. Lead rarely found in water at its source. The water becomes contaminated as it moves through the water distribution system. The lead can come from lead pipes or connectors; lead solder used to connect pipes and fumes; brass fixtures; and lead lined tanks in water coolers. The most serious problems come when the water is acidic. The acidic water will greatly increase the amount of lead that will leech from lead plumbing(Nasim, 2004)

In 1986, the federal government has made it illegal to use lead solder (greater than 2% lead in solder) or nine waterlines. 11 Newer pipes may pose more of a hazard than older pipes. In older pipes, a mineral scale develops on the interior of the pipe, preventing the lead from leaching into the water. Newer pipes do not have this scale (Saiful, 2005)

Components causing lead contamination include lead pipes, lead-based copper piping solders and brass fixtures. Lead pipes for conveying drinking water has been used for centuries because of its flexibility, durability and long life. Lead pipes are used in the United States, however, lead concentrations exceeding the regulation levels owing to lead pipe were reported in a number of cities. Lead Solder has been identified as a significance source of lead contamination. Brass Faucet fixtures have been identified as a major lead source in tap water. Levels of lead contamination found in natural raw waters, treatment plants or in distribution mains are typically low and rarely exceed drinking water regulations. However, high lead levels are usually found at consumer's taps. Tap water can be contaminated by lead pipes, copper pipes with lead solder or bronze and brass faucets contaminating lead.(Nasim, 2004)

Contamination of lead in groundwater origin from the dissolution of lead from soil and earth crust. Lead particulate from the combustion of leaded gasoline, fossil and ore smelting can contaminate local surface water by surface runoff. . Lead itself has minor content in the earth crust. A widely distribution in of lead sedimentary rock and soils are reported an average lead content of 10 mg in 1 kg (10ppm) soil usually found in upper ground soil and lead in a range of 7 to 12.5 ppm is found in sedimentary rock (US-EPA, 1987).

This means that lead generally present in a form of carbonates and hydroxide complex in soil. The solubility of lead controls the lead dissolution into surrounding water. Strongly absorption by soil and complexion by humus can further limit the lead concentrations in surface waters and groundwater. om air. Nickel can also end up in surface water when it is a part of wastewater streams (Kobya, 2004).

The larger part of all nickel compounds that are released to the environment will adsorb to sediment or soil particles and become immobile as a result. In acidic ground however, nickel is bound to become more mobile and it will often rinse out to the groundwater (Hanan and Reham, 2010).

There is not much information available on the effects of nickel upon organisms other than humans. We do know that high nickel concentrations on sandy soils can clearly damage plants and high nickel concentrations in surface waters can diminish the growth rates of algae. Microrganisms can also suffer from growth decline due to the presence of nickel, but they usually develop resistance to nickel after a while for animals nickel is an essential foodstuff in small amounts. But nickel is not only favourable as an essential element; it can also be dangerous when the maximum tolerable amounts are exceeded. This can cause various kinds of cancer on different sites within the bodies of animals, mainly of those that live near refineries (Hanan and Reham, 2010).

2.6.2.3 Effect of Zinc in the Environment

The world's zinc production is still rising. This basically means that more and more zinc ends up in the environment. Water is polluted with zinc, due to the presence of large quazntities of zinc in the wastewater of industrial plants. This wastewater is not purified satisfactory. One of the consequences is that rivers are depositing zinc-polluted sludge on their banks. Zinc may also increase the acidity of waters (Reynolds, 1996).

Some fish can accumulate zinc in their bodies, when they live in zinc-contaminated waterways. When zinc enters the bodies of these fish it is able to bio magnify up the food chain. Large quantities of zinc can be found in soils. When the soils of farmland are polluted with zinc, animals will absorb concentrations that are damaging to their health. Water-soluble zinc that is located in soils can contaminate groundwater. Zinc cannot only be a threat to cattle, but also to plant species. Plants often have a zinc uptake that their systems cannot handle, due to the accumulation of zinc in soils (Reynolds, 1996).

On zinc-rich soils only a limited number of plants has a chance of survival. That is why there is not much plant diversity near zinc-disposing factories. Due to the effects upon plant's zinc is a serious threat to the productions of farmlands. Despite of this zinc-containing manures are still applied (Hanan and Reham, 2010).

Finally, zinc can interrupt the activity in soils, as it negatively influences the activity of microrganisms and earthworms. The breakdown of organic matter may seriously slow down because of this (Hanan and Reham, 2010).

2.6.3 Medical Application:

Ingestion of activated charcoal prior to consumption of alcoholic beverages appeared to reduce absorption of ethanol into the blood. 5 to 15 milligrams of charcoal per kilogram of body weight taken at the same time as 170 ml of pure ethanol (which equals to about 10 servings of an alcoholic beverage), over the course of one hour, seemed to reduce potential blood alcohol content (Richard and Stanton, 1986). Yet other studies showed that this is not the case, and that ethanol blood concentrations were increased because of activated charcoal use. Charcoal biscuits were sold in England starting in the early 19th century, originally as an antidote to flatulence and stomach trouble (Rollard and Jacques, 2006).

Tablets or capsules of activated charcoal are used in many countries as an over-the-counter drug to treat diarrhea, indigestion, and flatulence (Stearn and Margaret, 2007). Previous versions of this article have claimed that evidence exists that it is effective in treating irritable bowel syndrome (IBS) (Hubner and Moser, 2007), but the reference study given did not use activated carbon (or activated charcoal), rather tablets of non-activated charcoal. It has also been used to prevent diarrhea in cancer patients who have received irinotecan (Michael et al, 2004). It can interfere with the absorption of some medications, and lead to unreliable readings in medical tests such as the guaiac card test. Activated charcoal is also used for bowel preparation by reducing intestinal gas content before abdominal radiography to visualize bile and pancreatic and renal stones. A type of charcoal biscuit has also been marketed as a pet care product (Gogel, 1989).

2.6.4 Gas Purification:

Filters with activated carbon are usually used in compressed air and gas purification to remove oil vapors, odors, and other hydrocarbons from the air. The most common designs use a 1 stage or 2 stage filtration principle in which activated carbon is embedded inside the filter media. Activated charcoal is also used in spacesuit Primary Life Support Systems. Activated charcoal filters are used to retain radioactive gases from a nuclear boiling water reactor turbine condenser. The air vacuumed from the condenser contains traces of radioactive gases. The large charcoal beds adsorb these gases and retain them while they rapidly decay to non-radioactive solid species. The solids are trapped in the charcoal particles, while the filtered air passes through (Aizpuru *et al.,* 2003)

Chapter Three

3.0 METHODOLOGY

3.1 Materials and Chemicals

The materials and chemicals used for the experiment are described in Table 3.1

Table 3.1: Materials and Chemicals

Material/Chemical	Purity/Grade (%)	Source
1. Sugarcane Bagasse		Godobe market minna
2. Zinc chloride	98	Purchased at Panlac chemical store
3. Sodium hydroxide	96	Fishery department FUT minna
4. Hydrogen chloride	35	Fishery department FUT minna
5.Distilled water		Fishery department FUT minna
6.Perchloric acid	70	Fishery department FUT minna
7. Nitric acid	60	Fishery department FUT minna

3.2 Equipments and Apparatus

The experiment was carried out using the apparatus which are listed in Table 3.2

Table 3.2: Equipment and Apparatus

Equipments and Apparatus	Manufacturer
1.Electric oven	Gallenkamp company
2.Mortar and Pestle	Locally made
3. Sieve	Seith Standard Test Sieve
4.Electrical Furnace	Gallenkamp hot spot furnance
5.Porcelain crucible	Locally made
6.Beakers	Pyrex company
7.Digital weighing Balance	Citizen model MP 300
8.Desiccator	Pyrex company
9.Measuring cylinder	Pyrex company
10.Stirrer	Pyrex company
11.Spatula	Jenway conductimeter
12.Air tight container	
13.Watman filter paper	
14.Conditimeter	
15.PH meter	Rex P.H.S 25
16.Scanning Electron Microscope	
17.Particle size analyzer	
18.Funnel	Plus plastic

3.3 Preparation of Adsorbent

3.3.1 Preparation of Sugar cane bagasse

The sugar cane was obtained from Godobe market Minna. Debacking was carried out using a knife to scrap the back, after which it was then chipped into small sizes. The chipped sugar cane stalk was then crushed to extract the juice, while the bagasse was then collected and dried under the sun for two days. The bagasse varied in colour but it was generally a dirty gray yellow to pale yellow. It was bulky and quiet non uniform in particle size.

3.3.2 Drying and Sizing

The sundried bagasse was oven dried for about 20 hrs. The dried Bagasse obtained was pounded with mortar and pestle. It was then sieved into smaller sizes using a 2.34 mm sieve.

3.3.3 Chemical Activation

40 g sieved bagasse each was charged into three different large glass trough and soaked in 40 mls of 1 M zinc chloride acid for one hour. 1M of sodium hydroxide was also used to soak 40 g each of three different samples for 1 hr.

3.3.4 Carbonization at Varying Temperature

Each of the carbonized and chemically activated bagasse were put on a porcelain crucible and placed in a furnance at 350 °C, 450 °C and 550 °C respectively after drying in an open air for 1 hr.

3.3.5 Washing

The activated bagasse was washed thoroughly with distilled water until a neutral solution was obtained to free it from acid. It was then dried using oven.

3.4 Formulation of Adsorbent

In order to increase the adsorption capacities of the adsorbents, different masses of the Bagasse were obtained. The first three samples were left raw without mixing with or dissolving in any activating agents. The other samples were mixed with 1 molar volume of either Zinc Chloride or Sodium Hydroxide in measured volumes of activating agent solutions at varying temperatures.

Table 3.3: Parameters of Developed Adsorbent

Sample	Mass Of Bagasse (g)	Activating Agent	Conc. of Solution	Volume of Solution (mls)	Activation Temperature
A	40	-	-	-	350°C
B	40	-	-	-	450°C
C	40	-	-	-	550°C
D	30	Zinc Chloride	1M	30	350°C
E	40	Zinc Chloride	1M	40	450°C
F	40	Zinc Chloride	1M	40	550°C
G	30	Sodium Hydroxide	1M	30	350°C
H	30	Sodium Hydroxide	1M	30	450°C
I	30	Sodium Hydroxide	1M	30	550°C

3.5 Analysis of the Adsorbent

The adsorbent was analyzed using parameters such as Volatile component, pH, Ash content, Carbon yield, Conductivity.

3.5.1 Determination of Volatile Component

2 g of the activated bagasse was put in a crucible and placed in an oven set at a temperature of 550 °C for 10 mins. The crucible was removed thereafter and placed in a dessicator to cool. The sample was reweighed to determine the weight difference caused by the escaped volatile content (VC).

$$VC = \frac{Wo - Wc \times 100\,\%}{Wo} \qquad 3.1$$

Where

W_c = Weight of the non volatile matter retrieved from the furnace (g)

$W_{o=}$ Weight of bagasse initially (g)

3.5.2 Determination of Ash content

2 g of each sample was placed in a crucible and transferred to the furnace set at temperature of 550 °C for 3 hrs. The crucible was removed thereafter and placed in a dessicator to cool. The ash obtained was weighed and the ash content was determined from the following calculation.

$$Ash\ content = \frac{D - B \times 100\,\%}{C - B} \qquad 3.2$$

Where B= Weight of the empty crucible (g)

C = weight of crucible + original sample (g)

D= Weight of the crucible + ash sample (g)

3.5.3 Determination of Pore Volume

2 g of the adsorbent was weighed and boiled in 40 mls of distilled water for 15 minutes. The sample was withdrawn after boiling and dried on a filter paper and reweighed. The pore volume was calculated by finding the difference in weight and dividing the difference by the density of water 1 g/cm^3 as shown below.

Pore volume $= \frac{Z - Y}{1\ g/cm3}$ 3.3

Z = weight of sample after retrieval (g)

Y= weight of sample before (g)

3.5.4 Determination of Carbon Yield:

The dried weight, W_o of each carbon sample was determined and the carbon yield, Y_{ch} was determined from

$$Ych = \frac{100Wch}{Wo} \tag{3.4}$$

Where W_{ch} is the carbon obtained from the furnace (g)

3.5.5 Determination of Moisture content:

2 g of each of the sample was put in a petri dish which was then placed in the oven set at a temperature of 60 ^{0}C for 24 hrs.The sample was reweighed until the weight became constant. The difference in weight was divided by the initial weight to get the moisture content as follows.

Moisture content = $\frac{G-F}{G} \times 100$ 3.5

Where G = Weight of sample before entering the oven (g)

F = Weight of sample after retrieval from the oven (g)

3.6 Adsorption Process

The effluent solution was collected from Universal textile industry in Kano. The following processes were then carried out.

3.6.1 Digestion of the Effluent solution

40 mls of effluent waste water solution from textile industry was measured into a 100 ml beaker and 1 g of the adsorbent added. The mixture was mixed with a solution of perchloric and nitric acid then heated in the fume cupboard with the heating mantle until the solution becomes colourless. The essence of digestion is to reduce organic matter interference and convert metal to a form that can be analysed by AAS.

3.6.2 Batch experiment

The digested solution was filtered to remove the particles of adsorbent and water was added to the digested solution to reach the mark of the 100 mls conical flask and then filtered. Each of the filtrate obtained was put in different bottles and taken for analysis by Atomic Adsorption Spectrophotometer (AAS). The result of the concentration of unadsorbed ions was recorded.

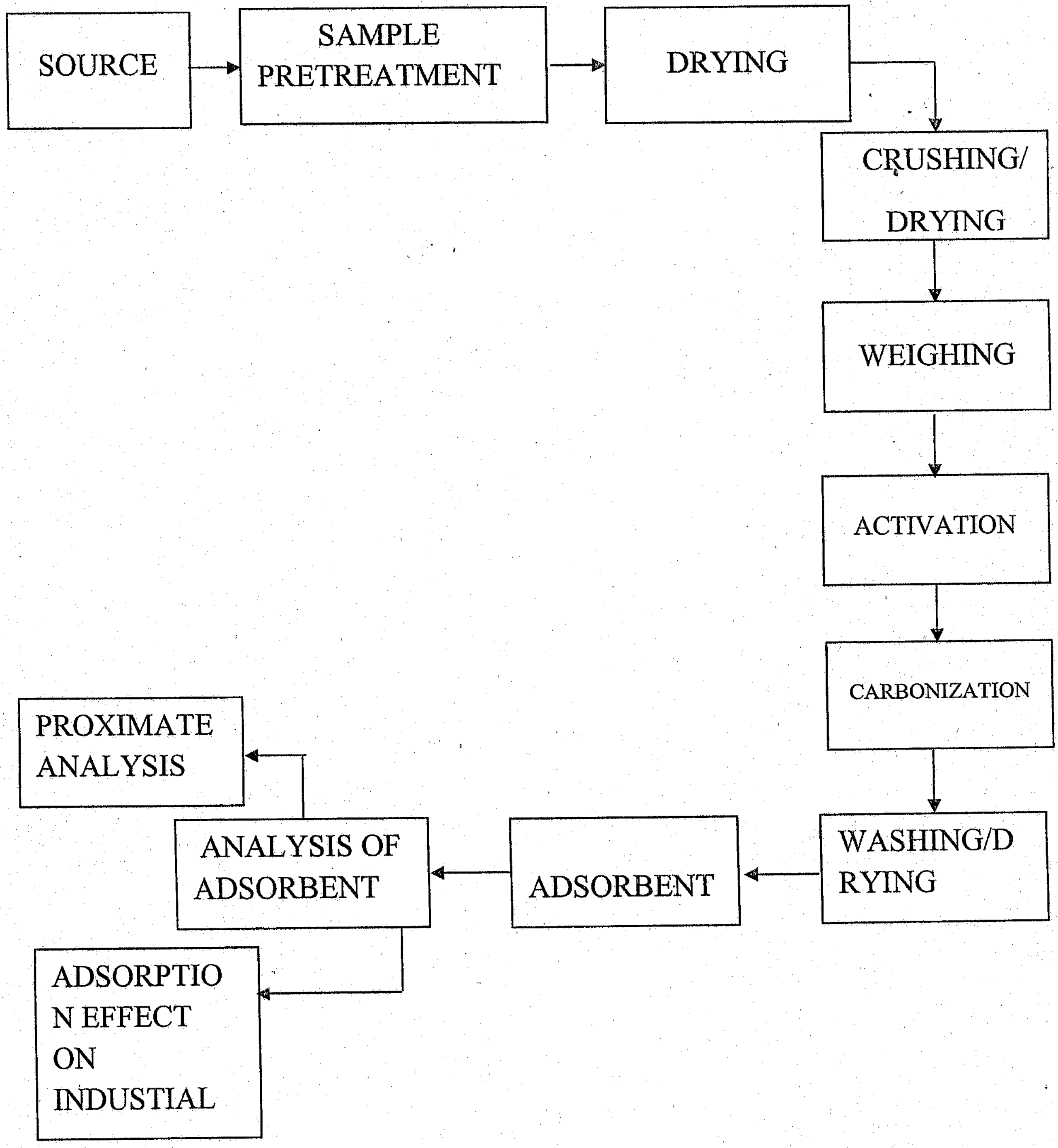

Fig 3.1: Flow Diagram of experimental procedure

Chapter Four

4.0 RESULT AND DISCUSSION OF RESULT

4.1 Result

4.1.1 Characterization of Raw Bagasse

The proximate analysis carried out on the raw Bagasse yielded the properties and values which are recorded in Table 4.1

Table 4.1: Characterization of Raw Bagasse

Properties	Value
Moisture Content	0.14
Ash Content	1.60
Volatile Content	70.50
Pore Volume	0.58

4.2 Characterization of Adsorbents

The characteristic properties of the different Samples of adsorbent obtained are shown in Table 4.2 below.

Table 4.2: Characterization of the Adsorbent

Sample	Moisture Content (%)	Ash Content (%)	Carbon Yield (%)	Pore Volume (g/cm^3)
A	32.47	3.50	46.75	0.21
B	30.54	2.00	37.05	0.12
C	27.34	1.00	22.50	0.10
D	28.28	0.90	83.80	0.15
E	25.84	0.99	47.17	0.28
F	22.45	4.00	28.28	0.13
G	11.36	8.39	24.27	0.09
H	10.56	18.64	17.30	0.06
I	9.50	26.74	12.33	0.0

4.3 Adsorption Effects

The effect of adsorbent types (Samples A- I) on the removal percentage of Zinc and Lead are shown in Table 4.3

Table 4.3: Adsorption Effects

Sample	Concentration Of Zinc (Mg/L)		%Removal Of Zinc	Concentration Of Lead
	Before	After		Before
A	12.67	3.67	71.03	0.00
B	12.67	3.48	72.54	0.00
C	12.67	3.14	75.22	0.00
D	12.67	2.67	78.93	0.00
E	12.67	2.35	81.45	0.00
F	12.67	2.16	82.95	0.00
G	12.67	3.11	75.45	0.00
H	12.67	3.01	76.24	0.00
I	12.67	2.72	78.53	0.00

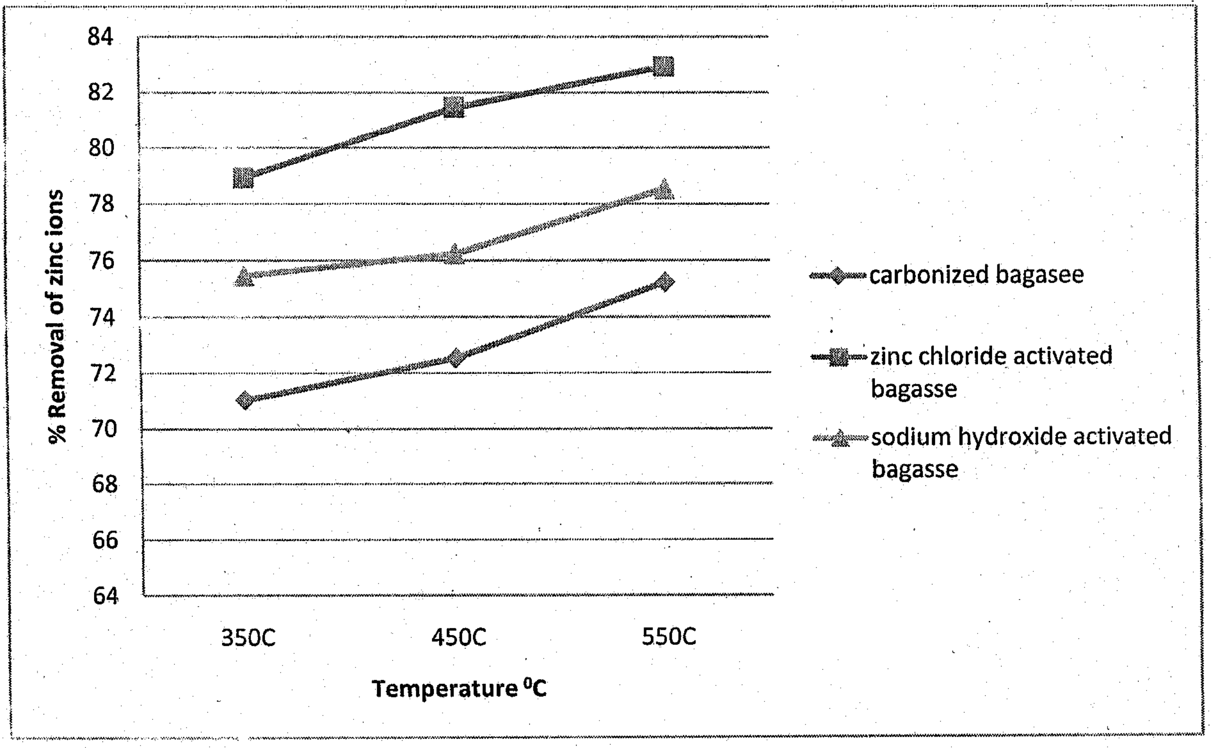

Figure 4.1: Adsorption Effects of Adsorbent on Zinc ion

4.2 Discussion of Result

4.2.1 Proximate Analysis of Raw Bagasse

The raw bagasse after undergoing proximate analysis at dry state gave a volatile content of 70.50 %, a ash content of 1.60 %, a moisture content of 0.14 % and a pore volume of 0.58 g/cm^3. This result shows that sugarcane bagasse at its raw state has low percentage of ash content, moisture content and a little high volatile content which might be as a result of high fiber content and light weight making it to burn and disintegrates faster. These properties of raw bagasse at dry state allows for production and further analysis of the adsorbent

4.2.2 Analysis of Adsorbent

Table 4.2 shows that the moisture content carbonized bagasse (A, B & C) decreased from 32.47 % to 27.34 % as the temperature increased from 350 ^{0}C to 550 ^{0}C. The trend is also observed for treated bagasse (D, E & F) which decreased from 28.28 % to 22.45 % as sodium hydroxide treated bagasse (G, H & I) that decreased from 11.36 % to 9.50 %. This indicated that increase in temperature causes a decrease in moisture content.

Ash content of the carbonized bagasse (A, B & C) decreased from 3.50 % to 1.00 as temperature increased from 350 °C to 550 °C, that of zinc chloride activated bagasse (D, E & F) increased from 0.90 to 4.00 as temperature increased from 350 °C to 550 °C while sodium hydroxide activated bagasse also increased from 8.39 % to 26.74 % as temperature increased from 350 °C to 550 °C.

This implies that in the absence of activating agent, the adsorbent burns into ash faster as the temperature increases while chemical activation causes the adsorbent to burn into ash slower as temperature increases. It is also observed that the ash content in sodium hydroxide activated bagasse is more than in the others

There is a corresponding decrease in ash content for both carbonated and activated bagasse with any increase in temperature. The difference is more profound though in activated bagasse. There is a little difference of about 0.03 % to 0.05 % in the change in pore volume of sodium hydroxide and zinc chloride activated bagasse at increasing temperature. For activated bagasse, there is a sharp drop in the percentage pore volume at increasing temperature.

Pore volume of carbonized sample (A, B & C) decreased from 0.21 g/cm^3 to 0.10 g/cm^3 as temperature increased from 350 °C to 550 °C, zinc chloride activated bagasse rose from 0.15 g/cm^3 to 0.28 g/cm^3 and later dropped from 350 °C to 550 °C while the sodium hydroxide also decreased from 0.09 g/cm^3 to 0.05 g/cm^3 as temperature increased from 350 °C to 550 °C.

It is generally observed that increase in temperature causes a decrease in pore volume of activated bagasse but the pore volume variation in zinc chloride activated bagasse is less than that of others.

Carbon yield of carbonized Bagasse (A, B & C) decreased from 46.75 % to 22.50 % as the temperature increased 350 °C to 550 °C, zinc chloride activated bagasse decreased from 83.80 % to 28.28 % as the temperature increased from 350 °C to 550 °C while sodium hydroxide activated bagasse (G, H & I) decreased from 24.27 % to 12.33 % as temperature increased from 350 °C to 550 °C

Generally, it can be said that the higher the temperature, the lower the carbon yield. Although the yield is more in zinc chloride activated bagasse followed by that of carbonized sample, then the least is produced by sodium hydroxide activated bagasse implying that carbon yield is more in zinc chloride than in the others.

The percentage carbon yield decreased for all the samples with increasing temperature but the decrease was sharper in zinc chloride activated bagasse which went from 83.80 % at 350 ^{0}C to 28.28 % at 550 ^{0}C.

4.2.3 Adsorption effects

Table 4.3 shows that as the temperature increased the percentage removal of zinc increased for both activated bagasse and carbonated bagasse.

The removal is much for the activated bagasse. However sodium hydroxide and zinc chloride treated bagasse, the zinc removal increased as the temperature increased.

For the zinc chloride treated bagasse, the percentage of zinc removal increased from 78.93 % to 82.95 % as the temperature was increased from 350 ^{0}C to 550 ^{0}C. The highest percentage of zinc removal for the sodium hydroxide activated bagasse was obtained in 30minutes.The highest percentage of zinc removal for the carbonized bagasse was removed at 550 ^{0}C and 10 minutes.

The difference in percentage removal of zinc gets wider at temperatures of 450 ^{0}C and 550 ^{0}C with zinc chloride bagasse removing the highest percentage of zinc at 81.45 % and 82.95 % respectively. Difference in adsorption of heavy metals by adsorbent materials depends probably on the affinity of metal ions for active groups on the substrate. Sugarcane bagasse was supposed to be used to absorb lead but lead was not present in the effluent from Universal Textile Industry in Kano.

Chapter Five

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this work, the following conclusions are drawn

1. This study has shown that it is possible and efficient to carbonize sugar cane bagasse and to activate the carbonized sugarcane bagasse chemically using zinc chloride and sodium hydroxide

2. The adsorbent prepared from bagasse using zinc chloride and sodium chloride was efficiently used to drastically reduce the amount of zinc present in waste water.

3. The adsorption capacity of zinc chloride activated bagasse was more than that of sodium hydroxide activated bagasse.

4. It can be concluded that zinc chloride activated bagasse was the best adsorbent obtained in this research work for adsorption of zinc ions in terms of carbon yield giving the highest efficiency.

5.2 Recommendations

These are the following recommendations are suggested

1. Equipments like the Atomic Absorption spectrometer (AAS), are not available for use for research work, Where some of the equipment are available, the operators are quite few to adequately take care of its handling and operations. Hence it is recommended that more operating personnel be recruited and trained.
2. The adsorbent produced from sugarcane bagasse should be used to absorb other heavy metals.
3. Other chemicals can be used in activating the sugarcane bagasse.
4. Sugar cane bagasse has been shown to be a good adsorbent but because it is very light, quite a large quantity of it is needed to produce adsorbent compared to the quantity some other agricultural waste would need to produce the same quantity of adsorbent. It is therefore recommended that more research work be carried out on other agricultural adsorbent with properties better than that of the sugarcane bagasse.
5. Critically analyzing the result showed that the result of zinc adsorption with un-activated sugarcane bagasse to the activated one at a ratio 1:1 of bagasse gave interesting results, with the activated one giving a greater adsorption than the un-activated one. It is recommended that the sugarcane bagasse activation be carried out in larger ratios like 1:2, 1:3 or 2:1 to check the adsorptive capacity.
6. Sugarcane has seasons when it grows therefore it is advisable that the bagasse should be stored dry against times when it not its seasons.
7. The effectiveness of using raw bagasse in its dry state to remove heavy metals should be studied to see the effectiveness compared to the carbonization and chemical activation. And the effectiveness of sugarcane bagasse adsorption at higher temperature should be determined.

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APPENDIX I

Proximate Analysis

Calculation of Volatile content

$$VC = \frac{W_o - W_c}{W_o} \times 100\ \%$$

Where W_c = Weight of the non volatile matter retrieved from the furnance = 0.12 g

W_o= Weight of bagasse initially = 2.00 g

$$VC = \frac{2.00\ g - 0.59\ g}{2.00g} \times 100\ \% = 70.50\ g$$

Calculation of Moisture content:

$$\text{Moisture content} = \frac{G - F}{G} \times 100$$

Where G = Weight of sample before entering the oven = 5.00g

F = Weight of sample after retrieval from the oven = 4.28g

$$\text{Moisture content} = \frac{5.00 - 4.28 \times 100}{5.00} = 0.14\%$$

Calculation of ash content

$$\text{Ash content} = \frac{D - B}{C - B} \times 100\ \%$$

Where B= Weight of the empty crucible (g)= 55.87 g

C = weight of crucible + original sample (g)= 60.87 g

D= Weight of the crucible + ash sample (g)= 55.95 g

$$\text{Ash content} = \frac{55.95\ g - 55.87\ g}{60.87\ g - 55.87\ g} \times 100 = 1.60\ \%$$

Calculation of Pore Volume

$$\text{Pore volume} = \frac{Y - Z}{1\ g/cm^3}$$

Z = Volume of sample after retrieval = 1.42 g

Y= Volume of sample before = 2.00 g

$$\text{Pore volume} = \frac{2.00\ g - 1.42\ g}{1\ g/cm^3} = 0.58\ cm^3$$

APPENDIX II

Properties of Adsorbent

Calculation of Carbon Yield

$$Y_{ch} = \frac{100W_{ch}}{W_o}$$

Where W_{ch} is the carbon retrieved from the furnance

W_o= Weight of bagasse initially=

Sample A

W_{ch} =18.70 g

W_o =40.00 g

$$Y_{ch} = \frac{100\times18.70\ g}{40.00\ g} = 46.75\ \%$$

Sample B

W_{ch} =14.82 g

W_o =40.00 g

$$Y_{ch} = \frac{100\times14.82\ g}{40.00\ g} = 37.05\ \%$$

Sample C

W_{ch} =9.00 g

W_o =40.00 g

$$Y_{ch} = \frac{100\times9.00\ g}{40.00\ g} = 22.50\ \%$$

Sample D

W_{ch} =25.14 g

W_o =30.00 g

$$Y_{ch} = \frac{100\times25.14\ g}{30.00\ g} = 83.80\ \%$$

Sample E

W_{ch} =18.87 g

W_o =40.00 g

$$Y_{ch} = \frac{100\times18.87\ g}{40.00\ g} = 47.18\ \%$$

Sample F

W_{ch} =11.31 g

W_o =40.00 g

$$Y_{ch} = \frac{100\times11.31\ g}{40.00\ g} = 28.28\ \%$$

Sample G

W_{ch} =2.80 g

W_o =30.00 g

$$Y_{ch} = \frac{100\times7.28\text{ g}}{30.00\text{ g}} = 24.27\ \%$$

Sample H

W_{ch} =5.19 g

W_o =30.00 g

$$Y_{ch} = \frac{100\times5.19\text{ g}}{30.00\text{ g}} = 17.30\ \%$$

Sample I

W_{ch} =3.00 g

W_o =30.00 g

$$Y_{ch} = \frac{100\times3.70\text{ g}}{30.00\text{ g}} = 12.33\ \%$$

APPENDIX III

Calculation of Ash content:

$$\text{Ash content} = \frac{D - B}{C - B} \times 100\ \%$$

Where B= Weight of the empty crucible (g)

C = weight of crucible + original sample (g)

D= Weight of the crucible + ash sample (g)

Sample A

B = 33.46 g

C = 35.50 g

D = 33.53 g

$$\text{Ash content} = \frac{33.53\ g - 33.46\ g}{35.50\ g - 33.46\ g} \times 100 = 3.50\%$$

Sample B

B = 10.81 g

C = 12.81 g

D = 10.85 g

$$\text{Ash content} = \frac{10.85\ g - 10.81\ g}{12.81\ g - 10.81\ g} \times 100 = 2.00\%$$

Sample C

B = 14.66 g

C = 16.66 g

D = 14.73 g

$$\text{Ash content} = \frac{14.73\ g - 14.71\ g}{16{,}66\ g - 14.66\ g} \times 100 = 1.00\%$$

Sample D

B = 23.07 g

C = 25.07 g

D = 23.07 g

$$\text{Ash content} = \frac{23.07\ g - 23.07\ g}{25.07\ g - 23.07\ g} \times 100 = 0.00\%$$

Sample E

B = 29.65 g

C = 31.66 g

D = 29.69 g

$$\text{Ash content} = \frac{29.69\text{ g} - 29.65\text{ g}}{31.66\text{ g} - 29.65\text{ g}} \times 100 = 1.99$$

Sample F

B = 31.29 g

C = 33.29 g

D = 31.37 g

$$\text{Ash content} = \frac{31.37\text{ g} - 31.29\text{ g}}{33.29\text{ g} - 31.29\text{ g}} \times 100 = 4.00\%$$

Sample G

B = 14.47 g

C = 15.33 g

D = 14.70 g

$$\text{Ash content} = \frac{14.70\text{ g} - 14.47\text{ g}}{15.33\text{ g} - 14.47\text{ g}} \times 100 = 26.74\%$$

Sample H

B = 9.98 g

C = 10.57 g

D = 10.09 g

$$\text{Ash content} = \frac{10.09\text{ g} - 9.98\text{ g}}{10.57\text{ g} - 9.98\text{ g}} \times 100 = 18.64\%$$

Sample I

B = 33.53 g

C = 34.09 g

D = 33.58 g

$$\text{Ash content} = \frac{33.58\text{ g} - 33.53\text{ g}}{34.09\text{ g} - 33.53\text{ g}} \times 100 = 8.93\%$$

APPENDIX IV

Calculation of Moisture content:

$$\text{Moisture content} = \frac{G - F}{G} \times 100$$

Where G = Weight of sample before entering the oven(g)

F = Weight of sample after retrieval from the oven(g)

Sample A

G = 0.77 g

F = 0.52 g

$$\text{Moisture content} = \frac{0.77\text{ g} - 0.52\text{ g}}{0.77\text{ g}} \times 100 = 32.47\ \%$$

Sample B

G = 2.00 g

F = 1.12 g

$$\text{Moisture content} = \frac{2.00\text{ g} - 1.39\text{ g}}{2.00\text{ g}} \times 100 = 30.54\ \%$$

Sample C

G = 2.00 g

F = 1.05 g

$$\text{Moisture content} = \frac{2.00\text{ g} - 1.45\text{ g}}{2.00\text{ g}} \times 100 = 27.34\ \%$$

Sample D

G = 0.98 g

F = 0.70 g

$$\text{Moisture content} = \frac{0.98\text{ g} - 0.70\text{ g}}{0.98\text{ g}} \times 100 = 28.28\ \%$$

Sample E

G = 0.76 g

F = 0.47 g

$$\text{Moisture content} = \frac{0.76\text{ g} - 0.56\text{ g}}{0.76\text{ g}} \times 100 = 25.84\ \%$$

Sample F

G = 0.90 g

F = 0.59 g

$$\text{Moisture content} = \frac{0.90\text{ g} - 0.69\text{ g}}{0.90\text{ g}} \times 100 = 22.45\ \%$$

Sample G

G = 0.88 g

F = 0.78 g

$$\text{Moisture content} = \frac{0.88\text{ g} - 0.78\text{ g}}{0.88\text{ g}} \times 100 = 11.36\ \%$$

Sample H

G = 1.02 g

F = 0.88 g

$$\text{Moisture content} = \frac{1.02\text{ g} - 0.91\text{ g}}{1.02\text{ g}} \times 100 = 10.56\ \%$$

Sample I

G = 0.46 g

F = 0.39 g

$$\text{Moisture content} = \frac{0.46\text{ g} - 0.41\text{ g}}{0.46\text{ g}} \times 100 = 9.50\ \%$$

APPENDIX V

Calculation of Pore volume

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

Z = Volume of sample after retrieval

Y= Volume of sample before

Sample A

Z = 0.79 g

Y= 1.00 g

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.79\ \text{g}}{1\ \text{g/cm}^3} = 0.21\ \text{cm}^3$$

Sample B

Z = 0.88 g

Y= 1.00 g

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.88\ \text{g}}{1\ \text{g/cm}^3} = 0.12\ \text{cm}^3$$

Sample C

Z = 0.90 g

Y= 1.00 g

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.90\ \text{g}}{1\ \text{g/cm}^3} = 0.10\ \text{cm}^3$$

Sample D

Z = 0.85 g

Y= 1.00 g

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.84\ \text{g}}{1\ \text{g/cm}^3} = 0.16\ \text{cm}^3$$

Sample E

Z = 0.72 g

Y= 1.00 g

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.87\ \text{g}}{1\ \text{g/cm}^3} = 0.13\ \text{cm}^3$$

Sample F

$Z = 0.89$ g

$Y = 1.00$ g

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.89\ \text{g}}{1\ \text{g/cm}^3} = 0.11\ \text{cm}^3$$

Sample G

$Z = 0.91$ g

$Y = 1.00$ g

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.91\ \text{g}}{1\ \text{g/cm}^3} = 0.09\ \text{cm}^3$$

Sample H

$Z = 0.94$ g

$Y = 1.00$ g

$\text{Pore volume} = Y - Z$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.94\ \text{g}}{1\ \text{g/cm}^3} = 0.06\ \text{cm}^3$$

Sample I

$Z = 0.95$ g

$Y = 1.00$ g

$$\text{Pore volume} = \frac{Y - Z}{1\ \text{g/cm}^3}$$

$$\text{Pore volume} = \frac{1.00\ \text{g} - 0.95\ \text{g}}{1\text{g/cm}^3} = 0.05\ \text{cm}^3$$