CHARACTERIZATION OF SOLID WASTE AND POLLUTION ASSESSMENT IN UNIVERSITY OF BENIN AND UNIVERSITY OF BENIN TEACHING HOSPITAL BENIN CITY, NIGERIA

BY

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DEPARTMENT OF ANIMAL AND ENVIRONMENTAL BIOLOGY

FACULTY OF LIFE SCIENCES

UNIVERSITY OF BENIN

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DECEMBER 2021.

CERTIFICATION

This is to certify that this project work was carried out by OLOTU ETINOSA STEPHANIE under my supervision

________________________ ________________________

Prof. (Mrs) E.U Edosomwan Date

Supervisor

Approved by:

________________________ ________________________

Prof. (Mrs) A. A. Imasuen. Date

Head of Department

________________________ ________________________

External Examiner. Date

DEDICATION

To my parents MR and MRS Maris OLOTU for their relentless support and Effort to make me a better person.

ACKNOWLEDGEMENT

First of all, I want to thank the almighty God for his grace, inspiration and strength. To my project supervisor Prof. (Mrs) E.U Edosomwan for her guidance, ideas, suggestion, correction and effort in making my project a success, I am indeed grateful.

My sincere thanks to my project mates; Promise Asokhia and Paul Disi for their care and cooperation during the course of this work.

My special gratitude to my family for their provision, care and love for me throughout my stay in the university. To my friend and little sister, I am indeed grateful.

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ABSTRACT

This study evaluated the many waste streams produced at the University of Benin and its teaching hospital in Benin City, Nigeria. Additionally, it evaluated the health risks related to the heavy metal concentrations in the soil around the waste dumps. Each of the waste dumps on the campus and hospital undergo waste characterization through material type sorting. The findings demonstrate that the waste produced has the potential to be recycled if it is separated, and it also demonstrate that Cadmium (Cd) is above the permissible limit of WHO (1996), FEPA (1991) and US EPA (2002) in refuse dumps 5, 8 and 9 which is 0.8 mg/kg, 1 mg/ kg and 0.48 mg/ kg respectively. The ten sampled sites has cadmium concentrations ranging from 0.05 to 2.70 mg/kg, with a mean of 0.49 $\pm$ 0.810mg/kg. In refuse dump 5, the Zinc concentration was higher than the 50mg/kg acceptable limit established by WHO (1996). Chromium (Cr) concentrations in the ten sampled sites are higher than the permissible limit which is 0.20 mg/kg, according to the FEPA (1991) guideline. It's concentration ranges from 1.70 mg/ kg to 8.05 mg/ kg with a mean of 4.28 $\pm$ 2.23 mg/ kg in the ten sampled sites. The lead (Pb) threshold set by FEPA (1991) is 0.05 mg/ kg and it shows that the concentration of lead in refuse dumps 4, 8 and 10 exceed the threshold. Manganese was the metal with the highest concentrations with a range of 26.10 to 124.40 mg/ kg and a mean of 64.5 $\pm$ 34.73 mg/ kg which was above the permissible limit of WHO (2004) and FEPA (1991) which are 12 mg/kg and 0.05 mg/ kg respectively.

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

In emerging nations with severe environmental degradation, rapid population development and unchecked urbanization have been a major factor in the increased accumulation of solid waste, making disposal a serious challenge. A considerable volume of solid waste from residential, agricultural, and industrial operations has accumulated because of advances in science and technology (Sangodoyin *et al*., 2000), rising resource consumption, and increased toxicity and risks that have put public health at risk (Oladejo,2011). Uncontrolled population growth, community density, consumption patterns, standard of living, wages per month, dwelling population, proportion of urban residents, size of housing units, geographic locations, land use patterns, productive activities, and cost of living are some common factors that affect waste generation, with population growth being the main factor. For effective solid waste management, it is crucial to estimate the amount of solid trash that is produced in a city. In most developing nations, local authorities provide waste management services, which include waste collection, transportation, and disposal. However, these services are hampered by insufficient financial support and human resource capabilities. Due to these obstacles, effective waste management services were inhibited (Barton *et al*., 2008), leading to adverse issues that negatively impacted human and animal health and eventually caused financial, environmental, and biological losses (Sharholy *et al*., 2008). But the insufficient documentation of the volume and nature of solid waste generated has hindered developing nations' ability to create effective and sustainable waste management systems (Ogwueleka, 2009; Olukanni, 2013; Olukanni *et al*., 2014). In Nigeria, solid waste management calls for immediate attention and the adoption of the greenest procedures.

The waste management system considers trash characterization heavily. It serves as a foundation for the construction of effective, affordable, and environmentally friendly waste equipment. Based on waste characterization study, it is necessary to establish the percentage of components in waste that will be burned (Beck, 2005; Chang *et al.,* 2008; Alhassan and Tanko, 2012). According to Oumarou *et al.,* (2012) The main goals of waste characterization include plant optimization, emission monitoring and data, providing the foundation for planning economic analysis, design and later management and operation of a disposal system or material and energy resource recovery facilities. To choose the most affordable collection methods, plan for suitable sanitary landfill sites, design composting plants or grinding plant, accurately forecast the cost and efficiency of operation when selecting a particular method of disposal, And finally forecast future demand, it is necessary to know the composition of the waste (Aguilar- Virgen *et al.,* 2010).

Dumpsites are locations that have been set aside for the disposal and potential treatment of waste materials produced. As is common in many poor nations, mixed trash, including domestic, industrial, and medical waste, is dumped at these sites without being separated or treated. However, materials from residential and agricultural sources make up the majority of the dumpsite makeup in these nations (Ike-Ihunwo *et al*., 2019). These dumpsites alter the physical aesthetics of the environment while also providing a breeding ground for small vertebrates and arthropods, many of which are parasite disease vectors. Due to the presence of both human and animal waste and other infections that could be passed from animal to human, dumpsites are also known to have a high frequency of gastrointestinal parasites (Cletus *et al*., 2015).

1.2 AIM AND OBJECTIVES

The aim of this study is to characterize the solid waste generated in University of Benin (UNIBEN) and University of Benin Teaching Hospital (UBTH), and to assess the heavy metal concentration of the refuse dumps.

The objective of this study are:

1. to determine the types of waste found in each refuse dumps.
2. to determine the concentration of heavy metal contamination in the soil around the refuse dumps.
3. to evaluate the characterization of waste in University of Benin and University of Benin Teaching Hospital.

1.3 JUSTIFICATION FOR RESEARCH

The University of Benin and the University of Benin Teaching Hospital both have a lot of refuse dumps. The rubbish dumped in these refuse dumps may have a variety of effects on the ecology and residents. The findings of this study will assist the authorities of the University of Benin and University of Benin Teaching Hospital in waste management and pollution control. It is also going to serve as resource for further studies in waste management.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1 THEORY OF WASTE

Waste is any item that needs to be discarded because it is damaged, worn out, contaminated, or otherwise ruined and has lost its value (Anifowose et al., 2011). It might be harmful and take the shape of a liquid or solid. These categories include waste from residences and other locations where people or animals live. The State of Vermont Agency of Natural Resources Department of Environmental Conservation (2012) defined solid waste as any tangible and non-free flowing undesired materials or substances that are a byproduct of human activity. When its sources are generated by commercial, agricultural, and industrial activity, it is referred to as municipal solid waste (Singh et al., 2012). In developing countries, homes contribute between 55 and 80 percent of the country's municipal solid waste, with commercial or market areas producing between 10 and 30 percent of it. Other sources of waste include streets, businesses, and institutions (Nabegu, 2010; Nagabooshnam, 2011; Okot-Okumu, 2012).

One of the most researched waste streams is municipal solid waste, which is a significant waste stream. Municipal solid waste is waste that local governments collect from residential and commercial sources, according to Buah *et al*. (2007). Municipal solid trash, according to Vergara and Tchobanoglous (2012), reflects the habits and way of life of the people who generate it. They continued by saying that improper management of municipal solid waste could have a detrimental effect on both public health and the environment. In the directive on the dumping of waste 1999/31/EC, the European Union outlined its legal definition of municipal trash for legislative purposes. Municipal garbage is defined as waste from houses as well as any other waste that, by nature or composition, is comparable to waste from households. Because it is comparable in composition to domestic waste, this larger definition classifies waste from commercial properties as municipal waste.

2.2 GENERATION AND CHARACTERIZATION OF WASTE

A crucial stage in efficient waste management is trash creation and characterization. A study of Makurdi's waste generation profile was conducted by Sha'Ato et al. in 2007 in north central Nigeria. He stated that homes produced most of the area's solid trash, rather than businesses, institutions, or industries. This trash primarily consisted of putrescible materials like ash, dust, and sand. On the other hand, research of solid medical waste revealed that hospitals and health organizations in Abuja, the federal capital territory, produce a sizable amount of solid trash collected each day that endangers both the environment and people. (Bassey *et al.*, 2006). According to the study, none of the hospitals studied employed segregation, and 26.5% of the daily total solid waste created was hazardous in nature. Similarly, Fadipe *et al*. (2011) noted that pathological wastes, such as unclaimed dead bodies, placentas, and umbilical cords, are being discarded into open dumps and other medical trash in Osun state is not being properly disposed of.According to a comparison of the composition of municipal solid waste (MSW) in three local government areas of Rivers State, waste generation rates in Emougha, Ohio/Akpor, and Port Harcourt were 0.45, 0.98, and 1.16 kg/capita/day, respectively (Babatunde *et al.*, 2013). The three categories that stood out the most were organic trash, paper, and nylon. In the local government areas of Emougha, Ohio/Akpor, and Port Harcourt, respectively, the mean percentage compositions for organic waste, paper, and nylon were 59, 65.5, 65, 6, 11 and 13%, respectively. They emphasized the possibility of resource recovery and energy production. Like Sha'Ato (2007), who recommended composting as the optimum method of waste management since a significant amount of household garbage (between 36 and 57%) comprises of diverse putrescible components.

Plastics, waterproof materials, and diaper production rates have all increased (Nnaji, 2015). In Nigerian cities, it was discovered that close to 50% of all municipal solid garbage was made up of food waste (Aliyu, 2010; Nnaji, 2015). There is a need for both the government and individuals to adopt holistic and sustainable waste management strategies to protect public and environmental health, as many Nigerian cities have become overrun by open dumps because of the dysfunctional state of many municipal waste management authorities (Nnaji, 2015). To establish cost-effective, dependable management procedures in Nigeria, sustained cooperation between all important actors (government, waste managers, public health workers, and citizens) could be developed (Olukanni and Mnenga, 2015). To manage the solid waste issue sustainably, the government must set aside a sizable amount of money and ensure that the populace is properly educated.

2.3 SOLID WASTE DISPOSAL METHODS

Methods for disposing of solid waste include the following:

1. Landfilling

Landfilling is the practice of disposing of garbage in the ground. A proper landfilling method should be used, including coating the base with a protective layer and choosing a location with low groundwater levels, among other things. This process calls for skilled labor. Construction of horizontal wells lowers leachate levels in municipal solid waste landfills in China (Hu, *et al.*, 2020). A model based on physical, chemical, and biological processes regulates the release of mercury (Hg) from landfills (Tao, Deng, Li and Chai, 2020).

2. Incineration

Incineration is the process of burning garbage at a high temperature. The proper filters are employed to prevent air pollution, which is brought on by the burning of garbage. The direct combustion method without anaerobic digestion was determined to be a more favored sustainable method for treating sludge (Hao, *et al*., 2020). Coal power plant technology and waste incineration methods were seen as promising technologies for the conservation and disposal of fossil fuels (Ye, *et al*., 2020). Plasma, mechanochemistry, hydrothermal, photocatalytic, and biodegradation technologies have demonstrated that they have a good purifying effect and are regarded as the best source of fly ash from municipal solid waste incineration (Zhang, Zhang and Liu, 2020).

3. Recycling

Recycling is the process of turning waste resources into new goods. In comparison to new production, it prevents the waste of useful material resources, lowers the use of raw materials and energy, and thus, lowers greenhouse gas emissions. The third element of the waste hierarchy and a fundamental idea in contemporary trash management is recycling. The goal of recycling is to remove waste items from the waste stream that would otherwise be landfilled or otherwise disposed of and use them as feedstock or raw materials for new or valuable products (Dyson and Chang, 2005). Materials that are recyclable, also known as recyclables, can come from a variety of places, including the household and the workplace. Glass, paper, aluminum, asphalt, iron, textiles, and plastics are a few of them. Biodegradable waste, such as food waste or garden waste, is also recyclable with the assistance of microorganisms through composting or anaerobic digestion (Khoo, 2009).

4.Composting

Separated from the other wastes, organic wastes are placed in a pit where bacteria can break them down over an extended period. This then turns into nutrient-rich compost, which is used as plant manure. These fertilizers increase the fertility of the soil. The organic process of composting improves the soil's fertility. The vermicomposting technique lessens the impact on the environment and improves the soil's nutrient content (Bhat, *et al*., 2020) Vermicomposting is a practical method for sustaining organic farming while preserving a healthy ecosystem (Kaur, 2020). Black soldier fly (larvae) was used for high levels of organic waste reduction and quick composting times. The remainders were then given a further treatment with E. Eugeniae, which produced vermicompost of the highest quality (Bagastyo and Soesanto, 2020). Vermicomposting onion waste with cow manure results in a beneficial nutrient cycle for agriculture (Pallejero, *et al*., 2020).

5. Bioremediation

Bioremediation is the process of employing microorganisms and bacteria to remove impurities, pollutants, and toxins from soil, water, and other environments. The main threat to the human population is posed by the radioactive waste that energy power plants release. Bioremediation is utilized to lessen these wastes. Bioremediation technology resolves the issue of heavy metal pollution and aids in restoring the soil's natural state (Saini and Dhania, 2020). For the safe discharge of water from industrial activities, bioremediation is a cost-efficient, environmentally beneficial solution that is supported (Coelho, 2020).

2.4 EFFECTS OF SOLID WASTE

Solid waste can come into touch with living things in several ways, including mechanical transmission by insects, birds, rodents, flies, and other animals. They serve as a vector, transferring pathogenic microorganisms from their bodies to food that is ultimately consumed by people. Direct untreated trash disposal into oceans, rivers, and lakes causes the plants and animals that eat it to contaminate our food and water supplies. Ground water pollution is a potential risk created by waste dump sites. Leachate-derived pollutants seep into the soil and travel through it to reach subsurface water (Szymanski *et al*., 2018). The people in places without suitable waste disposal methods, notably garbage workers and employees in facilities manufacturing dangerous and infectious materials, are among those at risk from the unclean disposal of solid waste (Alam, P., and Ahmade, K. 2013). The population that resides close to a landfill poses a high risk, as do those whose water supply has been affected by rubbish dumping or landfill site leaks.

According to the UNEPA (2019), improperly managed waste, particularly excreta and other liquid and solid wastes from homes and the community, pose a severe health risk and may contribute to the spread of illnesses. According to the report, abandoned garbage attracts rats, flies, and other animals that in turn harbor disease-carrying organisms. Typically, only moist waste decomposes and emits offensive odors. People living adjacent to the dumpsite are affected by the unpleasant odor, which clearly shows the grave consequences dumpsites have on those living nearby or close (Alam, P., and Ahmade, K. 2013).

Agriculture and industrial wastes pose a severe health danger as well. In addition, mixing industrial hazardous waste with municipal waste might put individuals in danger from radioactive and chemical substances. Additionally, uncollected solid trash can impede storm water discharge, creating stagnant water bodies that serve as a breeding ground for disease (Scragg, A.H. 2005). Waste placed close to a water source also contaminates the body of water or the source of ground water. Untreated trash dumped directly into rivers, lakes, and oceans causes hazardous compounds to build up in the food chain through the plants and animals that consume it (Medina, M. 2009). This demonstrates unequivocally how persons who live closer to landfills suffer major health effects from waste disposal. Hazardous chemical disposal may be a component of industrial waste. Populations exposed to these dangerous compounds may experience several serious health impacts. These negative consequences on health are listed by Vrijheid (2000) as follows:

- Carcinogenesis (i.e., causing cancer).
- Genetic defects, including mutagenesis (i.e., causing alterations in genes which are transmitted from one generation to another or causing heritable genetic damage).
- Reproductive abnormalities including teratogenesis (i.e., causing damage to developing foetus not necessarily related to toxic effects on mother).
- Alterations of immunobiological homeostasis.
- Central nervous system (CNS disorder), and
- Congenital anomalies.

Exposure to chemicals that leak into the environment almost always results in a shorter life expectancy and, in some cases, a time of lower quality of life from diseases, stress, and exposure-related anxiety. Therefore, it is possible to view an unregulated waste disposal method as a potential cause of several health and environmental issues (Misra, V., and Pandey, S.D. 2005).

2.5 HEAVY METALS

According to Lentech (2009) and Zaini *et al*. (2013), heavy metals are any metallic chemical elements that are dangerous or poisonous at low concentrations and have a relatively high density. It is also known as periodic table elements with atomic numbers greater than 20 or densities greater than 5 gcm-3 (Duffus, 2002). The biological system could be significantly impacted by this metal. When heavy metals accumulate in soft tissues without being digested by the body, they become poisonous to humans (Satarug *et al*., 2000; Eriyamremu *et al*., 2005;

Muchuweti *et al*., 2006). Natural elements including aluminum (Al), chromium (Cr), lead (Pb), zinc (Zn), manganese (Mn), and iron (Fe) are frequently found in low concentrations in the environment but can be hazardous in higher concentrations. These metals are mined, smelted from metallic elements and scrap metal, electroplated, applied as fertilizer and pesticides, dumped as sludge, and disposed of with municipal solid waste (Vidal *et al*., 2000; Oguzie *et al*., 2002; Speir *et al*., 2003; Razo *et al*., 2004; Remon *et al*., 2005; Lee *et al*., 2006; Mudgal *et al*., 2010; Lawson, 2011 and Sabri *et al*., 2013).

To evaluate soil pollution brought on by heavy metals, two metrics are used: the geo-accumulation index and ecological risk assessment (Aydi, 2015). Shittu *et al*. (2017) used pollution indices to analyze the heavy metal contamination in dumpsite environments, and their findings indicate that the soil is heavily contaminated with heavy metals. Additionally, the results of the geo-accumulation index calculation indicated that soils ranged from being unpolluted to moderately polluted, and they recommended that monitoring of heavy metals be investigated to determine the long-term effects of anthropogenic impact and heavy metal bioavailability. In Challawa Industrial Estate Kano, heavy metals like Cr, Fe, Zn, Cu, Pb, and Cd were found in soil samples taken from farmlands and tanneries. Koki and Jimoh's (2013) findings revealed that the heavy metals were found in increasing order. Using a pollution index, Ediene and Umoetok (2017) measured the heavy metal content in soils at the municipal dumpsite in the Calabar metropolis. Their findings indicate that the concentrations of heavy metals in the dumpsites were higher than those in the control soil.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 DESCRIPTION OF STUDY AREA

University of Benin (UNIBEN), a public research university, is situated in latitude $6^0$20.022'N and longitude $5^0$36.009'E in the Ovia North-East local government area of Edo state, Nigeria. It was established in 1970 and is one of the universities that the Federal Government of Nigeria owns. The institution currently has two campuses, fifteen faculties, a John Harris Library as its main library, and an estimated 77,000 students. Administrative, academic, research, and community services are the main activities on campus. Allotted places are offered for performing these tasks.

University of Benin Teaching Hospital (UBTH) is a premier and muti-specialty healthcare service provider in West Africa, opened in 1973. Located in PMB111, Ugbowo, Benin City, Edo state, Nigeria on latitude $6^0$23’26” N and longitude 5^0 36’44” E.

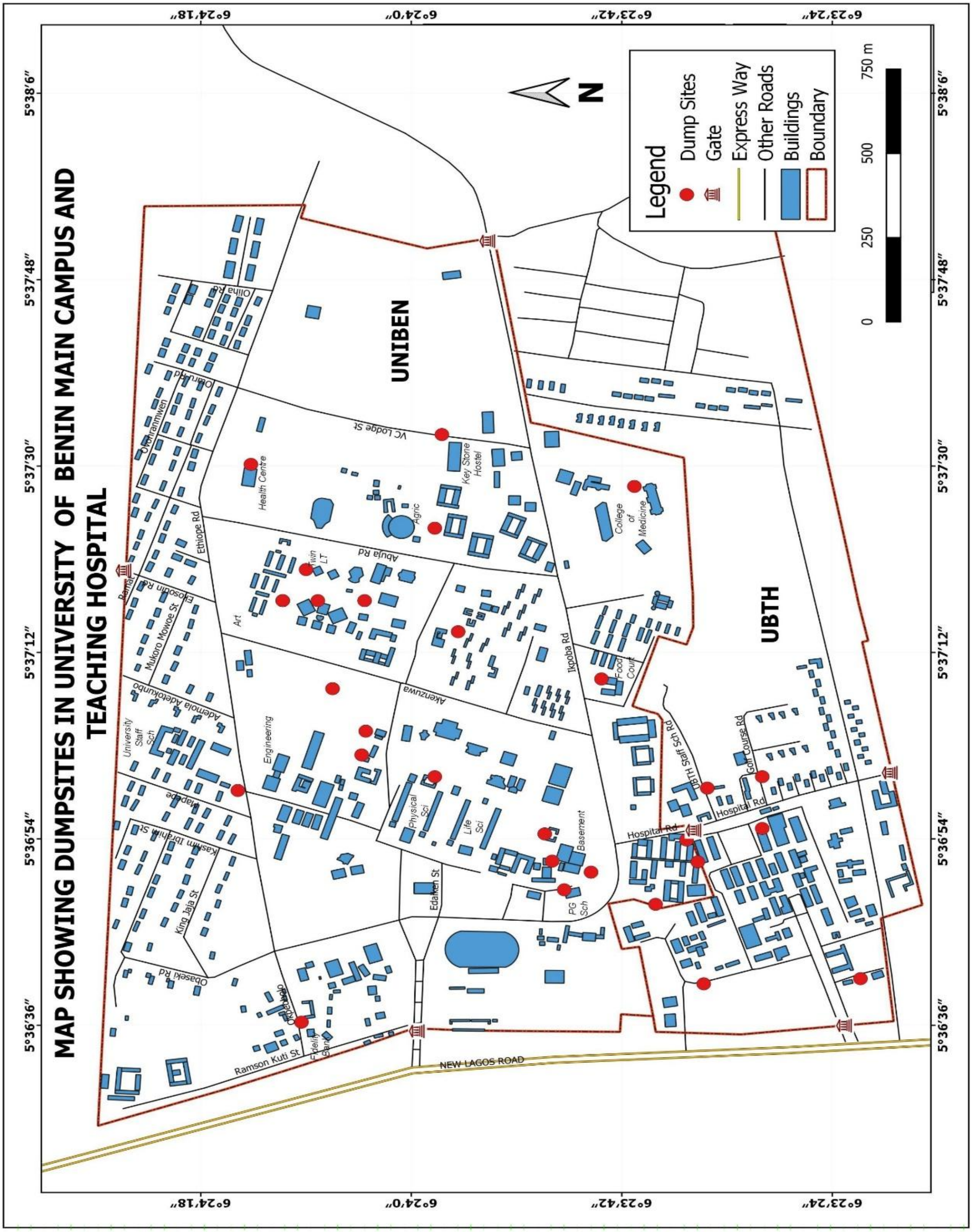

Figure 1: Map showing refuse dumps in UNIBEN and UBTH.

3.1.1 CLIMATE

The region has a tropical climate, which is divided into two distinct seasons marked by rain and sun. With a brief fall in August known as August break, the months of April through October are rainy. November through March are considered the dry months. The state's average annual temperature is 23.470°C, while the annual mean precipitation is 217.80mm. Temperatures are generally high throughout the state with very little seasonal or nocturnal change in the range of 22–360°C.

3.1.2 VEGETATION

From the South to the North of the country, three distinct vegetation belts can be seen: the mangrove swamp forest in the South, the rain forest in the middle, and the savannah vegetation in the North (Edo State, 2013).

3.1.3 METHODOLOGY

The study was conducted in both University of Benin (UNIBEN) and University of Benin Teaching Hospital (UBTH), with the field work comprising of reconnaissance survey to have general overview of solid waste generation areas in the study area; temporary collection and sorting points to observe the physical conditions regarding quantity and quality of solid waste of the campus and hospital.

3.2 Sampling Methods and Sampled Areas

Ten (10) specifically chosen zones where landfilling was practiced were sampled. These zones include:

- Behind Faculty of Environmental Science
- Behind PTDF ICT Building
- Behind Physical Science Complex

- Behind Department of Microbiology Building
- Behind Basement Complex
- Behind Drug Manufacturing Laboratory (Department of pharmaceutics and pharmaceutical technology)
- Beside Medical Laboratory Science
- Beside Keystone Hostel
- Behind Center for Entrepreneurial Development Building
- Beside Faculty of Social Sciences

An auger was used to dig the top 15cm layer of the surface for soil sampling. Three different places around the refuse dumps were dug and labelled RD1, RD2, RD3 (1st sampling) and the soils collected from each of the three different places were mixed to become one (1) sample. The collected samples were then stored in polythene bags and labelled with a masking tape. This process was repeated for each of the zones listed above. In total, there were 10 samples collected from the sites at a depth of 0-15cm. The collected samples were taken to the laboratory for heavy metals analysis.

3.2.1 Laboratory Analysis

The soil samples were air dried on a plastic tray for three days to ensure the removal of moisture. The soil samples were repeatedly crushed by the aid of mortar and piston and sieved with a 2mm mesh sieve to obtain fine particles.

3.2.2 APPARATUS AND REAGENTS

- 25 – 250ml digestion tube or conical flask
- Digestion block/heater

- 100ml volumetric flask
- Whatman filter paper NO42.
- Funnels
- Pg instrument AA500F (AAS)
- Concentrated HNO_3 – $HCLO_4$ mixture: 150ml of HNO_3 with 50ml of $HClO_4$
- 1000mg/l stock standard of each metal
- Distilled or deionized water.

3.2.3 DIGESTION PROCEDURE

1g of the soil sample was taken into a conical flask, then 10ml of Nitric – Perchloric acid mixture was added and allowed to soak overnight. A small glass funnel was inserted to act as a reflux condenser and heated for 1hr at 150 ^{0}C. Gradually, the temperature was raised to 235 ^{0}C. When dense white fumes occur, so heating was continuous until a colorless solution was obtained. The sample was filtered and poured into a 100ml volumetric, followed by making up the volume to 100cm^3 using distilled water. Prepare blank samples using the same procedure, and the digested sample was analysed for the presence of heavy metals with the aid of an atomic absorption spectroscopy (AAS).

3.2.4 CALIBRATION AND ANALYSIS

- Single elemental standard was prepared by dilution of 1000mg/l stock solutions of the individual elements (Pb, Cu, Zn, Fe, Ni, Cd, Mn, Cr, V, Ca, Mg, Na, K)
- A minimum of 5 standards working solutions were prepared daily from stock solutions. The solution ranged between 0.1mg/l – 10mg/l.

- External calibration was used by running de-ionized water and a suite of calibration standards for each element.
- The calibration curve was then generated for each metal.
- The digested samples and blanks were then run on the AAS to obtain the absorbance values.
- The concentrations of the metals in the sample were calculated from the equation of the calibration curve.

CHAPTER FOUR

4.0 RESULTS

4.1 LOCATIONS FOR SOLID WASTE

The zones where the refuse dumps are located, the sorts of solid waste produced on the campus and at the teaching hospital of the University of Benin, is represented in (Table1).

Table 1: Zones with waste dumps and different waste produced in UNIBEN and UBTH.

ZONES OF WASTE DUMPSITES	TYPES OF SOLID WASTE GENERATED	CHARACTERISTICS OF WASTE DUMP
Behind faculty of arts building	Paper, polythene bags, rubber, plastics, wood.	Not smelling, not well located and not built up
Behind dept. of philosophy	Leave, paper, rubber, plastics, polythene bags.	Not smelling, not well located and not built up
Beside keystone hostel	Food remains, polythene bags, rubber, plastics, paper, bottles.	Smelling, not well located and not built up
Behind basement complex	Paper, food remains, polythene bags, rubber, plastics.	Smelling, not well located and not built up
Beside Uniben table water	Paper, polythene bags, food remains, rubber, plastics, iron.	Smelling, not well located and not built up
Behind PTDF ICT Centre	Carton, foam, wood, bottles, rubber, plastics, polythene bags, paper.	Not smelling, not well located and not built up

Behind drug manufacturing Laboratory (dept. of pharmaceutics & pharmaceutical technology)	Sack, bottles, paper, rubber, plastics, polythene bags, food remains.	Smelling, not built up, well located
Behind Uniben methylated spirit & hydrogen peroxide production unit	Sack, polythene bags, bottles, food remains, glass, rubber, plastics.	Built up, smelling and not well located
Beside medical laboratory science building	Rubber, plastics, polythene bags, paper, carton, food remains, leaves.	Smelling, well located and not built up
Behind prof. Lilian Salami complex	Leaves, bottle, paper, polythene bags, sack, carton, rubber, plastics, diapers, food remains.	Built up, not well located and smelling
Behind dept. of MCB building	Sack, carton, paper, rubber, plastics, food remains, polythene bags, wood.	Built up, well located and smelling
Behind faculty of Environmental sciences	Paper, food remains, polythene bags, wood, plastics.	Not well located, smelling and not built up
Behind CED confectionery building	Rubber, plastics, polythene bags, paper, food remains.	Built up, not well located and smelling
Behind physical science complex	Rubber, plastics, polythene bags, paper, leaves, bottles, glass, sack, food remains, wood, carton.	Built up, not well located and smelling

Behind faculty of law	Polythene bags, carton, plastics, paper, food remains, leaves.	Smelling, not well located and not built up
Along golf court road	Paper, carton, leaves, food remains, plastics, nose masks.	Built up, smelling and not well located
Behind catering service	Paper, plastics, polythene bags, food remains, basket.	Built up, smelling and not well located
Beside UBTH cooperative complex	Polythene bags, paper, rubber, plastics, food remains, gloves.	Smelling, built up and not well located
Beside medical emergency ward	Polythene bags, rubber, plastics, paper, food remains.	Smelling, not well located and not built up
Along UBTH staff school road	Polythene bags, sack, rubber, plastics, paper, carton, nose masks, food remains, leaves.	Built up, not well located and smelling

Source: Fieldwork 2022.

4.1.1 WASTE CHARACTERIZATION

The data collection consists of quantitative data which includes waste characteristics and quantities as described by Bamgboye and Ojolo (2004), and Oyelola and Babatunde (2008). Generated solid waste was obtained from bins at different locations in University of Benin (UNIBEN) and University of Benin teaching hospital (UBTH) The materials were then sorted according to material types which include paper, plastic/rubber materials, bottles, nylon bags, sacks and other combustible miscellaneous waste materials. This data shows the kind of materials used mostly by the inhabitants. This waste all have potential for recycling if it is all sorted out from source as done in developed nations.

From analysis of the research data as shown in Table 1, it is obvious that paper material and nylon are the common categories found in the waste stream. Other categories include; Breakables: involving glasses of any kind and bottles, Biodegradables: involving food remains, leaves, wood, sack, rubber and plastics of any kind, foam, diapers etc. Olukanni and Akinyinka (2012) expressed that the amount of energy that is wasted by not recycling paper, printed material, glass, plastic and aluminum and steel cans could be much. Plastic can be recycled and reused depending on the quality. Recycling process of plastics involves washing, shredding, drying, wet grinding; extrusion, pelletizing and the final product are packaged and sold to consumers. Paper recycling saves the forest of trees which would produce new paper. It reduces the quantity of solid waste disposed and the pollution also reduces during manufacturing because the fibers have been processed once. A productive, healthy, competitive and well-functioning environment is a function of effective solid waste management systems.

4.2 LOCATIONS OF SAMPLED SITES

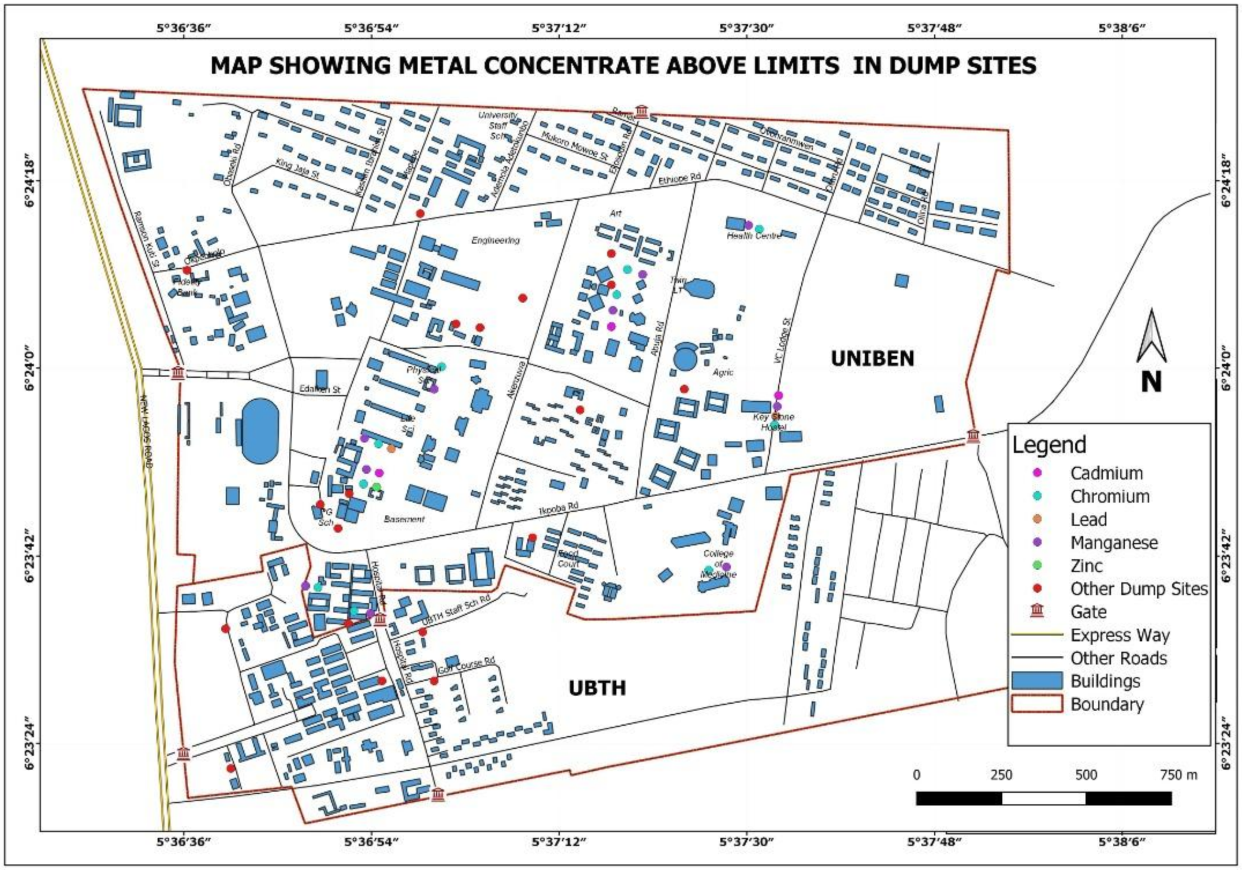

Fig. 4.1: Map showing concentrations of heavy metals above permissible limit

4.3 HEAVY METALS ANALYSIS

The results of the analysis of total heavy metals concentrations in the ten (10) refuse dumps are presented in Table 2.

Sample ID	Locations	Zn mg/kg	Cd mg/kg	Mn mg/kg	Cr mg/kg	Pb mg/kg	As mg/kg
Refuse dump 1	Behind Faculty of Environmental Science	4.30	<0.05	30.30	2.00	<0.01	<0.01
Refuse dump 2	Behind PTDF ICT building	4.30	<0.05	26.10	2.10	<0.01	<0.01
Refuse dump 3	Behind Physical Science Complex	5.30	<0.05	34.60	2.50	<0.01	<0.01
Refuse dump 4	Behind Department of Microbiology building	12.60	<0.05	111.50	6.03	10.3	<0.01
Refuse dump 5	Behind Basement Complex	97.80	0.90	73.10	8.05	<0.01	<0.01
Refuse dump 6	Behind drug manufacturing laboratory	29.20	<0.05	68.80	6.02	<0.01	<0.01
Refuse dump 7	Beside medical laboratory science	18.08	<0.05	124.40	4.02	<0.01	<0.01

Refuse dump 8	Behind Keystone hostel	4.30	0.90	30.30	1.70	10.3	<0.01
Refuse dump 9	Behind CED building	39.60	2.70	98.70	7.20	<0.01	<0.01
Refuse dump 10	Behind Faculty of Social sciences	5.30	<0.05	47.40	3.20	35.90	<0.01

Table 3: Showing results of metals and their mean, standard deviation, ranges and thresholds.

Refuse dumps	Zn mg/kg	Cd mg/kg	Mn mg/kg	Cr mg/kg	Pb mg/kg	As mg/kg
1	4.30	<0.05	30.30	2.00	<0.01	<0.01
2	4.30	<0.05	26.10	2.10	<0.01	<0.01
3	5.30	<0.05	34.60	2.50	<0.01	<0.01
4	12.60	<0.05	111.50	6.03	10.3	<0.01
5	97.80	0.90	73.10	8.05	<0.01	<0.01
6	29.20	<0.05	68.80	6.02	<0.01	<0.01
7	18.08	<0.05	124.40	4.02	<0.01	<0.01
8	4.30	0.90	30.30	1.70	10.3	<0.01
9	39.60	2.70	98.70	7.20	<0.01	<0.01

10	5.30	<0.05	47.40	3.20	35.90	<0.01
Mean ± SD	22.09 ± 27.76	0.49 ± 0.810	64.52 ± 34.73	4.28 ± 2.23	5.66 ± 10.87	0.01 ± 0
Range	4.30 - 97.80	0.05 - 2.70	26.10 - 124.40	1.70 – 8.05	0.01 – 35.90	0
WHO (mg/kg)	50	0.8	12	100	85	NA
FEPA (mg/kg)	NA	<1	0.05	0.20	0.05	0.1
US EPA (mg/kg)	300	0.48	NA	11	200	0.11
EU (mg/kg)	300	3.0	NA	100	300	100

Tables 2 and 3 show, respectively, the results for heavy metals and their means, standard deviations, and ranges for the ten sampled sites. Out of the ten sampled locations, refuse dump 5 (Behind basement complex) has the highest concentration of Zinc (Zn), with a value of 97.80 mg/kg, according to the analysis of the heavy metals displayed in the above tables. In the ten sites that were examined, it varies from 4.30 mg/kg to 97.80 mg/kg, with a mean and standard deviation of 22.09 + 27.76 mg/kg. With a value of 2.70 mg/kg, refuse dump 9 (behind CED building) has a higher quantity of cadmium (Cd). The ten sampled sites have a range of 0.05 to 2.70, with a mean and standard deviation of 0.49 $\pm$ 0.810 mg/kg. Both refuse dump 7 (beside medical laboratory science building) and refuse dump 4 (behind the MCB building) had significant manganese concentrations, with values of 124.40 mg/kg and 111.50 mg/kg, respectively. In the ten examined sites, the range is 26.10 mg/kg to 124.40 mg/kg, with a mean and standard deviation of 64.52 mg/kg ± 34.73 mg/kg. With a value of 8.05 mg/kg, refuse dump 5 (behind basement complex) has a high concentration of chromium (Cr). In the ten sampled sites, it has a range of 1.70 mg/kg to 8.05 mg/kg with a mean and standard deviation of 4.28 mg/kg ± 2.23 mg/kg.

With a value of 35.90 mg/kg, refuse dump 10 (Beside faculty of social sciences) has a higher concentration of lead (Pb). It has a range of 0.01 mg/kg to 35.90 mg/kg, a mean of 5.66 $\pm$ 0.87 mg/kg. All ten of the examined locations have arsenic concentrations that are less than 0.01 mg/kg.

Manganese (Mn) had the highest concentration in the analyzed refuse dumps, according to the data from the analysis. The figures below show graphic representations of each heavy metal.

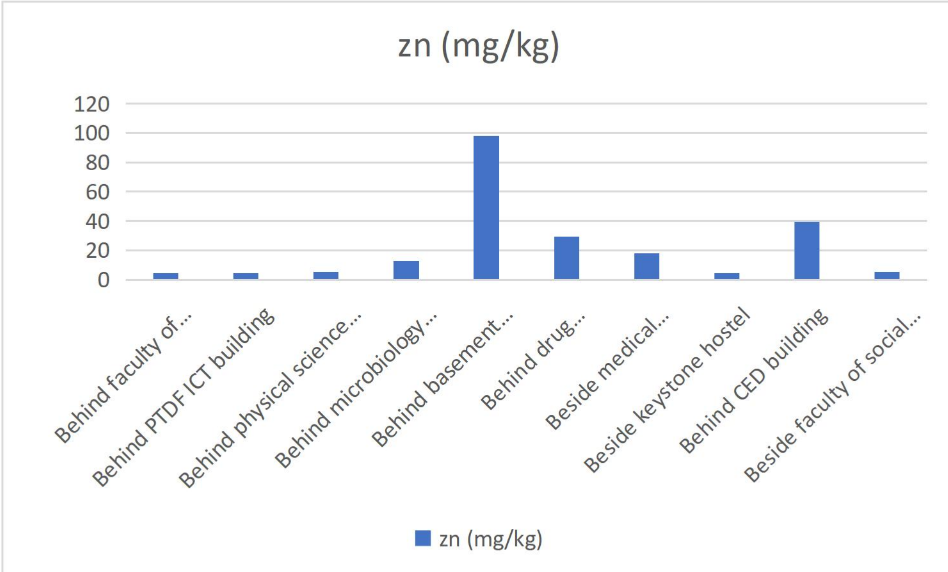

Fig. 4.3.1: A graphical representation of Zinc

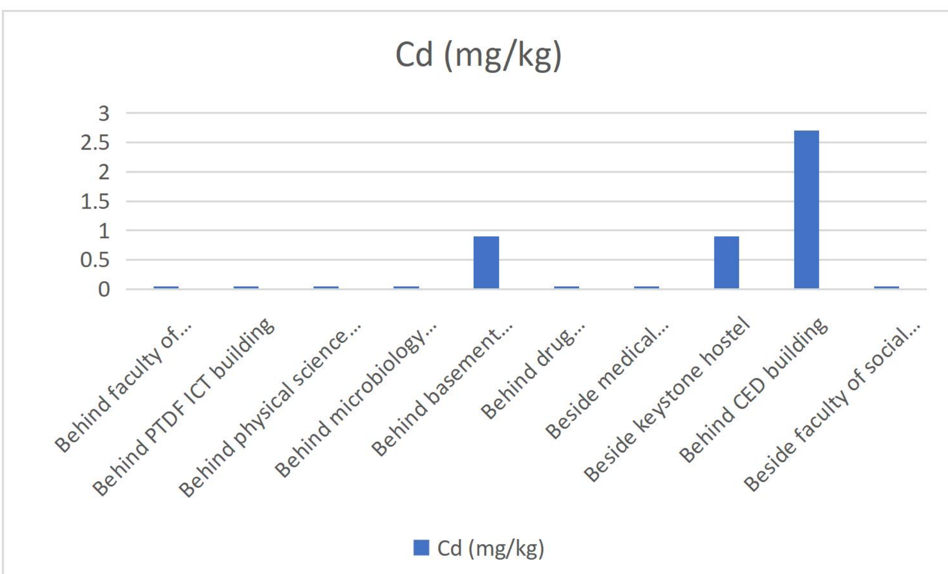

Fig. 4.3.2: A graphical representation of Cadmium

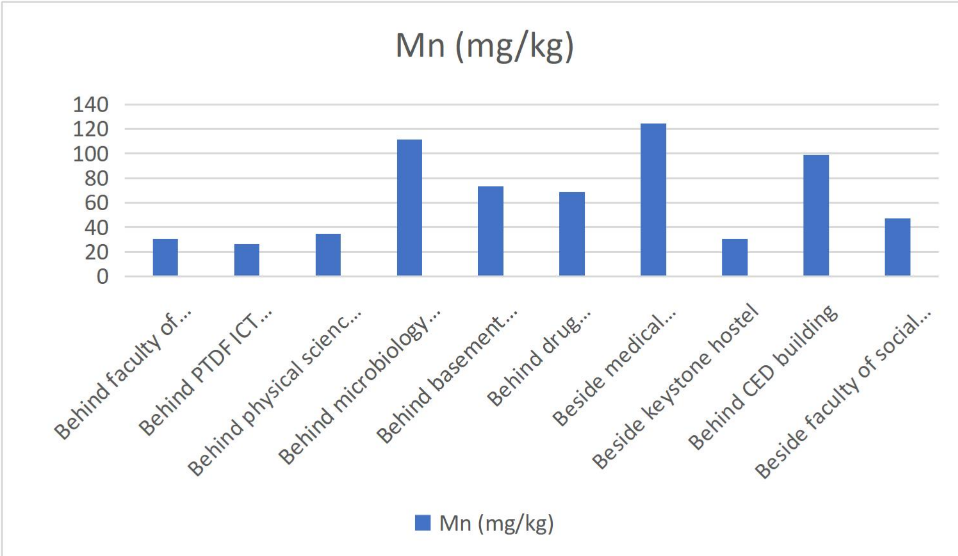

Fig. 4.3.3: A graphical representation of Manganese

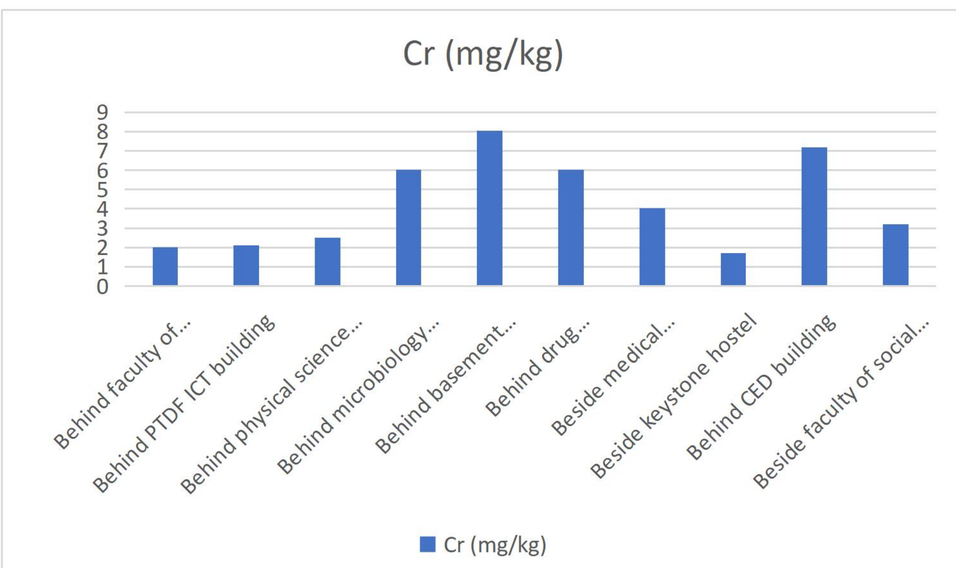

Fig. 4.3.4: A graphical representation of Chromium

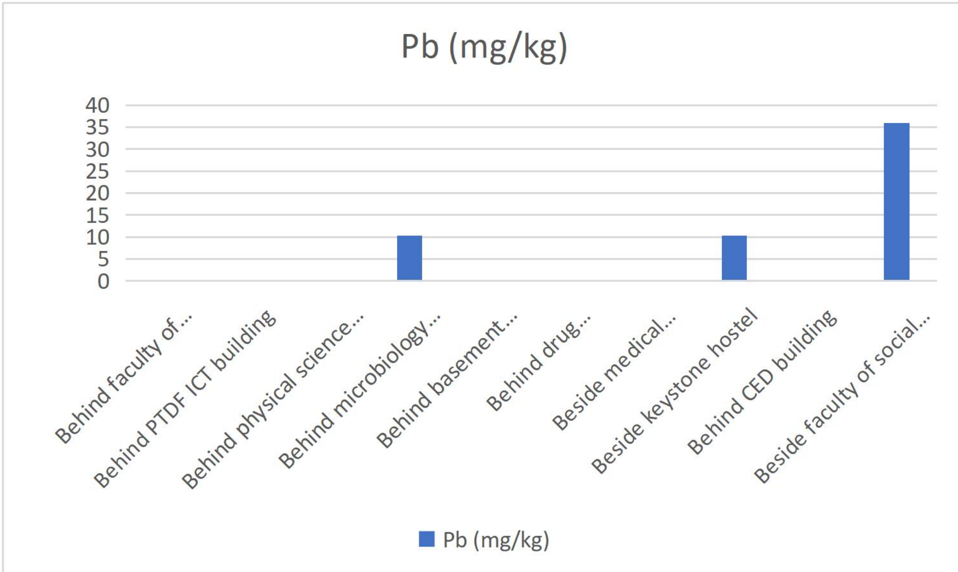

Fig. 4.3.5: A graphical representation of Lead

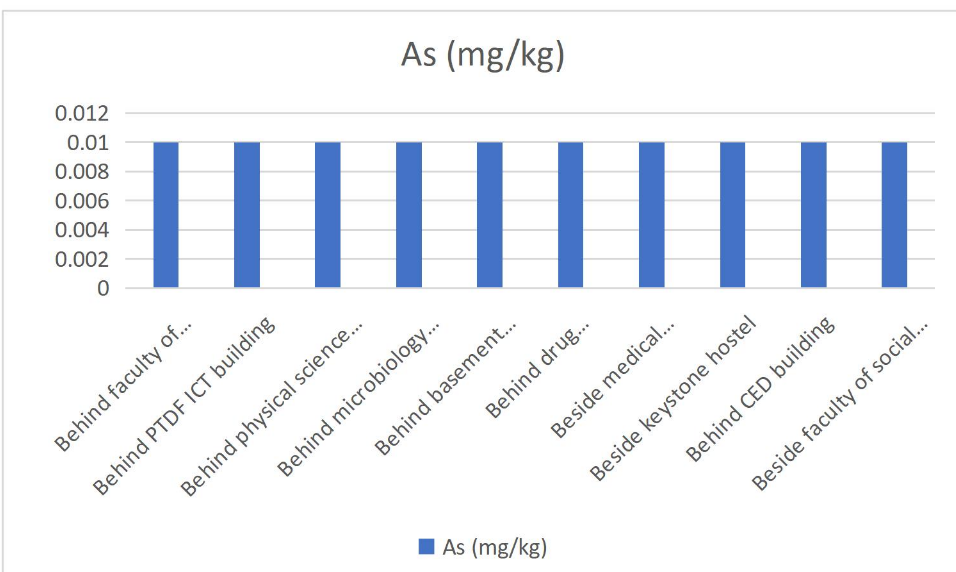

Fig. 4.3.6: A graphical representation of Arsenic

Table 4: Permissible limits for heavy metals

Metals	WHO (mg/kgl	FEPA (mg/kg)	US EPA (mg/kg)	EU (mg/kg)
Cadmium (Cd)	0.8	<1	0.48	3.0
Chromium (Cr)	100	0.20	11	100
Arsenic (As)	NA	0.1	0.11	100
Zinc (Zn)	50	NA	300	300
Manganese (Mn)	12	0.05	NA	NA
Lead (Pb)	85	0.05	200	300

Source: FEPA (1991), US EPA (2002) and EU (2002)

Plate 1: Waste dump beside UNIBEN table water

Plate 2: Waste dump behind faculty of law.

CHAPTER FIVE

5.0. DISCUSSION

Due to human activity, including but not limited to the combustion and cremation of metal ore, cadmium is present and remains in the environment Adriano (2001) and Cobb (2008). In each soil sample taken from refuse dumps 5, 8, and 9, the concentration of cadmium was found to be higher than the maximum permitted level established by WHO (1996), FEPA (1991), and US EPA (2002), which is 0.8 mg/kg, 1 mg/kg, and 0.48 mg/kg, respectively. The ten sampling locations had cadmium concentrations ranging from 0.05 to 2.70 mg/kg, with a mean of 0.49 $\pm$ 0.810 mg/kg.

Zinc (Zn) levels in the ten waste dumps, on the other hand, range from 4.30 to 97.80 mg/kg, with a mean of 22.09 $\pm$ 27.76 mg/kg. In waste dump 5, the zinc (Zn) concentration was higher than the 50 mg/kg upper acceptable limit established by WHO (1996). Zinc is essential for maximum plant growth and development as it is a component of several proteins and an enzyme cofactor (Broadley et al., 2007). However, Zn is phytotoxic at high soil concentrations, and plants that ingest it or deposit it through their roots endanger people's health (Bolan et al., 2014).

According to Jung et al. (2006), lead-chromium batteries, colored polythene bags, abandoned plastic products, and empty paint containers could all be sources of chromium in the soils. Chromium is a crucial micronutrient for both humans and animals (Bahijri and Mufti, 2002). However, when levels of chromium exceed a threshold level, it becomes toxic, mutagenic, and carcinogenic (Balamurugan et al., 2004; Han et al., 2004; Gili et al., 2002; Puzon et al., 2002; Wise et al., 2005 (Codd et al., 2003; Reddy et al., 2003; Sato et al., 2003). In chromium-contaminated areas, the effects on plants are just as severe as they are for humans, animals, and microbiological life. Reduced plant production and nutritional content toxicity are also seen because of chromium buildup (Pandney and Sharma, 2003; Klumpp et al., 2002). Taking in various kinds of Cr(vi) at relatively high concentrations might result in runny noses, sneezing, itching, nosebleeds, ulcers, and perforations in the nasal septum (Banerjee et al., 2003). Chromium can be accumulated by many microorganisms, including bacteria, algae, cyanobacteria, and protozoa (Dursun et al., 2003; Pas et al., 2004; Faisal and Hasnain, 2005). It is a difficult and contentious undertaking to create health-based clean-up standards and remediation techniques for chromium-contaminated soils based on the hexavalent forms of this heavy metal. It is important to first absorb this harmful Cr(vi) and then convert it into Cr(iii) to remove the toxic hexavalent chromium from the contaminated environment. Chromium concentrations in the ten examined sites are higher than the permitted limit, which is 0.20 mg/kg, according to the FEPA (1991) guideline. In the ten examined sites, chromium concentrations vary from 1.70 mg/kg to 8.05 mg/kg, with a mean of 4.28 mg/kg ± 2.23 mg/kg.

Lead (Pb) is primarily targeted at the brain, although it also damages other body organs and builds up over time. Children are the primary victims, according to WHO (2018). Many young children in Zamfara, Northern Nigeria, died from lead poisoning caused by lead-contaminated soil and dust from mining in 2010 and frequently in 2015. According to the World Health Organization, exposure to Pb during pregnancy increases the risk of birth defects and high blood pressure in both adults and children (2018). With a mean concentration of 5.66 mg/kg + 10.87 mg/kg, the range for lead concentration is 0.01 mg/kg to 35.90 mg/kg. The lead (Pb) threshold set by FEPA (1991) is 0.05 mg/kg, and it demonstrates that the concentration of lead in refuse dumps four, eight, and ten exceed the threshold.

With a mean and standard deviation of 64.5 ± 34.73 mg/kg, the concentration of Mn in the measured sites varies from 26.10 to 124.40 mg/kg. According to the WHO (2004) threshold for Mn and the FEPA (1991) threshold of 12 mg/kg and 0.05 mg/kg, respectively, Mn is far beyond the limit in the ten sampled sites. Mn2+, a form of manganese is rapidly absorbed by roots and accumulates in plant tissues. However, when concentrations are exceeded, it often becomes poisonous for the growth and development of plants (Yao et al., 2012).

CONCLUSION

The University of Benin and University of Benin Teaching Hospital created different forms of waste, and there was lack of characterization in the institution and hospital, which led to the high quantities of heavy metals discovered in the soil samples taken from the various refuse dumps.

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APPENDIX

Plate 3: Waste dump behind department of microbiology building.

Plate 4: Waste dump behind UNIBEN hydrogen peroxide production

Plate 5: Waste dump beside Keystone hostel

Plate 6: Waste dump beside medical laboratory science.

Plate 7: Waste dump behind PTDF ICT building

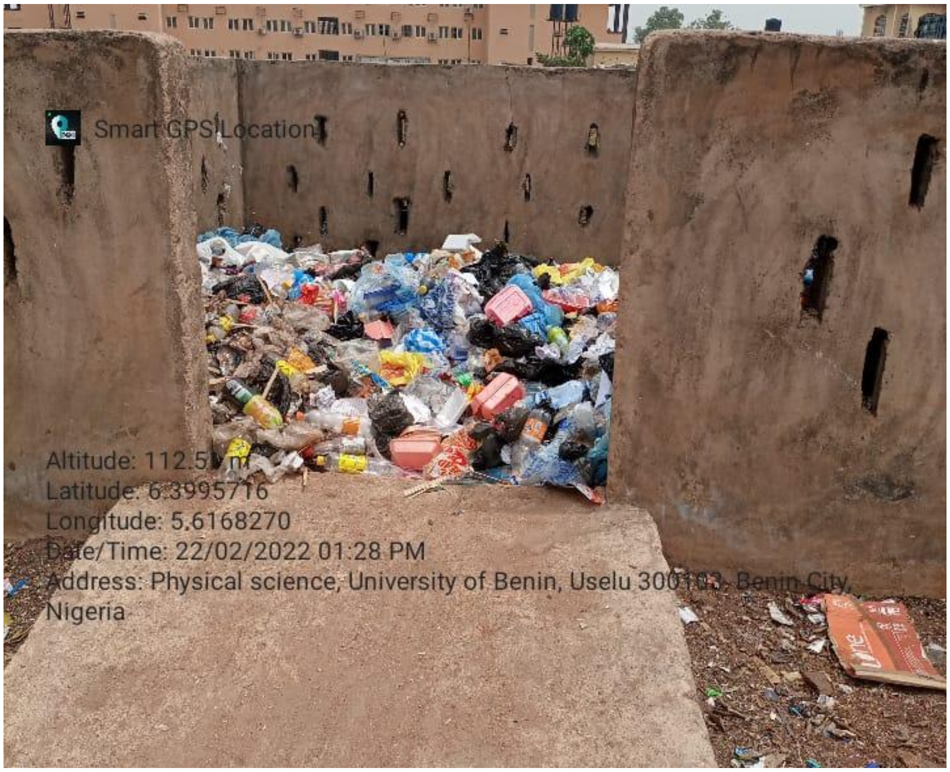

Plate 8: Waste dump behind physical science complex

Plate 9: Waste dump behind drug manufacturing laboratory

Plate 10: Waste dump behind faculty of social sciences

Table 4: Permissible limits for heavy metals

Metals	WHO (mg/kg)	FEPA (mg/kg)	US EPA (mg/kg)	EU (mg/kg)
Cadmium (Cd)	0.8	<1	0.48	3.0
Chromium (Cr)	100	0.20	11	100
Arsenic (As)	NA	0.1	0.11	100
Zinc (Zn)	50	NA	300	300
Manganese (Mn)	12	0.05	NA	NA

Lead (Pb)	85	0.05	200	300

Source: FEPA (1991), WHO (1996), US EPA (2002) and EU (2002)