EXTENT OF WATER POLLUTION IN MOUNTAIN TOP UNIVERSITY OGUN STATE, NIGERIA.

ESSIEN, GLORY ETOR

16010102003

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CERTIFICATION

This is to certify that this research project titled **“EXTENT OF WATER POLLUTION IN MOUNTAIN TOP UNIVERSITY, OGUN STATE, NIGERIA”** was carried out by ESSIEN, Glory Etor, with matriculation number 16010102003. This project meets the requirements governing the award of Bachelor of Science (B.Sc) Degree in Biochemistry, department of biological sciences of Mountain Top University, Ogun State, Nigeria and is approved for its contribution to knowledge and literary presentation.

ESSIEN E. GLORY Date

PROFESOR A.I. AKINWADE Date

(Project Supervisor)

DECLARATION

I hereby declare that this project report written under the supervision of Professor A.I. Akinwade is a product of my own research work. Information derived from various sources has been duly acknowledged in the text and a list of references provided. This research project report has not been previously presented anywhere for the award of any degree or certificate.

ESSIEN E. GLORY

Date

DEDICATION

I dedicate this project to God Almighty, who made all things possible including this research.

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ABSTRACT

In no small amount, human actions, including industrialization and farming practices, have contributed enormously to the destruction and contamination of the atmosphere that adversely affects the bodies of water (rivers and oceans) that are important for life. This paper aims to discuss simply what water pollution is and to address the cause, impact regulation and water pollution management as a whole in equal measure. Some recommendations have been mentioned, such as introducing environmental education.

This research focuses on assessing the level of microbiological contamination, the concentration of heavy metals in water Zn, Cr, Fe, Pb, Mn. And the nutrient content of phosphate concentrations found in water samples. The samples were obtained from the administrative block, organ house, ICT center, clinic center, collage of basic and applied research, humanities and management studies collage, new Elizabeth female hostel, rejection hall boys hostel, cafeteria, library, from ten separate locations in mountain top university.

The results obtained from the experiment carried out show water pollution in samples from CBAS, Canteen, Administrative block, with lead ranging from 0.012-0.45 mg/l and iron ranging from 012-0319 mg/l but with good and acceptable concentration of other metals tested for, phosphate is also at standard concentration. The sample's conductivity, concentration, and temperature are normal, but the pH ranges from 5.9 to 6.7, which indicates water acidity.

Therefore from result obtain the extent of water pollution in Mountain Top University is mild and can be corrected.

CHAPTER ONE

1.0 INTRODUCTION

1.1BACKGRONND OF THE STUDY

Tap water is mostly used in corporate environments like universities, banks etc., and sometimes this water can be polluted from point sources, which can be heavy metal from pipe, impurities in the zinc of galvanized piped and solders in fittings, water heaters, water coolers and taps (Charley, 2020) .

Radioactive metals, which can be toxic to human beings and biotic life, are usually found in rural, industrial and environmental runoff. Increased urbanization and industrialization are to be blamed for an increased amount of trace metals in our rivers, especially heavy metals (Seema et al., 2011). Many toxic chemical elements accumulate in the soil and water bodies' sediments until released into the atmosphere (Begum et al., 2013). Over 50 elements can be identified as heavy metals, of which 17 are known to be very toxic and relatively usable. Anions also play an important role in drinking water, characteristically, and studies have also demonstrated that they play an important role affect human health. (Khan *et al*., 2013. The degree of toxicity depends on the form of metal, its biological function and the type of species exposed to it. Heavy metals have a pronounced influence on aquatic flora and fauna that reaches the food chain by biomagnification and eventually affects humans as well (Lokhande et al., 2011) (Lokhande et al., 2011). The heavy metals most commonly associated with human toxicity of drinking water are lead, iron, copper, cadmium, zinc, chromium, etc. The body needs them in tiny concentrations, but they can also be harmful in large quantities. The essential trace elements are heavy metals such as copper, but toxicity is shown in excess concentrations in drinking water. The degree of toxicity depends on the form of metal, its biological function and the type of species exposed to it. Heavy metals have a pronounced influence on aquatic flora and fauna that reaches the food chain by biomagnification and eventually affects humans as well (Lokhande et al., 2011) (Lokhande et al., 2011). The heavy metals most commonly associated with human toxicity of drinking water are lead, iron, copper, cadmium, zinc, chromium, etc. The body needs them in tiny concentrations, but they can also be harmful in large quantities. The essential trace elements are heavy metals such as iron, but toxicity is shown where there are excess concentrations of drinking water.

1.2. SOURCES OF MOUNTAIN TOP UNIVERSITY WATER

Mountain top university is situated in Mowe-Ibafo, Prayer Region, Ogun State, the population is over 1000, distributed over numerous collages, departments and hostels. In the university setting, the water supplies are predominantly tap water flowing in both houses.

1.3. STATEMENT OF PROBLEM

Water pollution is the poisoning of water sources that occurs when contaminants are dumped into water bodies indirectly or directly without sufficient care to remove the destructive sediment (Muyibi et al., 2008). It will have an effect on the environment and human life and will become a concern today. Besides, owing to human or agricultural activity, water supplies are increasingly being contaminated and scarce. The growing pollution of freshwater environments with thousands of industrial and natural chemical compounds is one of the main environmental challenges facing mankind worldwide, according to Rene et al. (2006).

1.4 OBJECTIVE OF THE STUDY

The objectives of this study are listed below:

1. To determine the microbiological and mineral content of water.

2. To classify the water quality based on Water Quality Index (DOE- WQI).and National Water Quality Index (NWQI).

1.5 SCOPE OF STUDY

The scope of study for this thesis is the boreholes and tap waters of Mountain Top University. Which are housed in the hostels, and the atmosphere of the college. The goal of this research is to determine the water quality status of all water at Mountain Top University and to identify water quality based on the Water Quality Index (DOE-WQI). Temperature, chemical oxygen demand (COD), phosphate, dissolved oxygen (DO), pH, turbidity, electrical conductivity, chosen heavy metal will be used in the classification of water content dependent on WQI. Both parameters will be tested on the basis of in-situ test and laboratory test. The quality of water will be classified following the standard. In this research, the standard for water quality determined from the Department of Environment which is National Water Quality Standard (NWQS) is based on Water Quality Index.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 POLLUTION

Human behaviors have the potential to create changes in the climate. Soil surface shifts for various applications, including light and heavy industry, urbanization and residential development, have altered water paths and modified natural processes (Lohdip and Japheth, 2013). In developed countries such as Nigeria, the relevance of clean water and good hygiene has been ignored, making water-borne diseases widespread and thereby contributing to increased morbidity and mortality rates among residents (Olagoke et al., 2018).

2.2 WATER POLLUTION

Air, for everybody, is life. This water is sadly contaminated by our actions on a regular basis. Water contamination contributes to harmful consequences that inevitably impact us. Water contamination is a big global problem of great concern. It impacts drinking water, rivers, lakes and oceans worldwide. It also harms the health and well-being of human beings and the natural world (Khatun, 2017).

Water pollution can be characterized as a change in the physical, chemical and biological characteristics of water that can have adverse impacts on human and aquatic life (Khatun, 2017). Thus, water pollution is any contamination that harms human, plant or animal health with chemicals or other pathogenic species. These contaminants include pesticides and fertilizers for crop runoff, pollution from the sewage and food processing industry, lead, mercury and other heavy metals, hazardous waste from factory discharges and from high-risk waste sites for chemical pollution. Worldwide, nearly 3 billion people drink tainted water, which adversely affects their health.

2.3 TYPES OF WATER CONTAMINATION

Contamination of water bodies can be grouped into 4 categories based on anthropogenic activities and they include:

Chemical contamination

Industrial effluents

Radiation contamination

Biological contamination

CHEMICAL CONTAMINATION

In water sources, organic chemicals obtained as a result of anthropogenic practices are commonly contained. This concern is not just happening. In 1956, Middleton and Rosen analyzed raw and finished water from five midwestern U.S. cities and identified benzene compounds, insecticides, kerosene, phenols, compounds of polycyclic hydrocarbons, and synthetic detergents. Heavy metals and chemicals present in water sources that cause biotic activities in water acids, alkali, soluble and insoluble salts, metallic complexes, trace elements, organometallic compounds, organic polyphosphate detergents, metallurgical processes, are accounted for by chemical pollution In the water body, coal mining and endless natural cycles. Traces of heavy metals have been recognised as detrimental to the marine environment and human wellbeing, such as Hg, Cd, and Pb, As, Co, Mn and Cr. Mercury in fish is considered to be present as (CH3)2Hg in the food chain. Manganese also reaches the water supply via factory effluent and dry cell batteries.

INDUSTRIAL CONTAMINATION

Effluent from industry poses a health risk when not properly channeled and the release of these wastes into the environment untreated pose a threat to biotic life. Industrial wastes released to water bodies causes increase in nutrient (allochthanous) available and when these organic nutrient exceed the amount needed, this encourages massive growth of aquatic plants and there Will also be alga bloom which makes the water becomes eutrophic where the rate at which aquatic organisms carry out respiration exceed photosynthesis, in cases like this, the oxygen present in the water body is used up reducing the flow of water current which could lead to the death of aquatic organisms, increase in the concentration of organic waste present in the water and in some cases leads to drying up of the water body.

RADIATION CONTAMINATION

Radioactivity in continental surface waters is primarily due to the existence of radioactive components in the crust of the earth. Other artificial radionuclides have emerged as a result of human operations such as nuclear power plants, nuclear weapons testing, and radioactive sources manufacturing and utilization. Drinking water has two sources of radioactive contamination. The first is natural radionuclides contained in the soil through which water moves. Some regions are prone to phosphate-rich soil and rock contamination. The second source of contamination from radioactive sources is man-made. Radionuclides discovered in drinking water are components of three radioactive sequence, uranium, thorium, and actinium, including radium, uranium, and radioactive gas radon components that occur naturally. Radioactive waste can persist in the environment for thousands of years, making disposal a major challenge.

BIOLOGICAL CONTAMINATION

Contamination can also be triggered by the presence of living organisms in the water body. The presence of these organisms is pathogenic in nature and they are introduced into the water through various channels. The living contaminants discovered in the water are mostly microscopic in nature and would trigger either tropical or systematic infection when they come into contact with mammals. Water consumption, which is contaminated with human and animal excreta, is correlated with the biggest danger from microbes in water, although other sources and paths of exposure may also be important. Water-related infectious diseases induced by pathogenic bacteria, viruses, protozoa and helminths are the most prevalent and widespread health hazard. Currently, there are estimated to be 1407 species of human-infected pathogens, Including viruses (208 species), bacteria (538 species), parasitic protozoa (57 species), and various species of fungi and helminths (Woolhouse and Sequeria, 2006).

Pathogenic microbes: In developing nations, pathogenic microbes were the primary cause of death (Medema *et al*., 2003). The most significant waterborne microbial illnesses are shown in Table 1.0. Pathogenic microbes are liable for hazardous illnesses such as typhoid and cholera, and although to some extent less hazardous, they are liable for high numbers of childhood diarrhea. Diarrhea and other inner infections are the primary cause of death among individuals living in developing countries towns and villages (Behnam *et al*., 2013).

Viruses: Some viruses can establish their presence in the human alimentary channel and also in the mouth and larynx. These factors will be released from waste water and contaminated waters through feces that can be seen. Their mere existence, of course, is not enough reason to be harmful to animals. Polio virus diffusion has rarely been recorded in water. This is because it becomes diluted in water, and it can be very hard to separate it. Although the agent of infectious hepatitis is unknown, there is evidence that this disease has spread throughout the globe through contaminated water. (Behnam *et al., 2013*)

Parasites and Protistas: It is also possible to transfer a batch of protists and parasites to the human body through immediate consumption of contaminated water (Kim *et al*., 2011). Microbe water contamination may happen accidentally, but most contamination results from insufficient attention being paid to the disposal of sewage. Municipal and household waste water contains elevated concentrations and different pathogenic types of microorganisms. Although most of the human food channel's internal microbes cannot live out of the body for extended period of time, there are many reasons that show that a sufficient amount of pathogen can survive to infect the human being. Human health is vulnerable to the consumption of contaminated water and food, bathing in untreated water, recreation in water and, ultimately, the use of contaminated water for farming and industrial purposes (Behnam *et al*., 2013).

2.3.1 SOURCES OF CONTAMINATION

Surface water pollution originates from sources that are classified by agencies as either point sources or non-point sources.

Point origins include the emergence of pathogens through a common point of detection. It seems to be closely regulated and should normally be diverted to a care center. Oil refineries, chemical plants, and water treatment plants are examples. A single, detectable source, such as urban runoff, can not be related to pollution and is classified as a non-point source. In water that flows from city streets, parking lots and drive paths after rainstorm and from excess landscape irrigation, litter, metals, asphalt, grease and other automotive fluids can be found. In general, yard waste, animal waste, pesticides and fertilizers are found in drainage from houses, parks and agricultural fields, water flows into construction sites can contribute to problems and sediments, such as waterway turbidity, high pH from concrete cuttings, and pollution of plants and other chemicals used on site.

2.3.2 HEAVY METAL POLLUTION.

Metallic elements with high atomic weight and density are heavy metals. These include transition metals, lanthanides and actinides, some of which are metalloids. In general, concentrations of more than 20 metals occur in a positively charged form and can bind to organic molecules that are negatively charged. As metal ions, heavy metals can not be degraded or destroyed, so their stability makes them environmentally persistent toxic substances. Heavy metals can be found in the air, soil and water as environmental contaminants, posing a health hazard to the general public. The presence of heavy metals in water as contaminants is an indication of global industrialization due to the large scale of inappropriate disposal and untreated heavy metal wastewater from anthropogenic sources (United Nations Commission on Sustainable Development, 2010). Water acts as a means of transport for toxins which can affect living organisms as well as the environment (Harrison, 2001). During a period of time, heavy metals can bio-accumulate and the concentrations become evident and observable. Heavy metal bio-accumulation within the target organ or tissue of organisms will potentially endanger human health by food chains and trophic concentrations. Globally, regulatory organizations have introduced regulations in order to control contamination through the maximum permissible limits for the discharge of heavy metal in the aquatic environment and intervention through ISO 14000. However, in particular through anthropogenic point source, the heavy metal is released at a higher concentration than the prescribed limits, resulting in health hazard and water pollution.

Table 2.1: Parameter limits and health effects of heavy metal toxicity (Sud *et al*., 2008).

Metal(mg/l)	**EQA**		**INWQS**				**Health hazard**
	Standard A	**Standard B**	**Classes IIA/IIB**	**Classes III**	**WHO**	**USEPA**	
Arsenic	0.05	0.01	0.05	0.4	0.05	0.05	Carcinogenic, liver tumor Skin and gastrointestinal effect
Cadmium	0.01	0.2	0.01	0.01(0.001)	0.005	0.005	Carcinogenic, lungs fibrosis, dyspnea and weight loss
Copper	0.20	1.0	0.02	-	-	1.30	Long term exposure causes irritation of nose, mouth, eggs headache. Stomach ache, dizziness and diarrhea.
Lead	0.10	0.5	0.05	0.02	0.01	0.005	Suspected carcinogenic, loss of appetite anemia, muscle and joint pain diminishing IQ, causes sterility kidney problem and high blood pressure
Mercury	0.005	0.05	0.001	0.004	0.001	0.002	Corrosive to skin, eyes and muscle membrane dermatitis, anorexia, kidney damage and muscle pain
Nickel	0.2	1.0	0.05	0.9	0.02	0.1	Carcinogenic, dermatitis, allergic sensitization, lungs and nerves system damage.

Zinc	-	-	-	-	5.0	-	Corrosive to skin and eye, zinc pox, sweet taste. Throat dryness, cough, weakness, generalized aching, chills, fever, nausea, vomiting.
Chromium	-	-	-	-	0.1		

EQA – Environmental Quality Act Standard A – Effluent that is discharge upstream of water supply

Intake Standard B – Effluent that is discharge downstream of water supply intake

INWQS – Interim National Water Quality Standard,

USEPA- united states environmental protection agency.

Classes IIA – Water Supply II – Conventional treatment required.

Fishery II – Sensitive aquatic species,

Classes IIB – Recreational use with body contact,

Classes III – Water Supply III – Extensive treatment required.

Fishery III – Common of economic value and tolerant species; livestock drinking

Heavy metal reaches humans spontaneously as trace elements through intake, inhalation and absorption to a small extent. To sustain the human body's metabolism, trace elements are necessary. However, since they appear to bio-accumulate and bio-magnify, trace quantities of heavy metal are harmful. Over time, bio-accumulation and bio-magnification increase the heavy metal content in a biological organism or targeted organ until it becomes harmful to health (Mata et al., 2008) (Mata et al., 2008). This can contribute to food shortages and also lead to Parkinson's disease, tumors, skin diseases, asthma issues, stomach and digestive problems, disruption to the central nervous system, blood disorders and reproductive failure (United Nations Environmental Programme, 2007). Nausea, anorexia, fatigue, stomach irregularities and dermatitis may be caused by sudden exposure to elevated heavy metal concentrations. Each heavy metal imparts various effects and symptoms from the viewpoint of human health (Lesmana et al., 2009).

Table 2.2: Sources of heavy metal from industrial applications

Heavy metal	Source	Reference
Arsenic (As)	Metal processing, plant burning fossil fuel mining and pesticide	Anawar *et al*. 2002 Alluri *et al*. 2007
Cadmium(Cd)	Welding electroplating pesticides and fertilizer, mineral processing, battery and nuclear fission plant	Lesmana *et al.* 2009
Copper(Cu)	Copper planting, mining metal industries and copper ammonium rayon industries	Han *et al*. 2006 Salamatinia *et al.* 2008
Chromium(Cr)	Metal planting electroplating leather mining galvanometry and dye production	Suksabye *et al*. 2008 Baral *et al.* 2006
Lead (Pd)	Metal planting, textile, battery manufacturing automobile and petroleum industries.	Jalali *et al*. 2002 Babarinde *et al*. 2006
Nickel (Ni)	Electroplating, nonferrous metal mineral processing dye industries porcelain enameling and steric electric power plants	Yu and kaewsarn, 2000
Mercury(Hg)	Pesticides, battery, paper industry metallurgy industries clausal manufacturing and metal finishing	
Zinc(Zn)	Refineries brass manufacturing metal planting and plumbing	Alluri *et al.*2007

2.3.3 Sources of Heavy metal pollution

Heavy metals often obtain access to water supplies from both natural and anthropogenic sources. This are spread to sediments and biota, as they pass from one stage to another. Usually, an atmosphere that naturally includes mineralized minerals contains high amounts of gold. The amount of trace metals in river water is also impaired by the abundance of metals and their mobility in the rocks of the river catchment area (Olajire and Imeokparia, 2000). Soil degradation, especially rock weathering and dissolution of water soluble salts, are natural causes. Typically without negative consequences, naturally occurring metals often pass through marine ecosystems. They move regardless of human activity (Garbarino et al., 1995). Degrading environmental conditions and rising dependency on agrochemicals have contributed to increasing public concern over the potential deposition of heavy metals and other pollutants in agricultural soils (Nriagu, 1988; Alloway, 1995; Kabata-Pendias, 1995). Heavy metals are poured into the river from numerous sources. They reach the biological processes and also by atmospheric deposition through anthropogenic practices such as waste sludge treatment, agricultural fertilizer and pesticide application (Haiyan and Stuanes, 2003). Anthropogenic practices such as mining, the final dumping of treated and untreated waste effluents containing radioactive metals and metal chelates from different industries (Amman et al., 2002) and the use in agriculture of heavy metals containing fertilizers and pesticides have indiscriminately contributed to a decline in water quality, leading to significant environmental issues that pose a threat (Ghosh and Vass, 1997; Das et al., 1997). Many fertilizers and pesticides are known to have different heavy metal levels, including Cd and Cu (Kabata-Pendias, 1995). Therefore, the persistent and intense application of agrochemicals and other soil modifications can likely intensify the accumulation of heavy metals over time in agricultural soils (Karishma and Prasad, 2014). Copper is the active ingredient in certain pesticides used to prevent fungal growth in agricultural crops (Mcneely et al., 1998). In general, copper is only found in trace amounts up to a concentration of 0.005 mg/l in natural surface waters and higher levels are typically correlated with anthropogenic sources (Mcneely et al., 1998). The improper use of fertilizers and pesticides in farming practices affects both land and surface water (Hariprasad and Dayananda, 2013). Agricultural heavy metal runoff reaches natural water sources that control aquatic life and, in turn, ecosystems (Hariprasad and Dayananda, 2013). In rural areas, heavy metal soil degradation is associated with farmers' use of fertilizers, pesticides and herbicides (Yang et al., 2005). The use of agrochemicals such as pesticides and fertilizers may have contributed to the unwanted accumulation of trace metals such as arsenic, cadmium, copper, lead and zinc in the soil (Latif et al., 2009). Metal mining operations emit enormous volumes of heavy metal tailings and waste that pose a significant danger to water supplies and the environment (Ezeh and Chukwu, 2011). Heavy metals can also be absorbed from different causes into soils, including the atmospheric accumulation of particulate-bearing metal metalloids.

2.3.4 Heavy metals and water pollution

Water pollution is a major threat to human population and dumping of pollutants into water body resulted in rapid deterioration of water quality and affects the ecological balance in the long run. Pollution refers to any direct or indirect alteration of physical, thermal, biological or chemical property of water or water source so as to make it less fit for any beneficial purpose for which it is expected to be used or make it harmful or potentially harmful to the welfare, health or safety of human beings, any aquatic or non-aquatic life and property or the environment (Edwin, 2018)Water pollution has been suggested to be the leading worldwide cause of deaths and diseases (Pink, 2006) and it accounts for the deaths of more than 140,000 people daily (West, 2006). Current concerns in environmental protection are majorly focused on water due to its importance in maintaining human health and ecosystem health (Mahananda *et al*., 2010).Water will always contain minerals and organisms that it collects from materials it comes into contact with due to its chemical properties. These elements can be poisonous and therefore dangerous to humans, depending on the nature and dosage (Edwin, 2018). However, growing controversy has recently developed about the abundance of heavy metals in water as the public becomes more aware of their toxicity and effects on human health. Many metals in nature are not dangerous at trace amounts and some are also necessary for the proper functioning of the human body, such as iron, copper, cobalt, manganese, zinc and chromium (Edwin, 2018; Amartey et al., 2011). However, both metals are poisonous at higher doses, with their toxicity related to chronic disorders such as kidney failure, cirrhosis of the liver, Loss of hair and chronic anemia (Salem et al., 2000). Due to its prevalence, toxicity, concentration in the biological environment and risk to human health, heavy metal exposure has gained enormous worldwide concern (Varol and Sen, 2011). Heavy metals make their way to the waterways by underground intrusion of effluents from human operations, drainage from agriculture and factories, leaching and dissolution of metals that occur naturally in rock and soil. However, with limited interest in heavy metals, water contamination has focused on other forms of water. Generally, heavy metal emission has been limitedIf pollution related to anthropogenic causes such as inadequate waste management is suspected, it has just been brought to the fore. In this respect, owing to less sources of contamination, the heavy metal content of water is paid little consideration in many rural areas. Despite this, heavy metal water pollution in rural areas is still possible due to obscure sources, fertilizers and the presence of mineral deposits (Adegbola and Adewoye, 2012). Heavy metals are important among the inorganic pollutants of river water for their persistent nature and frequently accumulate at tropical levels, creating a deleterious biological impact (Jain, 1978). Heavy metals exposure to human beings has been associated with development retardation, kidney damage and various forms of cancer and in some instances death.

2.4 Heavy Metal Treatment Technologies

Heavy metals are well-known poisonous substances, and the global degradation of human health and environmental safety has been caused by heavy metal pollution. In order to overcome these challenges, new treatment technologies have been invented to conform to strict regulatory requirements. Heavy metal treatment technology in general can be divided into two categories, namely in-practice and advanced treatment technologies. Subsequent sections address the advancement of heavy metal treatment technologies.

2.4.1 In-Practice Treatment Technology for Heavy Metal Removal

In-practice treatment technology refers to conventional methods applied to treat heavy metal from industrial wastewater. Table 2.3 summarizes the process description and performance of the heavy metal treatment technologies. For in-practice technology, the major two subgroups of such treatment consist of high-end technology and low-end technology which are available to treat industrial effluent containing heavy metal. High-end technology includes ultra filtration, reverse osmosis, electro dialysis and ion exchange. Generally, the use of high-end treatment systems entails high cost in order to achieve desirable removal percentages or to meet the compliance level (Ahalya *et al*., 2003). For low-end technology heavy metal treatment, the usual chemical precipitation is applied to remove heavy metal from industrial wastewater due to cost effectiveness and simple operation. However, current treatment technology of chemical precipitation which is being applied in industrial wastewater laden of high nickel concentration produces toxic secondary products (Barakat, 2011). This method consumes excessive chemical usage as well as generates large quantity of toxic solid sludge that poses challenges in handling, treating and land filling of such chemical waste substances. Hence, an ideal progressing treatment as well as sustainability of the materials used and amount of waste produced from the treatment technologies technology should be in between the cost considerations.

Table 2.3: Comparison of the process description and performance using different in practice treatment technologies for heavy mental removal

Method	Process description	Disadvantages	Heavy metal	Removal efficiency	Reference
High-end technology					
Ultrafiltration	Pressure driven membrane operations that use porous membranes for the removal of heavy metal	Generation of sludge and expensive	Cr(vi) Ni(II) Cd(II)	95.0% 98.0% 99.0%	Aliane *et al*. 2001 Yurlova *et al*. 2002
Reverse Osmosis	Heavy metals are separated by a semi-permeable membrane at a pressure greater than osmotic pressure caused by the dissolved solids in wastewater.	Expensive Metal hydroxides formed clogged the membrane.	Cu(II) Cd(II) Pd(II)	98.0% 98.0% n.a	Abu-Qudais and Moussa, 2004 Sadrzadel *et al*. 2008
Electrodialysis	Metal ions are separated	Expensive Generation of	Cu(II) Zn(II)	n.a n.a	Lee *et al*. 2006

	through the use of semipermeable ion selective membranes. An electrical potential between the two electrodes causes a separation of cation and anion, thus cells of concentrated and dilute salts are formed	the sludge poses challenges in handling, treating and land-filling of the solid sludge.	Cd(II)	n.a	
Ion-exchange	Metal ions from dilute solutions are exchanged with ions held by electrostatic forces on the exchange resin				
Low-end technology					
Chemical precipitation	Precipitation of metal ion was achieved	Generation of the sludge poses	Ni(II) Cd(II)	n.a 99.0%	Dang *et al*. 2009 Matlock *et*

	by the addition of coagulants such as alum , lime, iron, salt and other organic polymers	challenges in handling, reating and land-filling of the solid sludge		*al.* 2001

2.4.2 Progressive Treatment Technology for Heavy Metal Removal

In current years, progressive treatment technology usually serves as alternative methods for heavy metal removal compared to conventional methods. Phytoremediation, activated carbon adsorption and biosorption are progressive treatment technologies for heavy metal removal as shown in Table 2.4. Phytoremediation offers advantages of low cost and sustainability of materials. However, the process takes a long time and depends on environmental abiotic factors. On the other hand, activated carbon adsorption is only applicable for the removal of certain heavy metal and is not environmental friendly due to high energy or chemical require in preparation of activated carbon from plant derived materials. Whilst the on-going research on progressing treatment for heavy metal removal technology by biosorption focused into areas of adopting biodegradable plant derived materials from industrial and agricultural waste as biosorbent presently. This makes the possibility of exploiting economical, large quantity and locally available biosorbent for heavy metal treatment as well as generates revenue from waste. Therefore, the alternative treatment technology of biosorption that is based on exploration of agricultural waste is highlighted in this study.

Table 2.4: Comparison of progressive treatment technology

Method	Process Description	Remarks	Reference
Phytoremediation	Use Of Certain Plants To Clean Up Soil, Sediment And Water Contaminated With Heavy Metal Ion	Long Time For Metal Removal And Regeneration Of The Plant, Affect By Abiotic Factors	Ghosh and Singh,2005
Activated Carbon Adsorption	The Surface Complex Formation Between The Metal Ions And The Acidic Surface Function Group	High Energy Requirement Or Chemicals Inquiry For Preparation Of Activated Carbon.	Monser and Adhoum, 2002
Biosorption	The Use Of Metabolically Inactive Non-Living Biomass Of Microbial Or Plant Origin Based Material To Bind With Heavy Metal Ions(Pd, As)	Widely And In Large Quantity Availability Performance And Selectivity	Wang and Chen,2009

2.4.3 Biosorption for Heavy Metal Removal

Biosorption has been defined as a passive physical-chemical process that biomolecules of non-living biological material, refer as biosorbent, bind with heavy metal ions from aqueous solutions. It is classified as an alternative sustainable remediation technology in terms of resource and environmental impacts where the biosorbent is biodegradable based material and the heavy metal in dilute acid could be extracted via electrolysis (Poliakoff and Licence, 2007; Hashim *et al*., 2011). Biosorption offers the advantages of low cost, effectiveness for dilute effluents, minimum chemicals usage and reduced toxic sludge generation (Gupta *et al*., 2000). Furthermore, biosorbent has advantages over live and immobilized micro-organism as it does not depends on nutrient availability, toxicity tolerance and metabolic activities (Krishnani and Ayyappan, 2006; Locci *et al*., 2008). Table 2.5 lists specific studies on biosorption process which have focused on types of processes that include their functionalities and economic feasibilities. Common independent parameters that have been used for the study of biosorption processes are biosorbent concentration, initial pH, contact time, initial heavy metal concentration, temperature, and agitation rate and particle size.

Table 2.5 Specific area of biosorption study and its parameters (Gupta *et al*., 2009)

Type of study	Parameter	Observation
Process	Biosorbent concentration Initial PH Contact time Initial heavy metal Temperature Agitation rate Particle size Efficiency percentage Effectiveness-uptake Versatile	Dependent process, maximum dosage or random selection dosage is used in batch study Dependent process, operate under wide range of PH condition. Important parameters for kinetic study Important parameter for kinetic study. Important parameter for isotherm study and calculation of q_{max} of bio sorbent. Generally not affected due to bio sorbent is inactive, important for thermodynamic study No consistent profile depends on type of bio sorbent. No consistent profile depends on type of bio sorbent. Depends on bio sorbent, selected heavy metal and operating condition Usually rapid under favorable conditions Good the binding sites on bio sorbent can bind with a variety of heavy metal ions.
Functionality	Selectivity Recovery Reusability	Generally poor for raw biosorbent modification of biosorbent, types and concentration of heavy metal may improve selectivity High Recovery using dilute acids, alkaline or other solution

		High possibility of reusability
Economic feasibility	Maintenance and cost comparison with conventional methods	Easy handling in operation and storage generally low cost. Biosorbent always widely and easily available from industrial or agricultural waste
Predictive modeling	Artificial neural network (ANN)	Prediction of output, no equation
	Response surface methodology (RSM)	Prediction of output with equation, depend on selected parameters generate from software

Biosorption performance can be evaluated through its removal efficiency and uptake Effectiveness. While versatile and selectivity of biosorption performance is desired to facilitate the application study. Generally, raw biosorbent are versatile and biosorbent functional groups can bind with variety of heavy metal ions. Selectivity of biosorbent is merely depending on types and concentration of heavy metal. Modifying functional groups in the biosorbent is not only improves selectivity of biosorbent, but also enhances efficiency in selected heavy metal removal. However, this method is not sustainable because excessive chemicals would be used in modification process and may form irreversible bonding between functional groups and heavy metal ions. Currently, laboratory studies related to desorption and regeneration of biosorbent provide a better understanding of reusability of biosorbent and leaching of heavy metal from biosorbent (Zakaria *et al*., 2009; Salamatinia *et al*., 2010).Economic feasibility of biosorption process includes reusability, maintenance and cost comparison with conventional methods (Wang and Chen, 2009; Das *et al*., 2010; Henini *et al*., 2011). From literature review, many researchers are not interested in the economic evaluation. This may be attributed to lack of available economic data, funding, expertise and industry collaborators. However, investigations and evaluations of biosorbent applicability need to be conducted in pilot or large scale in order to provide important information to develop this sustainable technology.

Predictive modeling of the biosorption functionalities also can be either by non-mathematical modeling or mathematical equations. Both ANN and RSM are useful modeling tools for output prediction that have been applied in biosorption study. The input parameters for ANN can be determined by researchers but no equation is generated from modeling when compared to RSM modeling where fixed input and equation are generated from the software. Most of the approach taken by researchers for biosorption studies are time consuming and contribute little to the development of knowledge in this field. Hence, new approaches and methods development are imperative for the development of this sustainable technology.

2.4.4 Biosorption Mechanisms

Biosorption mechanisms play an important role in biosorption performance evaluation. Mechanisms of heavy metal biosorption are influenced by physical and chemical interactions between the biosorbent and biosorbates, thus affecting the biosorption efficiency and effectiveness. Biosorption mechanisms occur in many forms which are complex and several mechanisms may occur simultaneously. Adsorption, ion exchange, chemisorptions, complexation, chelation and micro precipitation are mechanisms intensely discussed in biosorption process (Sud *et al*., 2008; Park *et al*., 2010).

Table 2.6 Mechanisms in biosorption and its description (Nurchi and Villaescusa, 2008).

Mechanism	Description
Adsorption	Adhesion of molecules to a surface.
Ion exchange	Heavy metal ions replacement by heavy metals ions.
Chemisorptions	Chemical bonds are formed through sharing electron between functional group and heavy metal ions.
Complexation	Coordinate bonds are formed through functional groups attached to central metal atom, especially a transition metal atom.
Chelation	Bonds formed between a centre atom with coordinate bonds.
Micro-precipitation	A process by which a substance is separated out of a solution as a solid by forming a chemical precipitate fine particles.

Currently, the biosorption mechanism has become focus of research area in most of the published journals. Ion exchange is the most popular mechanism that has been reported amongst other mechanisms. Table 2.7(a-c) shows bio sorption mechanism evaluation for ion exchange, chemisorptions and complexation. For ion exchange mechanism, a common trend whereby heavy metal ions replacement by heavy metal are usually observed. These heavy metal ions include alkaline metals of Na+ and K+ as well as alkaline earth metals of and Mg2+ and Ca2+. The mechanism is usually supported by EDX or bio sorption heavy metal analysis using ICP or Atomic Absorption Spectroscopy (AAS) with an exception for Murphy *et al*. (2009). Murphy *et al*. (2009) confirmed the result of FTIR by XPS analysis result. However, the proposed ion exchange mechanism cannot be correlated directly with the bio sorbent's biosorption performance.

Table 2.7(a): List of evaluation study for ion exchange mechanism by specific biosorbents

Biosorbent	Heavy metal	Remarks on involved ions	Reference
Sawdust deciduous trees	Cd(II), Cu(II), Fe(II), Mn(II), Ni(II),Zn(II),	Na^+, K^+, Ca^{2+}, Mg^{2+}, biosorption heavy metal analysis.	Bozic *et al*. 2013
Mango peel waste	Cd(II), Pd(II),	Na^+, K^+, Ca^{2+} and Mg^{2+} EDX and XPS analysis	Iqbal *et al*. 2009
Brown seaweed focus vesiculosus, the green seaweed palmeria palmate	Cr(VI)	Na^+ K^+, Ca^{2+} and $Mg^{2+,}$ EDX AND XPS analysis	Murphy *et al*. 2009
Moringa oleifera bark	Pd(II),	Ca^{2+}, Mg^{2+} biosorption heavy metal analysis	Reddy *et al*. 2010a
Fungus paecilomyces maequandii	Pd(II), Zn(II),	$K^{+,}$ EDX analysis	Slaba and Dlugonski, 2011
Fungus pleurotus ostreatus	Cd(II),	K^+, EDX analysis	Tay *et al*. 2011a
Olive tree pruning waste	Pd(II),	K^+, Na^+, Ca^{2+} and $Mg^{2+,}$ biosorption heavy metal analysis	Blazquez *et al*.2011
Fungus pleurotus waste	Cd(II),	Ca^{2+}, and Mg^{2+}, EDX analysis	Vimala and das, 2011
Cucumis melo seed	Pd(II),	Mg^{2+} and K^+, EDX analysis	Akar *et al*. 2011

2.7(b): List of evaluation study for chemisorption mechanism by specific biosorbent

Biosorbent	Heavy metal	Remarks on existing model evaluation	Reference(s)
Areca catechu heartwood powder	Cd(II),	The mean free energy of Dubinin-Radushkevich (D-R) isotherm	Chakravarty *et al*. 2010a
Moringa oleifera bark	Pd(II),	Pseudo second-order kinetic	Reddy *et al*. 2010a
Chestnut shell	Cu(II),	Pseudo second-order kinetic	Yao *et al*. 2010
Fungus pleurotus ostreatus	Cd(II),	SEM, the mean free energy of D-R isotherm	Tay *et al*. 2011a
Fungus trametes versicolor	Cu(II),	Pseudo second-order kinetic	Subbaiah *et al*. 2011a
Fumgus pleurotus platypus	Cd(II),	Pseudo second-order kinetic	Vimala and dae, 2011

Cucumis melo seed	Pd(II),	The mean free energy of D-R isotherm	Tunali Akar *et al*. 2012

Table 2.7(c): List of evaluation study for complexation mechanism by specific biosorbent

Heavy metal	**Functional groups identified through FTIR**	**Remarks on function groups involved in complexation**	**Reference(s)**
Cu(II), Ni(II), Zn(II) ,Cd (II),	-NH, C=O, C=N, -OH, C-O, -OH, -NH, C=O, C-O, C-N	- N-acetylglucosamine	Javaid *et al*. 2011 Tay *et al*. 2011a
Pd(II), Zn(II),	-OH, -NH, C-O, C-N	Amide group	Slaba and Dhgonski, 2011
Pd(II),	-OH, -NH, C=O, C-O		Elazquez *et al*. 2011
Pd(II),	-NH, -OH, C-O, C=O, C-O, S0, P=O		Akar *et al*. 2012

As shown in table 2.7(b), the chemisorption's mechanism can be suggested through the use of existing models, namely, pseudo second order kinetic or the mean free energy of Dubinin-Radushkevich isotherm. Obviously, there is lack of evidence from instrumentation analysis to support this mechanism. Therefore, this mechanism needs be investigated comprehensively and explained by equations.

Complexation mechanism characteristically is tied to double bonds structures of amide, carboxyl or phosphate functional groups as shown in Table 2.7(c). FTIR results are used to support the complexation mechanism. However, the mechanism has not been confirmed by other instrumentation analysis nor evaluated intensively to elucidate the complexes formed. This may due to lack of expertise and instrumentation in advanced characterization of solid biosorbent. Słaba and Dlugonski (2011) and Tay et al. (2011a) reported that nitrogen derived organic compounds that have double bond in structure are involved in complexation. It can be concluded that recent studies and publication show that heavy metal biosorption is still needs further study due to little information regarding the mechanism that is responsible for the heavy metal biosorption. Biosorption mechanism is based mainly on functional groups and the affinity between the biosorbent with heavy metal ions, thus mechanisms may differ according to the biosorbent.

2.4.5 Biosorption Modeling of Isotherm, Kinetic and Thermodynamic

Modeling of biosorption process usually used the initial heavy metal concentration, time and temperature as the experimental parameters, which were evaluated with a few existing models. Most of the study carried out the biosorption curve being fitted to existing isotherm, kinetic and thermodynamic models. For isotherm models, include two basic equations of Langmuir and Freundlich. Both contain two parameters equation. Thus, the derivation from both equations produced three-parameter equations such as Redlich-Peterson, Sips, Khan, and koble-Carrigan, Hill, Toth, Radke-Prausnitz, Jossens and Langmuir-Freundlich. Extended derivations have come up with the next four-parameter equations such as Weber-van Vliet, Fritz-Schlunder and Baudu. Five-parameter equation of Fritz-Schlunder also has been derived. Other than the isotherm-based modeling, biosorption parameters also can be derived from Pseudo first-order, pseudo second-order, Elovich and diffusion models are commonly employed existing kinetic models.

Table 2.8 summaries the trend of existing isotherm models evaluation for heavy metal biosorption using raw agricultural, sawdust and fungus based biosorbent. The trend of using existing isotherm models to evaluate biosorption effectiveness was initially simple and only focused on two parameters equations of Langmuir and Freundlich models. For the timeline of 2007 to 2010, a variety of prevalent isotherm models that include multi-parameters equations had been investigated. Most of multiple parameters equations are derivatives of the Langmuir equation. However, the trend has changed back to two parameters equations of Langmuir and Freundlich as well as simple derivatives of the Langmuir equation. The changes of trend throughout the timeline could be due to the small contribution of different existing isotherm models for the evaluation for heavy metal biosorption in order to better understand the biosorption system and mechanism. It can be deduced that the Langmuir isotherm is one of the most important model amongst the existing isotherm models evaluation. This model, as derived from a first-principle stand-by Langmuir, enables effectiveness comparison based on the calculated maximum heavy metal uptake value (qmax) of biosorbent and the evaluation on monolayer biosorption system.

Table 2.8: Timeline for prevalent isotherm models used for the evaluation of heavy metal biosorption using various types of biosorbent

Year	Existing isotherm model(s)	Biosorbent	Heavy metal	Reference(s)
2002-2006	Two-parameters equations Langmuir Langmuir Langmuir Freundlich	Sugar beet pulp Tea waste Sawdust Dalbergia sissoo	Ni(II), cu(II), Ni(II), Ni(II),	Redded *et al*. 2002. Malkoc and Nuhoghu, 2005. Shakirullah *et al*, 2006.
2007-2010	Multi-parameters equations Langmuir-Dubinin-Radushkevich Langmuir-Freundlich, Dubinin-Radushkevich Langmuir, Freundlich, Dubinin-Radushkevich, Temkin Halsey, Redlich-Peterson, Sips, Khan, Koble-Corrigan, Hill, Toth, Radke-Prausnitz, Jossens, Langmuir-Freundlish,Webervan-Vliet, Fritz-Schlunder, Baudu Langmuir, Freundlich, Dubinin-Radushkevich, Temkin Langmuir, Freundlich, Redlish-Peterson Langmuir, Freundlich, Temkin Langmuir, Freundlich, Scatchard Langmuir, Freundlich, Brunner Emmert Teller	Sawdust deodar cedrus Spent grain Fungus *Pleurotus platypus* Fungus *Agaricus bisporus* Egg shell powder Seed husk calophyllum Inophyllum Fungus *Mucor rouxii* Mansonia wood sawdust	Cd(II) Pd(II) Ag(II) Cu(II) Pd(II) Pd(II) Pd(II) Cu(II),Pd(II)	Memon *et al*. 2010 Li *et al*. 2009 Das *et al*. 2010 Ertugay and Bayhan, 2010 Kalyani *et al, 2010* Lawal *et al*. 2010 Majundar *et al*. 2010 Ofamaja *et al*. 2010
2011-2012	Two-parameter equations and simple derivatives of the Langmuir equation Langmuir, Freundlich Langmuir, Langmuir, Freundlich, Langmuir, Freundlich, Langmuir, Langmuir, Freundlich, Langmuir, Freundlich, Dubinin-Radushkevich,	Fungus *Pleurotus mutilus* Sea Grape Caulerpa Lentilifera Cassia Angustifolia Bark Fungus *Pleurotus platypus* Fungus	Cu(II) Cd(II) Cu(II),Pd(II) Cu(II),Pd(II) Cu(II),Ni(II) Zn(II) Cd(II) Cu(II),Pd(II) Cd(II) Cr(II) Ni(II),Zn(II) Pd(II)	Henini *et al*.2011 Apiratikul *et al*. 2011 Javid *et al*. 2011 Mulgund *et al*. 2011 Vimala and Das, 2011 Kumar *et al*. 2012 Akar *et al*. 2012

	Aspergillus niger Cucumis Melo Seed	

Existing kinetic models used are principally applied to suggest the mechanism and rate limiting factors involved in heavy metal biosorption process.

Table 2.9 summarizes the use of ANN as a prediction tool for the heavy metal biosorption. Multiple input data are from heavy metal biosorption optimization parameters such as biosorbent concentration, initial pH, contact time, initial heavy metal concentration, temperature, initial volume of heavy metal and particle size. Meanwhile, the single output is evaluated through the efficiency of heavy metal biosorption together with mean square error (m.s.e). Single output ANN model is thus limited if evaluation of a few outputs simultaneously is desired. Therefore, ANN model is vital for multiple inputs and multiple outputs, in order to predict effectiveness and efficiency of biosorption as well as for the treated effluent water quality. The development and application of a multiple output ANN model is expected to make contribution to the knowledge for the scale-up biosorption of heavy metal technology.

Table 2.9: Input and output of ANN for heavy metal biosorption modeling.

Materials	**Heavy metal**	**Input**	**Output**
Sawdust	Cu(II)	Optimization parameters of initial pH, initial Cu(II) concentration, temperature, particle size	Efficiency, mean square error (m.s.e)
Antepn pistchio (pistacia vera L.)	Pb(II)	Optimization parameters of biosorbent concentration, initial pH, contact time, initial Pb(II) concentration, temperature	Efficiency, m.s.e
Shelled Moringa oleifera seed powder	Cd(II)	Optimization parameters of biosorbent concentration, initial pH, contact time, initial Cd(II) concentration initial volume of Cd(II)	Efficiency, m.s.e
Shelled Moringa oleifera seed powder	Ni(II)	Optimization parameters of biosorbent concentration, initial PH, contact time, initial Ni(II) concentration,	Efficiency, m.s.e

initial volume of Ni(II)

CHAPTER THREE

3.0 MATERIAL AND METHODOLOGY

3.1 Area of study

The study area of interest is the community of Mountain Top University community in Ibafo Local Council Development Area (LCDA), which includes, Administrative Block, ICT Center, Library, Organ House, Clinic, Canteen, College of Basic and Applied Science (CBAS), College of Humanities Management Studies (CHMS), Male Hostel, Female Hostel.

3.2 Study Design

This study was a quantitative study which includes investigating the waters use within the community, for heavy metals, nutrients and pathogenic micro-organism.

3.3 Sample collection procedure

Water sample for this study was obtained from tap water in female restroom in administrative block, tap from female rest room in organ house, tap from female rest room in ICT center, tap water from kitchen in the canteen. Tap water from clinic, tap water from male rest room in CHMS, tap water from female restroom in CBAS, tap water from boys' hostel laundry, tap water from female hostel laundry.

3.4 Materials and Equipment used

Photometer, Atomic absorbent spectrophotometer, Erlenmeyer flask, refrigerator, filter papers, funnel, stopwatch, oven, disposable petri-dishes, glass spreader, spirit lamp, McCartney bottles, incubator, water bath, autoclave, colony counter, different size beakers, measuring cylinder, micropipette volumetric flask, conical flask, hot plate, gloves, scoop.

3.5 Chemicals

All chemicals and reagents employed are of high purity analytical grade; HNO_3 (69% LR, Breckland scientific supplies U.K) were used for both extraction and acid digestion procedure Titrisol standard 1000 mg of $Pb(No_3)_2$, phenolphthalein, sulfuric acid, ammonium per sulphate, crystal, sodium hydroxide, and $KMnO_4$ (Merck, Germany) dissolved in 1000 ML distilled water used for preparation of stock standards of 1000 mg l^{-1} and intermediate standard solution of 100 mg l^{-1} of Mn, Cr, Pb, Fe, Zn, Metals, distilled water were used throughout the experiment to prepare all the solution.

3.6 Instrumentation

Digital analytical balance used for all measurements of samples and chemical AAS was used to determine the concentration of Mn, Cr, Cd, and Pb. A potentiometric digital pH meter was used to determine the pH of water sample; conductivity meter was used to determine the conductivity of water sample.

3.7 Preparation of Media

The media selected for isolation were, Nutrient Agar, MacConkey agar, ands Salmonella Shigella Agar (SSA). The petri dishes and Durham bottles to be used for isolation were sterilized using the dry heat sterilization method (Oven) at 160ºC for 1hr. For The preparation of the media, 2.8g of Nutrient Agar, 5.2 of MacConkey agar, 6.3g of Salmonella Shigella agar was weighed using a weighing balance into Durham bottles and 100ml of distilled Water was measured into Durham bottles respectively. These were stirred respectively and kept in the water bath for 10min to homogenize after which all expect Salmonella Shigella agar were Transferred into the autoclave to sterilize at 120mmHg for 15min while Salmonella Shigella agar was kept in the water bath at 70ºC for 5 min. After which they were transferred to the water bath so as to maintain their temperature and prevent them from solidifying until they were needed.

3.8 Microbiological tests

For the isolation of the observation of bacteria from the water sample, Serial dilution of our sample was carried out from our stock (water sample) using a five-fold dilution. Isolation was carried using the spread plate method for the stock solution and the diluents. These agar were removed from the water bath and allowed to cool but not solidify and 20ml was aseptically poured into four sterilized glass petri dishes labeled control, 10^{-1}, 10^{-2} and 10^{-3}, and allowed to Solidify after which 0.1ml from the first diluent was dispensed into the labeled 10-1 Petri dish using a micropipette and a sterile glass spreader was used to spread the water sample on the petri dish gently without completely opening the petri dish under an aseptic condition, the same procedure was used for 10-2 and 10-3 respectively while nothing was inoculated on the last petri dish labeled Control which was used as a control for the inoculation. The Petri dishes were left for 20mins before inverting them and transferring into the incubator at 37oC for 24-48hrs. The results of the experiment were observed and documented.

3.9 Determination of Physico-chemical parameters

Few Physico-chemical analyses of water-body were carried out and they include Temperature, pH, Conductivity, Salinity, and Turbidity

3.9.1 pH Determination

The pH of the water samples was done in-situ using a probe by inserting the probe into a beaker containing the water samples and left for 2-3 minutes before readings were taken. This process was repeated three times.

3.9.2 Temperature

Using a probe, the air and water temperatures were taken at each station where by the probe was dipped into a beaker containing the water samples and left for 2-3 minutes before readings were taken. For air temperature, the probe was left in the air and left for 2-3 minutes before readings were taken.

3.9.3 Conductivity

The samples were measured using a conductivity meter which was calibrated by inserting the Probe into a beaker that contains the water samples and the readings were taken.

3.9.4 Salinity

Salinity was carried out by using a calibrated salinity probe. The probe was dipped into a beaker containing the water samples. This was left for 2-3 minutes before readings were taken.

3.10 Digestion of water sample

The digestion procedure for the water samples was performed by transferring to a flask a measured volume (50ml) of well mixed acid preserved water sample, then 5ml of conc. HNO3 and a few boiling chips were added into the flask, the mixture was boiled and evaporated to the lowest possible volume (20 ml) on a hot plate, continued to heat and added conc. HNO3 as necessary until digestion is complete, as shown by a clear solution of light color. During digestion, do not let the sample dry. After this, the flask was cleaned and filtered with water. The filtrate was then transferred into a 10 ml volumetric flask with two 5 ml portions of water which were added to the volumetric flask and cooled and distilled to the mark and thoroughly mixed.

For the appropriate metal determination, a portion of this solution was taken. On each of the ten samples, this experiment was performed.

3.11Method detection limit

The minimal concentration of a material that can be determined is the System Detection Limit (MDL). Determinative procedures include digesting and diluting the blank solution and then analyzing the concentration of each sample portion, then determining the normal derivations of the triplicate reading of the seven blanks. To give MDL, standard deviations were multiplied by three

3.12 Metal analysis in water samples

For the preparation of intermediate standards and working standards, atomic absorption spectroscopic reference solutions comprising 1000mgl-1 (buck scientific) were used in the metal analysis procedure; the intermediate standard was prepared using the dilution process. The working standard solutions were also freshly prepared by diluting the intermediate standard with purified water correctly.

Mn^{2+} and pb^{2+} were analyzed with the FAAS using calibration curves after the parameter (lamp alignment, wave length and all width adjustment and burner alignment) was optimized for maximum signal intensity and sensitivity of the instrument. At the beginning of the survey, the wave length and slit width were selected and modified and this condition was carried out in the same fashion during the research cycle until the end of the analysis.

3.13 Phosphate determination

50ml of sample was measured and diluted with distilled water, one drop of phenolphthalein indicator was added , red color was developed and sulfuric acid was added until red color disappears, 1ml of sulphuric acid was added and 0.4g of ammonium per sulphate was added also, this solution was boiled for 30 mint until the total volume was 10ml, solution was allow to cool and one drop of phenolphthalein and neutralizer to pink color with 1N sodium hydroxide was added, distilled water was added to make solution up to 50ml, then the digested sample is then tested for phosphate.

CHAPTER FOUR

4.0 RESULTS

Results obtained from the study as presented in tables 4.0, 4.1, and4.2, shows the significant physiochemical parameters including pH, temperature, conductivity, concentration, heavy metals and phosphate level in the samples

The pH of the water range from 05.2 to 06.7 with mean of6.11, the conductivity range from 0.11 to 0.26with mean of 0.177, concentration range from 82 to 184 with mean of 130.8, , temperature range from 27.6 to 35.3 with mean of 30.14.

Table 4.1: Result of physicochemical parameters of the sample

Parameter	**Male hostel**	**Female hostel**	**CBAS**	**CHMS**	**Library**	**Admin**	**ICT**	**Medical centre**	Organ house	Canteen	WHO limits
pH	06.4	06.1	06.4	05.6	06.0	05.9	05.2	06.6.	06.2	06.7	6.5-8.5
Conductivity(µs/cm)	0.20	0.16	0.13	0.17	0.26	0.23	0.11	0.21	0.15	0.15	400
Concentrations(ppm)	143	127	109	123	184	166	082	133	109	132	30-400
Temperature(^{0}c)	32.3	32.6	31.6	29.8	28.2	27.6	28.5	27.8	27.7	35.3	50-72

CHMS (collage of humanities management studies), CBAS, (collage of basic and applied sciences).

Table 4.2: Result of Heavy Metal Analysis

S/N	Parameter	pH(mg/L)	Cr (mg/l)	Mn(mg/L)	Fe(mg/L)	Zn(mg/L)
1	CBAS collage	0.45	0.005	0.029	0.319	0.094
2	Male hostel	0.012	0.005	0.002	0.000	0.149
3	CHMS collage	0.07	0.005	0.132	0.088	0.289
4	Canteen	0.012	0.005	0.135	0.023	0.159
5	ICT	0.012	0.005	0.091	0.005	0.280
6	Admin	0.24	0.005	0.149	0.180	0.083
7	Clinic	0.28	0.005	0.209	0.005	0.259
8	Female hostel	0.15	0.005	0.103	0.005	0.374
9	Library	0.10	0.005	0.171	0.005	0.662
10	Organ house	0.012	0.005	0.151	0.005	0.258

Table 4.3 Quantity of phosphate in water samples

Location	**Phosphate (mg/l)**
CBAS collage	0.04
Male hostel	0.06
CHMS collage	1.80
Canteen	0.50
ICT	0.70
Admin	2.70
Clinic	0.03
Female	0.30
Library	0.25
Organ house	0.4

Table 4.4: WHO (2004) limit for heavy metal in drinking water.

Heavy metal	WHO (2004)standard
Cr	0.05(mg/l)
Pb	0.01(mg/l)
Zn	5.0(mg/l)
Mn	0.50(mg/l)
Fe	0.01(mg/l)

Table 4.5 Bacteria Count of Water Samples on Media

Media		**Dilution factors**		
	10^{-0}	10^{-1}	10^{-2}	10^{-3}
MAC	33	21	5	1
NA	26	15	7	5
SS	7	3	2	0

4.1DISCUSSION

The pH of sample range from CHMS, and Administrative block is 5.6 and 5.9, which shows acidity, not health for consumption and can cause skin disease. the conductivity of sample range from 0.11-0.26µs/cm, and the WHO limit acceptable is 0-800µs/cm, at temperature of 27.7-35.3^{o}c, within acceptable limit for WHO level for temperature which is 50-72^{o}c. concentrations for sample was between 082-166, acceptable limit is 30-400ppm.

The phosphate level range from 0.03 to 2.70, signifying low phosphate concentration as the general acceptable limit of total phosphate that will not contribute to growth of objectionable plants forms is 50mg/liter and below comparing table 4.3 and 4.4, shows that the level of heavy metal in some of the sample exceeded the expected WHO limit, thereby the samples are not heavy metal free, iron (Fe) which is an essential element in human nutrition, estimate of the minimum daily requirement for iron depend on age, sex and iron bioavailability and range from about 10 to 50mg/day as a precaution against storage of excess iron in the body. The WHO permit able limit for iron in drinking water is 0.01, and sample range from 0.012-0.319, iron in sample CBAS is 0.319, Canteen is 0.023, and Admin is 0.180, which are unsafe for consumption.

Lead(Pb) is specified as 0.01mg/l by WHO(2004) for drinking water and the sample range from 0.012-0.45mg/l, as sample from CBAS, CHMS, Admin, Clinic, Female Hostel, Library, rise above this limit, which make each of them unsafe for consumption.

The concentration of zinc (Zn) in water sample range from 0.083 to 0.662, and the WHO limit is 5.0mg/l for drinking water; therefore zinc in the samples is balance.

Chromium (Cr) is essential to animals and humans, but in excess can be toxic especially the hexavalent form, chromium is used in metal alloys and pigment for paints, cement, paper and other material, it can be release by electroplating and acid spray and air-borne Cr-trioxide. WHO limit is 0.05mg/l and sample did not exceed this limit, as it ranges from 0.05-0.05.

Manganese in drinking water is associated to neurological damage, manganese is a mutagen, and the accumulation of manganese is very toxic to the body. Water sample range from 0.029 to 0.209 and WHO limit is 0.50mg/l, all samples are safe from manganese poisoning when consumed. Table 4.4 shows the presence of bacteria in water sample, growth range from 0 to 33, too low to count.

CHAPTRER FIVE

5.0CONCLUSION

Results shows that water in Mountain top university water is contaminated with lead and iron, as bacterial contamination is mild and 2% acidity present in water, therefore water in the university is 20% polluted.

5.1 RECOMMENDATION

Base on the result obtained, treatment should be done to reduce the concentration of lead and iron to suit the WHO permit able limit for drinking water, any of the in-practice treatment (ultrafiltration, reverse osmosis, electrodialysis, ion exchange) or progressive treatment(biosorption, activated carbon, adsorption)methods can be used to correct lead and iron concentration in the water. And also the pH of CHMS and Admin sample should be adjusted by adding a tablet designed to neutralize the acid, lower water pH.

REFERENCES

Abu-Qudais, H. and Moussa, H. (2004). Removal of Heavy Metals from Wastewater by Membrane Processes: A Comparative Study. *Desalination*, 164(2), 105-110.

Adegbola, A.A., Adewoye, A.O. (2012). On Investigating Pollution Of Groundwater from Atenda Abattoir Wastes, Ogbomoso, Nigeria. *International Journal of Engineering and Technology*, 2(9)

Ahalya, N., Ramachandra, T.V. and Kanamadi, R.D. (2003). Biosorption of Heavy Metals. *Research Journal of Chemistry and Environment*, 7(4).

Akar, S.T., Arslan, S., Alp, T., Arslan, D. and Akar, T. (2012). Biosorption potential of the waste biomaterial obtained from cucumis melo for the removal of Pb2+ ions from aqueous media: equilibrium, kinetic, thermodynamic and mechanism analysis. *Chemical Engineering Journal*, 185(6), 82-90.

Alloway, B.J. (1995). “The origin of heavy metals in soil” in Heavy Metals in Soils, Ed, 29-39, Chapman and Hall, London, UK.

Alluri, H.K., Ronda, S.R., Settalluri, V.S., Bondili, V.S., Suryanarayana, V. and Venkateshwar, P. (2007). Biosorption: An eco-friendly alternative for heavy metal removal. *African Journal of Biotechnology*, 6(11), 2924-2931.

Amartey, E.O., Aumadu-Sakyi, A.B., Adjei, C.A. and Quashie, F.K. (2011). Determination of Heavy Metals Concentration in Hair Pomades on the Ghanaian Market Using Atomic Absorption Spectrometry Technique. *British Journal of Pharmacology and Toxicology*, 2(4), 192-198.

Amman, A., Michalke, B. and Schramel, P. (2002). Speciation of Heavy Metals in Environmental Water by Ion Chromatography Coupled to ICP-MS. *Analytical Biochemistry*, 372, 448-452.

Anawar, H. M., Akai, J., Mostofa, K. M., Safiullah, S. and Tareq, S. M. (2002). Arsenic poisoning in groundwater: Health risk and geochemical sources in Bangladesh. *Environment International*, 27(2), 597–604.

Babarinde, A., Babalola, J.O. and Sanni, A.R. (2006) Biosorption of lead ions from aqueous solution by maize leaf. *International Journal of Physical Sciences*, 1(1), 23-26.

Barakat, M. (2011). New Trends in Removing Heavy Metals from Industrial Wastewater. *Arabian Journal of Chemistry*, 4(4), 361-377.

Baral, S.S., Das, S.N. and Rath, P. (2006). Hexavalent chromium removal from aqueous solution by adsorption on treated sawdust. *Biochemical Engineering Journal*, 31(2006), 216-222.

Begun, A., Saeedfar, S. and Mojaveryazdi, F. (2013). Technology, Education and Science International Conference (TESIC). Faculty of Bioscience and Bioengineering, Johor.

Behnam, H., Saeedfar, S. and Mojaveryazdi, F. (2013). Biological Contamination of the Water and Its Effects. Technology, Education and Science International Conference (TESIC).

Bozic, D., Gorgievski, M., Stankovic, V. and Strbac, N. (2013). Adsorption of heavy metal ions by beech sawdust – Kinetics, mechanism and equilibrium of the process. *Ecological Engineering*, 58, 202-206.

Charley, G. (2020). Water pollution in New York Harbor: What can we do about it? *HYDRO*.

Dang, V.B.H., Doan, H.D., Dang, Vu.T. and Lohi, A. (2009). Equilibrium and kinetics of Biosorption of Cadmium (II) and Copper (II) by wheat straw. *Journal of Bioresource and Technology*, 100, 211-219.

Das, P., Samantaray, S. and Rout, G.R (1997). Studies on cadmium toxicity in plants: a review. *Environmental Pollution*, 98, 29-36.

Edwin, M. (2018). Determination of Selected Heavy Metals in River Mukurumudzi to Establish Potential Contamination from Land Based Activities and Sources. *Environmental Sciences*.

Ehi-Eromosele, C. and Okiei, W. (2012). Heavy metal assessment of Ground, Surface and Tap Water Samples in Lagos Metropolis Using Anodic Stripping Voltammetry. *Resources and Environment*, 2(3), 82-86.

Eze, H.N. and Chukwu, E. (2011). Small Scale Mining and Heavy Metal Pollution of Agricultural Soils: The case of Ishiagu Mining District, South Eastern Nigeria. *Journal of Geology and Mining Research*, 3, 87-104.

Garbarino, J.R., Hayes, H., Roth, D., Antweider, R., Brinton, T.I. and Taylor, H. (1995). Contaminants in the Mississippi river. *US Geological Survey Circular*, Virginia.

Ghosh, M. and Singh, S. (2005). A Review on Phytoremediation of Heavy Metals and Utilization of its By-products. *Applied Ecology and Environmental Research*, 3(1)

Hey, Ghosh, S. Ok, and Vass, K.K. (in 1997). The role of a sewage treatment plant in mitigating the climate. K. With K. Vass and M. Sinha (Eds.), National Seminar

Proceedings on Changing Inland Fisheries Perspectives, Inland Fisheries Society of India, Barrackpore, 36-40.Haiyan, W. and Stuanes, A

Hey, Ghosh, S. Ok, and Vass, K.K. (in 1997). The role of a sewage treatment plant in mitigating the climate. K. With K. Vass and M. Sinha (Eds.), National Seminar Proceedings on Changing Inland Fisheries Perspectives, Inland Fisheries Society of India, Barrackpore, 36-40.(2003). Heavy Metal Pollution in Air-Water-Soil-Plant System of Zhuzhou City, Hunan Province, China. *Water Air and Soil Pollution*, 147(1), 79-107.

Han, Y.M., Du, P.X., Cao, J.J. and Posmentier, E.S. (2006). Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China. *Science of the Total Environment*, 355, 176-186.

Hariprasad, N.V. and Dayananda, H.S. (2013). Environmental Impact due to Agricultural runoff containing Heavy Metals-A Review. *International Journal of Scientific and Research Publications*, 3(5).

Jain, V. K., (1978). Studies on effect of cadmium on the growth pattern of *Phaseolus aurius varieties,* Absi, I. Bot. Conf. JIBS, 57-84.

Jalali, R., Ghafourlam, H., Asef, D. and Sepehr, S. (2002) Removal and recovery of lead using non-living biomass of marine algae. *Journal of Hazardous Materials,* 72(3), 253-262.

Kabata-Pendias, A. (1995). Agricultural problems related to excessive trace metal contents in soils. In: Salomons, W., Forstner, U., and Mader, P., (Eds.), Heavy Metals: Problems and Solutions. Springer-Verlag, Berlin Heidelberg, 8-11.

Karishma, B. and Prasad, S. (2014). Effect of agrochemicals application on accumulation of heavy metals on soil of different land uses with respect to its nutrient status. *Journal of Environmental Science, Toxicology and Food Technology,* 8(7), 46-54.

Khan, N., Hussain, S. and Saboor A. (2013). Physiochemical investigation of the drinking water sources from mardan, khyber pakhtunkhwa, Pakistan. *International Journal of Physical Sciences*, 8(33), 1661-1671.

Khatun, R. (2017). Water Pollution: Causes, Consequences, Prevention Method and Role of WBPHED with Special Reference from Murshidabad District. *International Journal of Scientific and Research Publications,* 7(8).

Kim, Y. M, Harrad, S. and Harrison, R. M. (2001). Concentrations and sources of Vocs in urban and public microenvironments. *Environment Science Technology*, 35, 997 – 1004.

Lantzy, R.J. and Mackenzie, F.T. (1979). Atmospheric trace metals: global cycles and assessment of man's impact. *Geochemica et Cosmochimica Acta*, 43(4), 511-525.

Latif, S.A., Afroj, D., Hossain, S.M. *et al* (2009). Determination of Toxic Trace Elements in Foodstuffs, Soils and Sediments of Bangladesh Using Instrumental Neutron Activation Analysis Technique. *Bulletin of Environmental Contamination and Toxicology*, 82, 384.

Lesmana, S.O., Febriana, N., Soetaredjo, F.E. and Sunarso, J. (2009). Studies on potential applications of biomass for the separation of heavy metals from water and wastewater. *Biochemical Engineering Journal*, 44(1), 19-41.

Lohdip, Y. and Japheth, G. (2013). Nigerian water bodies in jeopardy: The need for sustainable management and security. *Water Resources Management*, 171, 11-21.

Lokhande, R., Singare, P. and Pimple, D. (2011). Toxicity study of heavy metals pollutants in waste water effluent samples collected from Taloja Industrial Estate of Mumbai, India. *Resources and Environment*, 1(1), 13-19.

Mahananda, M. R., Mohanty, B. P. and Behera Mahananda, N. R. (2010): Physico - chemical analysis of surface and ground water of Bargarh district, Orissa, India. *International Journal of Recent Research and Applied Studies*, 2, 26 -30.

Mata, Y.N., Blázquez, M.L., Ballester, A., González, F. and Muñoz, J.A. (2008). Characterization of the biosorption of cadmium, lead and copper with the brown alga *Fucus vesiculosus*. *Journal of Hazardous Materials*, 158(2-3), 316-323.

McNeely, P., Boilson, D., Curran, N., Hopkins, M. and Vender, D. (1998). Recommissioning the deuterium negative ion source experiment ion source for studies in support of ignition device to test engineering concepts. *Review of Scientific Instruments*, 69, 983.

Medema, G.J., Shaw, S., Waite, M., Snozzi, M., Morreau, A. and Grabow, W (2003). Catchment characterisation and source water quality, in: Dufour, A., Snozzi, M., Koster, W., Bartram, J., Ronchi, E. and Fewtrell, L. (Eds.), Assessing microbial safety of drinking water: Improving approaches and methods. Published on behalf of the World Health Organization and the Organisation for Economic Co-operation and Development by IWA Publishing, London.

Monser, L. and Adhoum, N. (2002). Modified Activated Carbon for the Removal of Copper, Zinc, Chromium and Cyanide from Wastewater. *Separation and Purification Technology*, 26(2), 137-146.

Murphy, V., Tofail SAM, Hughes H, McLoughlin P (2009) A novel study of hexavalent chromium detoxification by selected seaweed species using SEM-EDX and XPS analysis. *Chemical Engineering Journal*, 148, 425–433.

Muyibi, S., Ambali, A. and Eissa, G. (2008). The Impact of Economic Development on Water Pollution: Trends and Policy Actions in Malaysia. *Water Resources Management*, 22(4), 485-508.

Nriagu, J.O. (1990). Global metal pollution-poisoning the biosphere? *Soil Biology and Biochemistry*, 20(4), 415-424.

Nurchi, V.M., Villaescusa, I. (2008). Agricultural biomasses as sorbents of some trace metals. *Coordination Chemistry Reviews*, 252, 1178-1188.

Olagoke, O., Awojobi, K., Adekeye, A., Olasupo, A., Aboriaade, A. and Ogunrinde T. (2018) Isolation and Characterization of Stream Water Bacteria from ESA-OKE Metropolis. *Journal of Medical Microbiology and Diagnosis*, 7(2).

Olajire, A.A. and Imeokparia, F.E. (2000). A study of the water quality of the Osun River: Metal monitoring and geochemistry. *Bulletin of the Chemical Society of Ethiopia*, 14(1), 1-8.

Pink, D.H. (2006). Investing in tomorrow’s liquid gold. *World Journal of Analytical Chemistry*, 2, 42-46.

Reddy DHK, Seshaiaha K, Reddy AVR, Raoc MM, Wang MC (2010) Biosorption of Pb2? from aqueous solutions by Moringa oleifera bark: equilibrium and kinetic studies. *Journal of Hazardous Materials*, 174, 831–838.

Rene, S., Escher, B., Fenner, K., Hofstetter, T., Johnson, C., Gunten, U. and Whrli, B. (2006). The challenge of micropollutants in aquatic systems. *Science*, 313(5790), 1072-1077.

Ross, S.M. (1994).Toxic metals in soil-plant system. John Wiley & Sons, Ltd., London.

Salamatinia, B., Kamaruddin, A.H. and Abdullah, A.Z. (2008). Modeling of the continuous copper and zinc removal by sorption onto sodium hydroxide-modified oil palm frond in a fixed-bed column. *Chemical Engineering Journal*, 145, 259–266.

Salem, H.M., Eweida, E.A. and Farag, A. (2000). Heavy Metals in Drinking Water and their Environmental Impact on Human Health. ICEHM, Cairo University, Egypt, 442-555.

Seema, S., Swati, L., Jeena, H., Sulbha, A. and Katari, H. (2011). Potential of metal extractants in determination of trace metals in water sample. *Advanced studies in Biology*, 3(5), 239-246.

Slaba, M. and Dlugonski (2011). Biosorption of cadmium by various types of dried sludge: an equilibrium study and investigation of mechanisms. *Journal of Hazardous Materials*, 2, 378-383.

Subbaiah MV, Yuvaraja G, Vijaya Y, Krishnaiah A (2011) Equilibrium, kinetic and thermodynamic studies on biosorption of Pb (II) and Cd (II) from aqueous solution by fungus (*Trametes versicolor*) biomass. J Taiwan Inst Chem Eng, 42, 965–971.

Sud, D., Mahajan, G. and Kaur, M.P. (2008). Agricultural waste material as potential adsorbent for sequestering heavy metal ions from aqueous solutions - a review. *Bioresource Technology*, 99(14), 6017-27.

Suksabye, P., Thiravetyan, P., Nakbanpote, W. and Chayabutra, S. (2008). Chromium Removal from Electroplating Wastewater by Coir Pith. *Journal of Hazardous Materials*, 141(3), 637-644.

United Nations Environmental Programme, 2007

Varol, M. and Sen, B. (2011). Assessment of nutrient and heavy metal contamination in surface water and sediments of the upper Tigris River, Turkey. *Catena*, 92, 1-10.

Wang, J. and Chen, C. (2009). Biosorbents for heavy metals removal and their future. *Biotechnology Advances*, 27(2), 195-226.

West, L. (2006). "World Water Day: A Billion People Worldwide Lack Safe Drinking Water". Wikipedia.

Woolhouse, M. and Sequeria, S. (2006). Host Range and Emerging and Reemerging Pathogens. *Emerging Infectious Disease*, 11(12), 1842-1847.

Yang, Z., G. Li and D. Wang, 2005. The assessment of heavy metals of Baiyang lake sediment and its potential ecological risk. *Journal of Agricultural and Environmental Science*, 24, 945-951

Yu, Q. and Kaewsarn, P. (2000). Adsorption of Ni2+ from aqueous solutions by pretreated biomass of marine macroalga *Durvillaea potatorum*. *Separation Science and Technology*, 35(5), 689-701.

Yurlova, L., Kryvoruchko, A. and Kornilovich, B. (2002). Purification of water containing heavy metals by chelating enhanced ultrafiltration. *Desalination*, 144(1), 243-248.

Zakaria, Z., Suratman, M., Mohammed, N. Ahmad, W. (2009). Chromium (VI) Removal from Aqueous Solution by Untreated Rubber Sawdust. *Desalination*, 244(1-3), 109-121.