CHAPTER ONE

INTRODUCTION

1.0 Background of the Study

The healthcare services delivery all over the world creates waste that may itself pose health challenges to health workers and communities in general. It has also been observed that healthcare waste all over the world, Nigeria inclusive have sharply increased in recent decades due to increased population, numbers and sizes of healthcare facilities as well as the use of disposal medical products, (Ajimotokan, 2012). The major issues related to the current hospital waste management are haphazard, improper and indiscriminate manner of waste disposal. Most hospitals in Enugu state do not segregate wastes which results to the incorrect method of waste disposal.

Hospital waste scattered in and around hospital environment invites flies, insects, rodents, cats and dogs that are responsible for spread of communicable diseases like plague, ebola and rabies and so on. Recent case in history is the Laser Fever. Moreover, some hospitals do not have mechanism to ensure that all wastes collected and segregated, reach their final destination without any pilferage, (Abor, 2012). Additional hazards include recycling of disposables without treatment and building of incinerators close to the hospital offices. Usage of same wheel barrow for transportation of all categories of waste is also a cause of infection spreading.

Despite the fact that current medical wastes management practices in Nigeria vary from hospital to hospital, the method of waste disposal and management are similar for all healthcare units and at all stages of management in Enugu State. The most authentic definition from World Health Organization (2006) characterized healthcare waste (HCW) as those wastes generated from hospitals, medical centers, healthcare establishments and research facilities in diagnosis, treatment, immunization and associated research. The major sources of HCW are hospitals, medical clinics, dispensaries, healthcare camps, medical and biomedical laboratories, medical research centers, mortuary and autopsy centers, animal research and hospitals, blood banks and so on.

The most commonly noted issues in appropriate healthcare waste management are often safe disposal of wastes, occupational health and safety for healthcare workers and illegal scavenging. Safe disposal of HCW consist of four key stages such as segregation, collection and storage, treatment, transport and safe disposal WHO (2008) where national legislation must be followed. Collection, storage and treatment of these wastes differ from each other. Incineration, disinfection, sterilization, plasma arc and landfilling have been adopted for the treatment of HCW in different parts of the hospitals in Enugu state, Nigeria. In most of the visited hospitals, infectious, pathological wastes and sharps are incinerated rarely with required air pollution control/open burned and the ash is disposed along with the municipal waste. Chemical liquid wastes are claimed to be collected and treated through the hospital effluent treatment system and disposed into municipal sewers in some of the visited hospitals. However, the efficiency of the treatment is uncertain. Pharmaceutical wastes including expired medicine are often left unattended. Among healthcare wastes, sharps are of major concern to all healthcare staff alike, doctors, nurses, midwifes, healthcare workers, recyclers and the community at large because according to the healthcare workers questioned, they are the most commonly wastes generated in larger quantity daily from the hospital.

When hospital wastes are disposed on unlined landfills, as observed from the National Orthopaedic and University of Nigeria Teaching Hospitals that were selected for this study, the wastes could lead to the contamination of groundwater and surface water particularly when large quantities are disposed. This can threaten the health of people who use the water for drinking, bathing and cooking. Such water can also damage plants and animals in the local ecosystem. Burning or incinerating healthcare wastes as a better option than disposal in an unlined pit, may create additional health problems. Burning or incineration of healthcare waste may produce toxic air pollutant such as nitrogen oxides (NOx), particulates, dioxins, and heavy metals are of particular concern (Abor, 2012). Dioxins believed to be potent cancer causing agents, do not biodegrade, and accumulate in progressively higher concentrations as they move up the food chain (WHO, 1999). Heavy metals such as mercury and cadmium are toxic and can cause birth defects in small quantities, and can also concentrate in the food chain, (Abor, 2012). Disposal of pressurized containers pose another hazard for incineration, as they can explode if burnt.

The health hazards due to improper healthcare waste disposal and management in Enugu could affect not only hospital occupants but also spread into the vicinity of hospitals which could lead to the contamination of vegetable grown around the dumpsite, water and soil. Vegetables for instance play an important role in human nutrition and health, particularly as sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals, and dietary fiber, (Long and Willams, 2006). Vegetables take up heavy metals and accumulate them in their edible and non-edible parts at quantities high enough to cause clinical problems to both animals and human beings. As an example, the consumption of contaminated food can seriously deplete some essential nutrients in the body causing a decrease of immunological defenses, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer (Oliver, 1997). Oliver further stressed that soil and vegetables contaminated with heavy metals in Copsa Mica and Baia Mare, Romania cities, significantly contributed to decreased human life expectancy (9-10 years) within the affected areas. Improper dumping can induce some chromosomal aberration in the body of living organism according to (Onwuemesi, 2012). Heavy metals, in general, are not biodegradable, have long biological half-lives, and have the potential for accumulation in different body organs, leading to unwanted side effects (Onwuemesi, 2012, Sathawara, Parikh, and Agarwal, 2004). Plants take up heavy metals by absorbing them from airborne deposits on the parts of the plants exposed to the air from the polluted environments as well as from contaminated soils through root systems. Also, the heavy metal contamination of fruit and vegetables may occur due to their irrigation with contaminated water

The general public's health can also be adversely affected by healthcare waste. Improper practices, such as dumping of medical waste in municipal dustbins, open spaces and water bodies, which are often the case in most cities in Nigeria, can lead to the spread of diseases. In most visited hospitals in Enugu state, there are often no systematic approaches to healthcare waste disposal especially in the two selected hospitals due to lack of policies.

From recognizant survey, it was observed that hospital waste were simply mixed with municipal waste in collecting bins at roadsides and disposed of similarly while some wastes are simply buried without any pre-treatment measure. The improper disposal of hospital waste causes serious environmental problems in terms of air, water and land pollution. Based on the above observations, this study was carried out in order to assess the level of pollution caused by improper disposal of hospitals waste in Enugu state, Nigeria so as to proffer solution on how best to overcome the issue of poor disposal of hospitals wastes.

1.2 Statement of the Research Problem

Enugu State has numerous healthcare service delivery including National Orthopaedic Hospital and University of Nigeria Teaching Hospital. These hospitals are health institutions that provide health care services while healthcare establishments look after the public health directly through patients care. It is also done by ensuring a clean, healthy environment for employees and community members. In other words, health care activities facilitate protecting the environment, curing patients and saving lives. However, in the course of their activities, wastes are generated, 20 percent of which expose humans to risk of infections, trauma, chemical or radiation exposure and sometimes death, (Abor, 2012).

The abundance of these hospitals and healthcare operators is an indication that there are huge generation of medical waste. However, Enugu State has two specialist hospitals and two teaching hospitals according to Enugu State Ministry of Health. Amongst these hospitals, National Orthopaedic Hospital and University of Nigeria Hospital were chosen for the study to be used in order to generate data for the entire hospitals. These hospitals generate waste that poses health challenges to healthcare workers and the communities in general. The types of waste generated in these hospitals are special wastes, including sharps, chemicals, genotoxic, pasteurized, pressurized, pathogenic and infectious wastes. A survey made to the two hospitals revealed careless, unhygienic and indiscriminate disposal of healthcare waste. At University of Nigeria Teaching Hospital Ituku/Ozalla, the waste dump were located very close to the Ufam river. The river according to the villagers cut across the whole town, and the same river serves as the source of domestic water to the entire community. At National Orthopaedic Hospital Enugu, wastes are disposed mainly by open dumping to the surrounding environment without segregation and pre-treatment. Medical waste comprises of diverse toxic components from human bodies and those used for diagnosis, (Zohre, 2011). This wastes can be a source of pollution to both humans and the natural environment.

Hospital wastes may be hazardous if it leads to contamination of water supplies or local sources used by nearby communities or wildlife such as Ufam river used by resident doctors at University of Nigeria Teaching Hospital Ituku/Ozalla and Ituku/Ozalla town located at University of Nigeria Teaching Hospital (figure 2b). The approach of open dumping shows lack of institutional regulatory system in the State. This was as a result of the absence of full compliance with the protocol for handling medical wastes as stipulated in the relevant sections of the guidelines and standards for environmental pollution control in Nigeria. Furthermore, there are no national guidelines, policy or legislation stipulated for hospital wastes management and the existing policy is still in draft form. This was buttressed by Abah and Ohiman, (2011) that there are problems of lack of management commitment, poor waste handling practices; inadequate training on hospital waste and non-existence of segregation of waste.

In addition, in the two studied hospitals, treatment facilities such as incinerator and autoclaves are not available and where they are available are not functional like that seen at University of Nigeria Teaching Hospital Ituku/Ozalla. Hence, this hospitals resort to open burning of the wastes generated from the hospitals which are below the recommended temperature for burning of hospital wastes by the World Health Organization. This was in line with a study carried out by Ngwuluka, Ochekpe, Odumosu and John, (2009) at Jos metropolis, Nigeria where they discovered that there was no evidence of segregation of non-hazardous waste from hazardous waste.

Furthermore, open dumping method attracts flies, insects, rodents, cats and dogs (plate 5.1 in appendix) that are responsible for transferring communicable diseases such as scabies, plague, ebola among others. Some domestic animals when allowed to graze in open hospital dumps, there is a risk of reintroducing pathogenic microorganisms into the food chain. Subsequently, the exposed waste may become accessible to scavengers and children if a landfill is insecure as the case of UNTH (plate 5.2 in appendix B). Windblown dusts from these dumps also have the potential to carrying pathogens and hazardous materials.

Medical wastes therefore pose a risk to individuals, communities, and the environment if not carefully and sustainably handled. As the waste ferments, it gives off foul odors, favors fly feeding and contaminates both surface and groundwater. When the waste is burnt, it contaminates the air and causes human health related diseases. Piles of refuse or landfill during its decomposition process generate several gases, the most important among which are methane (CH_4), nitrogen (N_2) and occasionally hydrogen sulfide (H_2S), World Bank, (1991). If burnt, carbon dioxide (CO_2) is released. CH_4 and CO_2 are greenhouse gases and have potential greenhouse effects. The soil underlying these wastes may be typically contaminated by pathogenic micro-organisms, heavy metals, salts, and chlorinated hydrocarbons. These wastes also cause public nuisance by blocking sewers and open drains, encroaching on roadways, diminishing landscape aesthetics and giving off unpleasant odour and dust (World Bank, 1991).

In line with the above, hospital waste are one of the largest sources of dioxin and mercury pollution especially the incineration. The ash contains high levels of toxic substances such as heavy metals, dioxins and furans. Ironically, as the air pollution equipment becomes more effective in removing particulate matter, the toxicity of the fly ash increases. In most cases, disposal of incinerator ash in landfills without a sufficient soil or other impermeable cover (non-cracked rock zone) may contaminate groundwater and well water as was observed at National Orthopaedic Hospital. Incineration has specific health concern since it does not only destroys the pathogen but also the material on which the pathogen resides. Thus, those materials go under a process of transformation and dematerialization. In the process they transform solid and liquid toxic waste into gaseous emissions and particulate matters. The acid gases (hydrogen chloride, nitrogen oxides and sulphur dioxides), can cause acute effects such as eyes and respiratory irritation, it can contribute to acid rain, and may enhance the toxic effects to heavy metals. Particulate matter can cause chronic health effects. Burning of chlorine made material e.g. PVC, creates dioxin, a known animal carcinogen, and considered as human carcinogen.

In view of the above review, there is need to identify the potential toxicants from disposed hospital waste that poses health challenges to the environment. Moreover, Pratibha; Nupur, Anuradha, Pradeep, Ruchika and Sogani, (2014), carried out a study on efficiency analysis of a hospital effluent treatment plant in reducing genotoxicity and cytotoxicity of hospital wastewaters in India using short term microbial bioassays, Ames test and saccharonmyces cerevisiae respiration inhibition assay. They show that in many developing countries including India, the major part of hospital wastewater is discharged in surface watercourses or in public sewers or percolates into underlying groundwater aquifers with no or only partial treatment.

Supporting the above, Long and William (2006) carried out a preliminary study of toxicological impact of medical waste in Ghana using empirical data and they found out that the medical waste practice in the studied hospitals indicated an absence of full compliance with the stated guideline for handling of medical waste and hence, the increase in incidence and cases of diseases associated with improper disposal of medical waste in the area. Sequel to the above, Bansal, Manoj, Ashok, Guatam, Praveen, Changulani, Richa, Srivastava, Dhiraj, Singh and Neeraj (2011) identified 73 injuries from needles and other sharp objects in a retrospective survey of all self-reported documents in Buraidah Central Hospital, Saudi Arabia. These injuries according to them was as a result of improper disposal of hospital waste without pre-treatment to the general waste collection centre in the area.

Consequently, in a study of occupational exposure to needle stick injuries and hepatitis B vaccination coverage among healthcare workers in Egypt, Mohankumar and Kottaiveeran (2011) reported that majority of the populace in the study area were exposed to at least 1 needle stick injury during the past 3 months with an estimated annual number of 4.9% needle stick injury per worker. Moreover, in a similar study in the United State, Joseph, Paul, Premkumar, Rabindranath, Paul, and Michael (2015) reported that the increase in health related diseases in the study area is a result of improper hospital waste disposal. According to them, the coverage level of vaccine against such diseases is still significantly low and hence need to be improved.

Supporting the above, studies conducted in Tanzania by Manyele, Anicetus and Bilia (2003); Manyele (2004b); Manyele and Anicetus, (2006) showed that medical waste management in Tanzania was poor and based on that, improper hospital waste disposal has led to many illness and diseases that claimed lives and disfigured many especially children between the ages of 0-5.

Moreover, Okunola and Olutayo, (2011) carried out a study on the toxicological effects of hospital wastewater using animal bioassays at Lagos state. The findings showed that the hospital wastewater is genotoxic and causes chromosome aberration and sperms with abnormal morphology with observed decrease in mean sperm count. Nwguluka, *et al*, (2009) assessed the management of healthcare wastes in six selected hospitals in Jos, Nigeria. They found out that method of wastes disposal and management in the area was substandard and below the recommended waste management practices as prescribed by World Health Organization (2006). Akmotokan and Aremu, (2012) examined healthcare wastes management challenges in hospitals within Ilorin of Kwara State. The found out that on daily basis, about 177.67kg of waste were generated and disposed openly without treatment. Okore *et al* (2009) also investigated the impact of disposal of hospital waste into Nworie River in Imo state, Nigeria. The results revealed that the disposal of untreated hospital wastes poses an environmental threat and public health risk.

Vivan, Blamah, Ezemokwe, and Okafor (2011) worked on public health implication of improper hospital waste disposal in Zonkwa district of Zangon-kataf Local Government Area, Kaduna state. They found out that the disposal of untreated hospital wastes poses an environmental threat and public health risk. They recommended therefore, an implementation of proper environmentally safe mode of disposing hospital wastes.

However, these studies and others have established that improper disposal of hospital waste can have adverse effects on the public healthcare and environment. This is an indication of the relevance of this timely study. As medical wastes can be complicated couple with human increasing population and spread of diverse diseases in recent times (example ebola, cancer and other epidemic that their diagnoses are still under scientific investigation) have equally escalated and promoted major studies on medical wastes management.

These studies, however, did not further include the toxicological impact of hospital waste using a living organism to indicate the consequences of human exposure to unstainable disposed medical wastes.

There is need to address to these glaring gaps in literature, in order, to include a timely, documented and comprehensive study. Hence, this study investigates the toxicological and health implications of improper hospital waste disposal with particular focus on Enugu state in South East Nigeria. It investigates the hydrodynamic dispersion of the solute (heavy metals) in soil and water of the study areas. The level of these toxicants on rat liver and kidney was also investigated. The study also ascertained the chromosomal aberration induced in the rat liver and kidney. Finally, the study determined the health implications of these wastes on human via vegetable consumption and to determine the level of interactions between the disposed waste and the impact on environment.

1.3 Aim and Objectives of the Study

The aim of this study is to evaluate the toxicological and health implications of improper hospital wastes disposal at the National Orthopaedic Hospital and University of Nigeria Teaching Hospital Ituku Ozalla in Enugu State with a view of establishing the relationship between improper disposal of hospital wastes and public health issues in the areas. To achieve this aim, the following specific objectives were pursued; to:

1. Investigate the physicochemical and bacteriological parameters of heavy metal contamination of hospital wastes on soil, water, vegetable and rats at different points.

2. Determine the hydrodynamic solute dispersion trend of the heavy metals in soil and water samples in the study area.

3. Evaluate the parasitological and bacteriological parameters of heavy metals on vegetable grown around the hospital waste dump.

4. Ascertain the toxicological impact of hospital wastes disposal on living animal (rat).

1.4 Research Questions

1. What are the physicochemical and bacteriological parameters of heavy metal contamination of hospital wastes at different points?

2 What are the hydrodynamic solute dispersion trend of the heavy metals in soil and water samples in the study area?

3 What are the parasitological and bacteriological parameters of heavy metals on vegetable grown around the hospital waste dump?

4 What are the toxicological impact of hospital wastes disposal on the rats liver and kidney?

1.5 Research Hypotheses

Ho: There is no significant interaction among the leachate, soil, plants and water of the study area.

Ho: The hydrodynamic solute dispersion trend of the heavy metals in soil and water samples in the study area do not significantly differ.

Ho: The parasitological and bacteriological parameters of heavy metals on vegetable grown around the hospital waste dump do not vary significantly.

Ho: the toxic waste has no significant negative effects on rats sampled within the hospital vicinity.

1.6 Research Justification/Rational for the Study

Healthcare services, in pursuing the goals of reducing health problems and eliminating potential human health risks, inevitably create waste that may itself pose health hazards. It has also been noted that healthcare wastes in Nigeria, particularly Enugu, have sharply increased in recent decades due to increased population, numbers and sizes of healthcare facilities as well as the use of disposable medical products (Uwa, 2012).

Toxicological and genotoxical testing of hospital wastes samples is important for human and environmental hazard evaluation. This study estimates the toxicological and genotoxicity impact of hospital wastes in order to provide the unfavorable health effects generated due to hospital waste disposal from two multi-specialty hospitals in Enugu. This can be achieved by the use of chromosomal aberration assessment of the hospital wastes by the use of standardized bioassays and physicochemical parameters. The proposed scenario allowed a quantitative risk characterization of hospital waste. Hence, this study created awareness to hospital discharging sectors to apply genotoxicity testing of liquid effluent routinely before disposal so that the necessity of setting up Effluent Treatment Plant (ETP) in hospitals.

Due to these concerns, this study was conducted in order to evaluate the toxicological impact of improper hospital wastes disposal in two hospitals in Enugu. This study provided information regarding the toxicity and genotoxicity of hospital wastes and its management in healthcare facilities and also generated interest in the systematic control effort for effective medical waste management. The findings helped to supplement and complement the existing knowledge on hospital waste management systems used in Enugu healthcare facilities. It is also hoped that the research may help the government departments, and local authorities to improve their existing waste management policies and planning measures in order to mitigate the likely impacts of ineffective hospital waste management methods.

1.7 Significance of the Study

The study is considered significant because of the following reasons;

a. Findings of this study will supplement and complement the existing knowledge on the hospital waste management system.
b. It will also provide an insight into the prevailing toxicological impact of hospital waste in the environment
c. The information and recommendations from the study will be used for effective management of hospital wastes in order to reduce the attendant risks to healthcare workers and the community at large.
d. The findings of this study will serve as a reference material for study researching similar topic in the future.
e. It will assist the government in beefing up a strong striker law guiding hospitals administrations towards disposal and management of hospital waste in a sustainable manner.
f. It will also provide useful information as a guide for monitoring of solute/pollutant dispersion on water and soil. This help to forecast the effect of solute in future if continuous disposal is maintained at a particular point over a period of time.

1.8 Scope/Delimitation of the Study

This study covers two major hospitals in Enugu State namely: National Orthopaedic hospital and University of Nigeria Teaching Hospital Enugu. These

Hospitals were chosen because they have large facilities, and they are among the well-known hospitals located in the Eastern part of the country.

The study area comprised several departments namely General Out-Patient Clinic, General Adult Out-Patient Clinic and Staff Clinic, Ophthalmology (wards; Ophthalmic Surgery and Community Ophthalmology), Internal Medicine (wards; Dermatology, Cardiology, Nephrology, Endocrinology, Gastroenterology, Respiratory Medicine, Neurology and Infectious Disease) Obstetrics and gynecology and the department of Surgery. The University of Nigeria Teaching Hospital Ituku/Ozalla is a multi-disciplinary tertiary hospital with several departments which are further subdivided into wards and units. Departments of interest and selected for this study are department of Obstetrics and Gynecology, Ophthalmology, Pediatrics, Physiotherapy, Radiotherapy and Oncology and Surgery department (units: General, Orthopedic, Neurosurgery and Spine). While National Orthopaedic Hospital is a specialist hospitals with several departments which were also further subdivided into wards and units. These departments were chosen because they generate huge quantities of wastes that are disposed into the environment on daily bases. Hence, it can give enough and useful data for the outcome of this investigation.

The study evaluates the method of hospital wastes generation from the selected hospital, it compared the method of the wastes disposal and management strategies used by each of the hospitals. Analysis of samples were conducted in order to test for the presence of heavy metals using rats, plant (vegetables), water from hospital discharging points and soil around the hospital waste so as to establish the health implication of the hospital wastes on the populace living within the hospital vicinity and in Enugu at large. Hydrodynamic dispersion of solute (heavy metals) in soil and water were conducted using Triple Vector Product Model to show the transportation of solute by advective fluid flowing through the solute point source to other areas within the study areas.

Moreover, water, vegetable and soil samples within and around the hospitals waste dump were analyzed for the presences of heavy metal while rats (liver and kidney) samples were analyzed for the estimation of the health implications of the hospitals waste on the population within the hospitals vicinity.

The study also covered the toxicity testing and genotoxicity testing, bioassay testing, physiochemical and bacteriological testing of each of the collected samples in order show the toxicity of the impact of improper disposal and management of biomedical wastes. Finally, the study was carried out in the two hospitals for a period of six (6) months from February to August, 2016, in order to ascertain the method of wastes disposal, quality of water, vegetable and soil of the hospitals and also to evaluate the toxicological impacts of the hospital waste using rat organs.

1.9 Limitations of the Study

This dissertation encountered some limitations during the process of data collection.

(1) There are about 366 healthcare centers, two teaching hospitals, two specialist hospitals, over 700 private hospitals and 36 cottage hospitals in Enugu State according to Enugu State Ministry of Health District Board (2016), but only 2 hospitals were used to generate quantitatively the data for the entire state.

(2) There are other possible sources of heavy metals in the state, such as host rock and anthropogenic activities, but in this study all these were kept silent.

(3) A study of this nature ought to spread to more than two years and two seasons, but in this study one season was used to generate data for the study because of the nature of data needed for the study.

1.10 Plan of the Study

This study has been planned into six chapters. Chapter one introduces the study. It treated the following: background of the study, statement of the problem, aim and objectives of the study, research questions, and research hypotheses, rational for the study, significance of the study, scope, limitations and definition of terms used in the study. Chapter two shows the review of relevant related literature to the topic of the study. It also discusses the theoretical/conceptual framework upon which the study was based. The chapter finally showed the identified gaps from the reviewed literature which the present study filled. Chapter three shows the study area where the study was carried out, it locations of the study area and sample collection, geology, climate condition, population of the area, socioeconomic activities in the area and physiographical characteristic of the study area. Then the chapter four deals with methodology used to collect data, the design used, data needs, population of the study, sample size, frame and techniques used for data collection, method of data analysis, validity and reliability of the instrument with statistical tools used to achieving the stated aim and objectives of the study and also the statistical tools used to test for the hypotheses of the study. Chapter five deals with the presentation of data and discussion of results. While chapter six summaries the entire findings of the study. The chapter also recommends the ameliorative measures for the control and treatment of the shortfalls found in the two hospitals and entire hospitals in the state. It also present the study's contribution to knowledge.

CHAPTER TWO

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.0 Theoretical Framework/conceptual framework of the Study

This section discusses the theoretical and conceptual framework on which the study was based. It is discussed under the concept of Impact Analysis Model/Health Impact Analysis.

2.1 Concept of Impact Analysis Model/Health Impact Analysis

The conceptual framework used in this study is the impact analysis model/Health Impact Analysis. Impact Analysis/Health Analysis Model that was developed by Chiras (1998) seems to summarised different ways by which the environment suffer when environmental pollution occur. In this study the model showed that human activities (healthcare service delivery) can have diverse impacts on various components of the environment (air, water, and land). It explains that any alteration of the biotic environment as a result of human activities via waste generation, collection, disposal and management can have adverse impact on the environment and the general public at large.

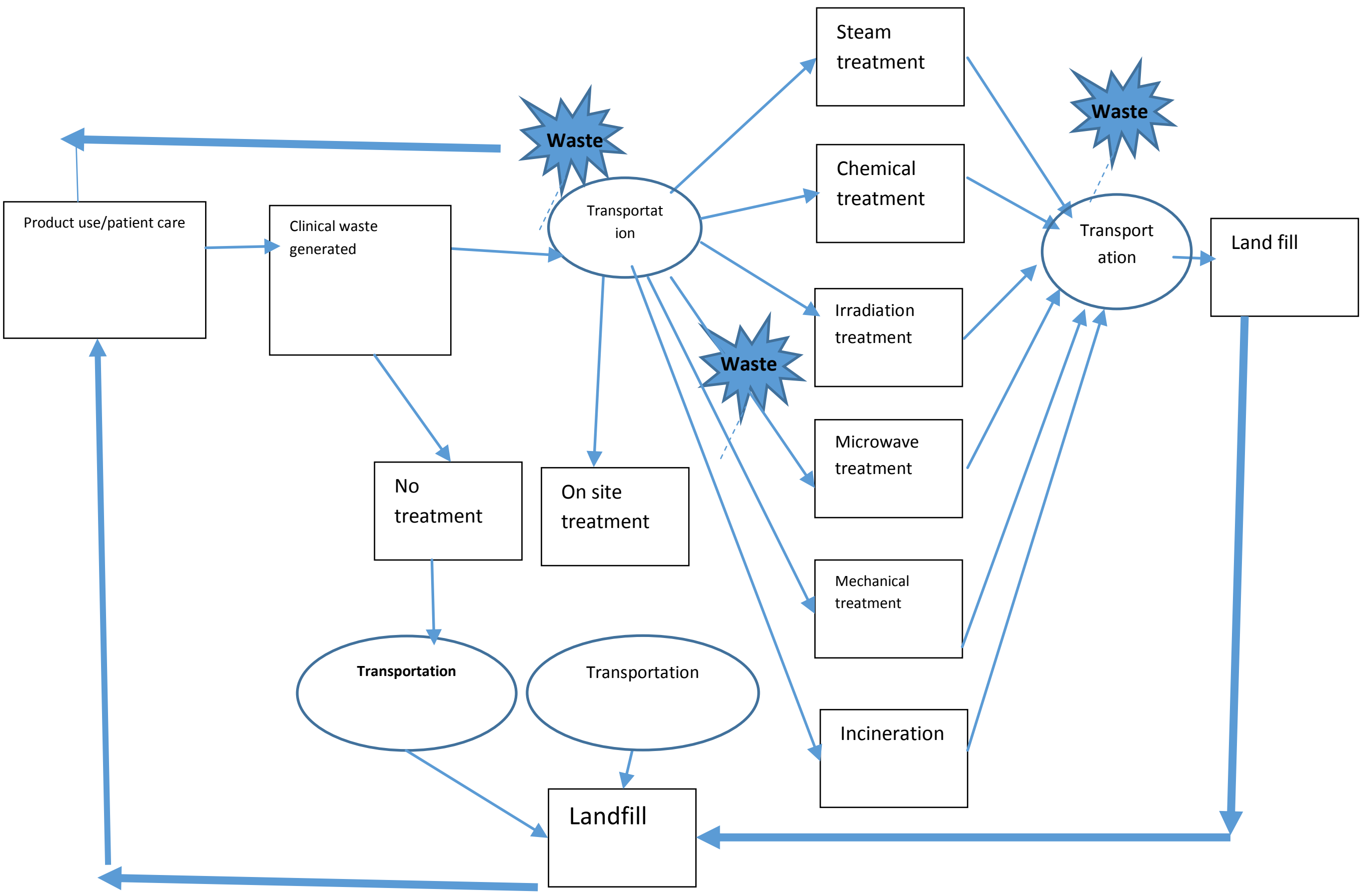


Fig. 2.1: Impact Analysis Model showing the waste cycle as modified by the researcher.
Source: Chiras, (1998).

Figure 2.1 shows impact analysis model which was used to explain the impact of waste on environment when disposed carelessly into the environment. The diagram emphasizes the fact that human activities (healthcare service delivery and waste generation) often alter the chemical and physical nature of the environment through illegal waste disposal. It shows that once one component of the environment is affected, it could spread to other components, thus affecting the whole environment. Many human activities such as healthcare delivery may produce pollutants that may change the chemical composition of the environment which may have adverse health effects on the ecosystem. From figure 2.1, waste are generated during diagnosis, treatment and immunization of animal and human beings. This waste could come from different departments in the hospital which include; laboratory, pharmaceutical, maternity, mortuary and dispensary department. Generally, hospital wastes contain some amount of pollutants which could constitute health hazard to the public if not properly disposed and managed. These pollutants can be generated from the chemicals used for diagnosis, human anatomical or surgical wastes, animal wastes, pathological wastes including tissues, organs, blood and body fluids, microbiological cultures, cotton, swabs, used syringes, I.V. tubes, blood bags and other items contaminated with blood and body fluids, items such as plaster, casts and bandages, when contaminated by blood and pus. According to research, wastes from isolation wards are the major sources of environmental pollution especially in places where they are not properly disposed and managed. It can also generally enter the aquatic environment (surface and groundwater) when carelessly disposed. The toxic contents of these hospital wastes can contaminant the water bodies, land and soil as the case may be. The progressive and irreversible accumulation of these toxic wastes in the various organs of freshwater organisms ultimately leads to metal-related problems in the long run because of their toxicity, thereby endangering the ecosystem and its dependents.

Healthcare operation may have adverse impact on the environment when it is not properly handled and managed. It is well established fact that recently, government makes provision of health facilities that is well-equipped and furnished with specialist but due to numerous emergence of private hospitals in the country now, these hospitals are been operated by unqualified medical consultant and practitioners. Most of them operate without government approval and as such their mode of operation, management and disposal of wastes are not properly monitored and hence they accelerated environmental pollution. These uncontrolled and unregulated wastes management and disposal by unapproved hospital and clinics may result in the generation of wastes and pollution of the environment which in turn may lead to distortion of the ecological balance.

These issues are aggravated by population explosion and urbanization in the urban areas giving rise to more wastes generation that encompasses the strength of government and its agencies in management of the generated wastes. As a result of this lack of law enforcement agencies in the country, hospital wastes generated from these hospitals are sometimes carelessness disposed into the environment resulting to increase health problems to the resident of such area as can be seen from the diagram. During medical treatment and diagnosis, huge quantity of wastes are generated, these generated wastes are simply dumped in the landfill system, some incinerated, buried or burnt without proper treatment and thus create environmental problems to ecosystem. Based on the above, this study deems it necessary to incorporate the impact analysis model in order to show the various pathways human being are exposure to improper hospital wastes disposal.

2.2 Literature Review

The review of the literature is done under the following: global perspectives of the hazardous medical wastes management, generation and disposal of medical wastes and health impacts of improper healthcare disposal and management.

2.3 Global perspectives of the hazardous hospital waste

Assessment of medical waste disposal methods in Jalingo Metropolis, Taraba State Nigeria was carried out by Oruonye (2012) using an inventory assessment of the waste generated in each of the sampled hospital/clinics in the study area. The type of waste generated was identified through direct observation and use of questionnaire. Three instruments, questionnaire administration, in-depth interview and participant observation strategy/discussion were adopted in his study. The result of the findings shows that there was no sanitation department or waste manager responsible for medical waste management in the private hospitals/clinics. Most of the medical waste handlers, particularly in the private hospitals/clinics do not have formal training in medical waste management techniques. The study showed that none of the health institutions surveyed treated its medical wastes before disposing it into the municipal dumpsites or otherwise. Waste management practices employed by the surveyed hospitals/clinics included disposing their waste through burying, burning and use of incinerator. From the findings, it was recommended that legislation should be adopted in all the hospitals in the state to help enforce standard practices in the handling of medical waste.

Supporting these, studies conducted in Tanzania by Manyele, Anicetus, Bilia(2003); Manyele, (2004b); Manyele and Anicetus (2006) regarding medical waste management showed that medical wastes management in Tanzania was poor and that the general awareness on issues related to medical waste management, is lacking among generators and handlers. Apart from the poor medical waste management practices reported in Tanzania, steps to combat the problems posed by poor management led to construction of 13 pilot small scale incinerators in various parts of the country, the situation which motivated the government to extend the small scale incinerators to all referral, regional and district hospitals. The study also showed that there is a serious inadequacy in handling medical solid wastes in the Dar es Salaam City due to poor control of wastes. As a result of lack of legislation according to the same author, hospital owners are not well inspected on how they handle and dispose the wastes they produce; as a result, hazardous wastes reach the dumpsite without notice.

Sequel to the above, Manyele, (2004b); Manyele and Anicetus (2006) reported that, data on waste generation in Dar es Salaam is inadequate, making it difficult to plan for an efficient medical waste management system in the area. Some of the healthcare facilities have been reported in the area dispose off the syringes in the pit latrines. When the syringes are not disposed-off properly by burning (destructive incineration) or burying, it could lead to diseases outbreak to the community.

In addition, poor management of healthcare waste exposes health workers and the public to the toxic effects of wastes generated from health establishments. According to Ngwuluka, Ochekpe, Odumosu and John (2009) the disposal of these wastes could also lead to environmental problems if not done properly. Ngwuluka, *et al* (2009) assessed the waste management practices in six hospitals at Jos and to compare same with international standards. The findings indicated that these hospitals fell below the recommended waste management practices as prescribed by World Health Organization and other regulatory authorities. From the findings, it was noticed that wastes were not segregated, and were inappropriately disposed. The health workers were unaware of relevant regulations and the existence of a hospital waste management policy. Based on the findings, the authors was able to recommend that there should be staff training to create awareness on wastes, their effects, importance of existing guidelines and the implementation of the waste management options for the different categories of wastes so that hospitals do not become infection centres that contribute to the damage of both the environment and human health.

Mohankumar and Kottaiveeran (2011) carried out a Hospital Waste Management and Environmental Problems in India using questionnaire and they found out that most countries of the world, especially the developing countries, are facing the grim situation arising out of environmental pollution due to pathological waste arising from increasing populations and the consequent rapid growth in the number of hospital units. In India, according to them, there are about 612 hospital beds, over 23,000 primary health centers, more than 15,000 small and private hospitals. It was also noted that in India, the Biomedical Waste (Management and Handling) Rules 1998 make it mandatory for hospitals, clinics, and other medical and veterinary institutes to dispose of bio medical wastes strictly according to the rules. The few studies on bio medical waste management from India have established that hospitals did not manage health care waste properly. The report also stated that hospital waste management sector market revenue (2008) is 8% of the total waste management revenue in India expected growth in next 5-6 years is around 20%.There are many institutions which pollute the environment but recently the ignored field which produce the pollution by way of hospital wastes and attracts the attention of the environmentalists are the hospitals, dispensaries, medical shops, medical clinics of doctors and other paramedical staff.

Supporting the above, Srivastav, Mahajan and Mathur (2012) conducted a study in order to evaluate the bio-medical waste management practices in a Government Medical College in Jhansi using questionnaires distributed to the hospital management. The result of the analysis showed that the collection and proper disposal of biomedical wastes in the state has become a significant concern for both the medical and the general community as improper management poses risks to the health care workers, waste handlers, patients, community in general and to the largely environment. From the study, the hospitals in the area although generates 0.52kgs waste per bed per day, the management is so easy because of the use of separate color coded bins in wards for collection of waste but segregation. Despite the colour code, the study recommends the need for safety measures to be taken by health care workers in order to maintain a safer environment.

Sequel to the above findings, Hossian, Hassan, Ahmed, Rahman, and Biswas (2013) investigated the Infectious Risk Assessment of Unsafe Handling Practices and Management of Clinical Solid Waste in Malaysia. This was done by collecting wastes from different wards/units in a healthcare facility in Penang Island, Malaysia. The presence of bacterial agents in clinical and general waste was determined using the conventional bacteria identification methods.

The assessment of healthcare waste management practices among healthcare workers in healthcare facilities of Gondar town was carried out by Azage, Gebrehiwot and MollaMesafint (2013) using a cross sectional descriptive method, a semi structured questionnaire and observational check list. From the assessment done 31.5% of the respondents had a health care waste management practices. Knowledge on types of healthcare waste and diseases transmission with healthcare waste and training were significantly associated with healthcare waste management practices of healthcare workers. Segregation of waste was not practiced in the surveyed healthcare facilities. None of the healthcare facilities had colored coded containers and healthcare waste management documents. The study finally conclude by showing that majority of healthcare workers did not practice healthcare wastes management. Hence, providing adequate numbers of waste bins, regular training and supervision on healthcare waste management are recommended to improve the problems of poor management of healthcare wastes.

In order to confirm if poor management of healthcare waste exposes health workers and the public to the toxic effects of wastes generated from health establishments Ngwuluka, *et al* (2009) carried out a study at Jos Metropolis, Nigeria in order to compare the result with World Health Organizaton Standard. The survey was carried out in six major hospitals in Jos metropolis. The findings indicated that these hospitals fell below the recommended waste management practices as prescribed by World Health Organization and other regulatory authorities. Wastes were not segregated, and were inappropriately disposed. The health workers were unaware of relevant regulations and the existence of a hospital waste management policy. Recommendations was made for staff training to create awareness on wastes, their effects, importance of existing guidelines and the implementation of the waste management options for the different categories of wastes so that hospitals do not become infection centres that contribute to the damage of both the environment and human health.

Supporting the above, healthcare wastes hold higher priority due to their hazardous nature was observed by World Health Organization (WHO, 2007). According to the report, healthcare wastes are considered most hazardous and can affect human health and pollute the environment badly. Supporting their report, Johannessen, Dijkman, Bartone, Hanrahan, Boyer and Chandra (2000), Sawalem, Selic, Herbell (2009) and Pruss, Giroult and Rushbrook (1999) noted that a working environment that have unsafe health care waste management practices may result to an exposure to infectious wastes by Healthcare workers (HCWs), patients, clients that could in turn create infection due to blood borne pathogens contained in the generated wastes.

In addition, poor medical waste management (MWM) practices and its risks to human health and the environment was reviewed by Babanyara (2013) and he found out that the waste generated from medical activities can be hazardous, toxic and even lethal because of their high potential for diseases transmission. The hazardous and toxic parts of waste from healthcare establishments comprising infectious, medical and radioactive material as well as sharps constitute a grave risks to mankind and the environment. The researcher therefore recommend that the wastes should be properly treated and disposed or not allowed to be mixed with other municipal waste because it will increase the toxicity of the wastes to the environment and causes hazards to the people living around the hospital premises.

In line with the above, a study on evaluation of medical waste management systems was conducted in the low-level health facilities (LLHFs) in Dar es Salaam by Manyele and Lyasenga (2010) using questionnaires, interviews, visits and observation as a methodology. Two hospitals were compared at Ilala and Kinondoni municipalities of Dar es Salaam. The study revealed that most of the facilities have no specific disposal sites. In Ilala for instance, he found out that about 70% of the health facilities burn wastes in poorly designed incinerators, open pit burning or on the ground while in Kinondoni, 83% of the facilities bury wastes in the pits. More than 50% of the disposal sites surveyed are not fenced and were in close proximity to human settlements. About 60 and 70% of incinerators in the surveyed facilities in Ilala and Kinondoni municipalities, respectively, are not in good working conditions, 50% of them being of low capacity with some parts missing, chimneys, ash pits, covers for waste loading and ash removing doors. Also, 9 and 47% of the healthcare facilities in Ilala and Kinondoni, respectively, do not have the Standard Operating Procedures.

Moreover, medical waste transportation is a serious problem, as 71% of the facilities in Kinondoni carry the wastes on hands to the disposal sites while in Ilala, 40% of LLHFs use wheelbarrows. Waste segregation and colour coding are poorly adhered to while most of the storage areas are too small. It was concluded and recommended that, the medical waste management in LLHFs is still poor. Awareness should be raised among LLHFs workers on proper management of the medical wastes.

Sequel to the above, improper disposal of medical waste could expose the hospital to significant penalties, including fines and the suspension of services. According to Manyele and Lyasenga (2010), Yale-New Haven Hospital and Yale University was assessed and found out that during handling of wastes, the medical and ancillary staff as well as the sanitary laborers can be injured if the waste has not been packed safely. In that respect, sharps are considered to be the most dangerous category of waste. Many injuries occur because syringe, needles or other sharps have not been collected in safety boxes or because these have been overfilled. On dumpsites, scavengers may also come in contact with infectious waste if not properly treated or disposed of.

Ajimotokan and Aremu (2012) examined health-care waste (HCW) management challenges in hospitals within Ilorin metropolis of Kwara State, Nigeria using questionnaire. The result of the finding showed that about 177.67kg of wastes was found to be generated daily and the average waste generated per bed per day was 1.56kg. The management of these wastes is often poor, with a mixture of potentially infectious and non-infectious wastes being a common sight in hospital waste bins and hospital environment. According to them, the method of waste disposal in the study area is by open burning at Ita-Amo or Asa dam dumpsite. The results also showed that the approach is hazardous and constitutes environmental threats, increased vulnerability to potential transmission of communicable diseases and natural disasters. They recommended that treatment facility coupled with environmentally friendly recycling and recovery options are the most single effective environmental measure necessary for HCW management.

Okore; Mbanefo,Onyekwere, Onyewenjo, Ozurumba, Nwaehiri and Nwagwu (2009) investigated the impact of disposal of hospital waste into Nworie River in Imo State Nigeria using experimental techniques. The study evaluated the presence of pathogenic microorganisms influenced by improper hospital wastes disposal into Nworie River. The study results revealed that the disposal of untreated hospital wastes poses an environmental threat and public health risk. Indiscriminate disposal of untreated hospital wastes is often the cause of the spread of several infectious diseases. Standard biochemical tests were carried out to confirm the presence of the bacterial isolates. The bacteria and fungi isolated include *Salmonella* spp, *Shigella*spp, *Escherichia coli, Vibrio cholera, Enterobacter*spp, *Klebsiella*spp, *Bacillus* spp, *Vibrio parahaemolyticus, Aspergillus*spp, *Peniculllium*spp, *Sporothrixschenckii, Phycomycetes*spp and *Fusarium*spp.

The analyzed water samples revealed that there was higher microbial population in sample A (point of discharge) than the other samples. The statistical analysis showed that there is a significant difference in the counts at the different sampling points. This is as a result of prolonged disposal of the hospital wastes into Nworie River. *Escherichia coli* was found to have the highest percentages occurrence and present in all the samples. Based on the above findings, the study therefore recommended a study to determine the extent of pollution so as to monitor likely health dangers, not only to the human population but also to the aquatic life. From the research result, it is recommended that to reduce the burden of diseases, healthcare hospital wastes need sound management, including alternatives to incineration. Also, re-orientation of political leaders, inspectors, environmental health officers and the general populace to ensure better public health.

Supporting the above, Zohre (2011) carried out a survey to find out the medical waste production at Obstetrics and Gynecology hospital in South of Iran using qualitative method. From the findings it was shown that medical waste management is an important public. The result showed that one of the first critical steps in the process of developing a reliable waste management plan requires a comprehensive understanding of the quantities and qualities wastes that needs to be managed. The 126 samples analysed for the study showed that hospital wastes generation rate at the area was 196.478 kg per day, which beyond the ranging 0.2-0.25 of total waste. It was also noted that none of the hospitals in the study area segregate their wastes but simply dump it in general municipals waste bin thereby increasing the risk of infection to the general public especially those living very close to the hospitals.

In line with the above, Abah and Ohimain (2008)investigated the healthcare waste management at a tertiary health facility (Teaching Hospital) in

Nigeria with the aim of assessing the current practices and commitment to sustainable HCW management in a tertiary healthcare facility. The study approach involved the estimation of the quantity of HCW generated, evaluation of the waste segregation practices and determination of the knowledge of healthcare workers regarding HCW management. Daily waste inventory of each ward was carried out. An evaluation of the status of the waste management practice in the health facility was carried out using the following criteria: waste management (responsibility, segregation, storage and packaging); waste transport; waste recycling and reuse; waste treatment and final disposal. Results show that the average amount of HCW was 0.62 kg/person/day at the out - patient units and 0.81 kg/bed/day in the inpatient wards. The proportion of respondents who had received specific training in the management of HCW was 11.5% (6/52).

The number who understood the importance of HCW management in the provision of safety to the public was 46% (24/52). The level of healthcare waste management practice was found to be 0 (that is, unsustainable). The paper has highlighted the pitfalls of HCW management in Nigeria, a developing country where resources are limited. It then concluded by recommending measures to improve the HCW management practices in the country which includes proper disposal techniques, incineration method, segregation of wastes at point source and provision of strong legislation.

Sequel to the above, a survey by Suwannee (2002) was carried out to review medical waste management in Phitsanulok province, Thailand in order to improve waste management. The objective of study was to classify the characteristics of waste and create the implementation structures at hospital. The result showed that the average daily waste generated from hospital and clinics where beyond the hospital management alone and therefore need extra hand by government. The result also showed that numerous factors such as type of hospital, specialization, proportion of reusable items, and waste management plan were among the hindrances in effective hospital waste management in the study area. It therefore recommends joint effort of government, NGOs and individual effort toward the management of the wastes in the study area. In line with the above, Askarian, Vakiliaand Kabirb (2006) conducted a survey on management and disposal of clinical waste in private hospitals in Fars province, Iran.

The study looked at the amount of different kinds of waste produced at hospitals was determined and a relationship between the weight of the waste generated and several factors such as number of bed, economic, social and cultural status of the patients and the general condition of the area where the hospital was situated. The result showed that the above factors affect the management of hospital generated wastes in the study area. But the results did not confirm a statistically significant correlation between types of health services provided but recommended a further investigation the find the relationship using statistical method.

Supporting the above, Aylward, Lloyd and Zaffran (2004) used mathematical-statistical models to predict quantity of waste generated at hospitals in Irbid, Jordan. The generation rates were evaluated on the basis of kilogram per patient/per day and kilogram per bed/per day. In their model, they observed that the significant factors including the number of patients, number of beds and type of hospital affect on weight of generated waste. They showed that there is a linear relationship between the waste quantities and number of beds occupied.

Sequel to the above, Halbwachs (2006) determined hazardous and nonhazardous waste generation rates at two public hospitals in Kuwait. Some important factors such as the number of patients, number of beds and the type of activity were identified in relation to the generation rates. The results indicated that the calculation of generation rates based on number of patients was more applicable than the number of beds. Consequently, Abdulla, Qdais, and Rabi (2001) evaluated CWM practices in the south of Brazil and reported the amount of medical waste depend upon several factor such as the type of healthcare facility, status, capacity, level of instrumentation, and location of the facility.

A study was conducted by Alhumoud and Alhumoud (2007) to determine the amount of different kinds of solid hospital wastes and assess the obstacles in the existing hospital's solid waste management system in government hospitals of Kuwait. The findings showed that the waste generation rates depend on several factors such as established waste management methods, type of health-care establishment, hospital specializations, proportion of reusable items employed in health care and proportion of patients treated on a day-care basis.

In line with the above, Blackman (1996) conducted a survey on all existing methods for handling and management of medical waste disposal. In the study, statistical methods were used to develop mathematical models for prediction of hospital waste quantities. Moreover, important factors including the number of patients, number of beds, and hospital type which are effective in waste management were investigated. Their study provided tools for better medical waste management. Supporting the above, Muhlich, Morselli, Passarini, and Bartoli (2003) provided a review of management of hazardous waste production in Croatia. They mentioned that the quantity of clinical waste generation depends on the size and the type of healthcare institution, but also based on national income and level of development, it differs from country to country.

Moreover, Katoch and Kumar (2008) presented a technique to develop mathematical model in biomedical waste generation in three major hospitals in Shimla town, India. Their proposed model correlated the waste generation rate as function of bed occupancy and type of ailment in terms of seasonal changes. They stated that biomedical waste quantities depend upon the number of patients and the nature of illnesses of patients in different seasons. Different trends in waste generation rate and bed occupancy were observed during the research period. In addition, due to the similar seasonal illnesses pattern and social factors, a fixed seasonal variation was observed in biomedical waste generation rate. Again, Taghipour and Mosaferi (2009) argued that the availability of sufficient information about the amount and composition of the waste generated are fundamental prerequisites for the implementation of CWM. Study determined the characteristics of medical waste such as quantity, quality, composition and medical waste generation rate at different hospitals. The results showed the effect of many factors such as medical waste management methods, type of hospital (i.e., governmental, educational, university, private, NGO and military), type of specializations, ratio of reusable items, the general condition of the place where the hospital is located, number of patents per day and their economic, social and cultural conditions in generation rate among hospitals.

Sequel to the above, Yoseph (2009), carried out a survey of medical waste management status at Nanjing, China to evaluate the medical waste management aspects in selected hospitals. Moreover, the medical waste generation rate was calculated in order to improve waste management practices. Again, several factors such as hospital size, hospital location, beds occupancy percentage, medical waste segregation program, type of hospital and type of services were investigated in order to calculate medical waste generation rate. The result showed that the above factors affect the effective management of hospital generated wastes in the study area and therefore should be considered when promulgating laws guiding the establishment of hospitals.

In line with the above, Elijah (2002), investigated the quantities of generated medical waste and the factors associated with the generation rate in Taiwan. The study looked at the medical waste generation rate with the potential associated factors such as the types of hospital, number of beds, bed occupancy, reimbursement payment, number of infectious disease beds and outpatients per day. Multiple variable regression analysis was applied to predict the factors associated with waste generation. The results demonstrated that two insurance reimbursement and number of beds were the significant medical waste prediction factors in medical establishments with the multivariate regression model. It is suggested that large hospitals are the major source of medical waste in Taiwan.

Furthermore, Sawalem, Selic and Herbell (2009) conducted a survey to evaluate hospital waste management in Libya. The study found that several factors such as the type of healthcare establishment, level of instrumentation and location affect waste generation rates. The result showed that the highest generation rates at Tripoli Medical Centre are attributed to larger number of patients due to being in the capital of Libya. Supporting the above, Azage, Gebrehiwot and Molla (2012) evaluated waste management system and assessed the rate of waste generation at ten public health centres in West Gojjam Zone, Amhara Region, Ethiopia using a cross-sectional method to estimate waste generation rate. From the study it was reported that numerous factors such as established methods of waste management, type of healthcare establishment, degree of healthcare facility specializations, reusable items employed in health care, seasonal variation and patient work load effect on characteristics of waste generation. It is concluded that the unit generation rate was relatively lower than similar health facilities in developing countries.

Sequel to the above, Sanida (2010), investigated the amounts of infectious medical waste generated daily and average generation indexes in relation to several parameters factors at public hospital in Central Macedonia, Greece using questionnaire. The parameters were number of beds, type of hospital, bed coverage and the difference in hospital divisions and wards and the number of operations and laboratory test performed. The provided tools for estimating waste quantities are useful for medical waste management. The result showed that several factors as such mentioned above affects the management of hospital wastes.

A research was conducted in Malaysia to evaluate the management of clinical waste and its obstacles in Selangor ‘hospital by Razali and Ishak (2010). In the results, it was mentioned that the quantity of clinical waste depends upon the hospital size, the segregation program and the medical activities. Kagonji and Manyele (2011) carried out statistical methods to measure and analyze clinical waste generation rate at Amana hospital and Ligula hospital in Tanzanian. They have described that the generation rates depend on number of factors such as the number of patients, number of beds and the type of activity in different sections. The study indicated the daily medical waste generation rates were not consistent at the two studied hospitals.

The high fluctuation in pathological waste can be related to large number and type of surgical procedures conducted on specific day and the fluctuations in infectious waste could be related to large number of in-patients admissions. Comparison of the range of medical waste generations over a period of time between these two hospitals revealed that Amana hospital had higher range compared to Ligula hospital. The high range in Amana can be attributed to its nature of location in the big city. Therefore, the location of a hospital can be another factor in waste generation rate. The study also measured the amount of waste based on generation rate per bed. Two hospitals had fewer beds and this caused high waste generation rate per bed/day. Therefore, waste generation rate based on number of patient is more applicable than the number of beds.

Komilis and Katsafaros (2011) investigated the potential correlation between the various hospital parameters such as the number of examinees, the number of patients that occupied beds and the number of tests performed daily and the hazardous medical waste generation rates at the General Hospital of Ikaria. The result based on statistical correlations showed that the selected hospital parameters were statistically significant predictor of medical waste generation rate. In line with the above, Eker and Bilgili (2011) determined waste was generated from healthcare services (private hospitals, state hospitals, and university hospitals) in Istanbul, Turkey.

Statistical analysis was performed to evaluate the relationship between the amount of waste (medical waste materials, sharps, liquid waste and recyclables) and the bed capacities, inpatient and outpatient numbers. It was concluded that except for recyclable and hazardous waste, evaluation of waste generation in accordance with the bed capacity is reasonable. The results indicated that only the amount of sharps and medical waste can be evaluated using number of inpatients. Moreover, the evaluation of waste stream on the basis of number of outpatients was more applicable than other evaluation method because it did not show any reasonable change according to services categories.

Supporting the above, the hazardous medical waste unit generation rate was calculated by Komilis and Katsafaros (2011) in different categories of health-care facilities including public and private and seven sub-categories in Greece based on the quantities of the wastes that were regularly transferred to the specific incinerator. Results revealed that there is variance in the weights of medical waste even among hospitals of the same categories. The reason of this variance may be attributed to other parameters in medical waste generation. For example, in the public hospitals, medical waste generation rate is correlated positively with number of beds. Therefore, the number of beds is the prediction factor in medical waste generation rate.

Khalaf (2012) carried out a study to analyze and evaluate the present status of medical waste management in the light of medical waste control regulations recommended by the WHO in Jenin district using questionnaire. The results indicated that the average hazardous healthcare waste generation rate ranges from 0.54 to 1.82 kg/bed/day with a weighted average of 0.78 kg/bed /day. There was no waste segregation of various types of healthcare wastes in all hospitals. All hospitals still use some of the unqualified staff for medical waste collection, and all of the hospitals do not have temporary storage areas. Additionally, 67.9% of cleaning personnel at the three hospitals have reported that they received training about healthcare waste handling; however, none of the hospitals have ongoing training and education. It was found that healthcare waste is finally disposed in a centralized sanitary landfill (Zahrat al Finjan) that has been constructed for domestic solid waste disposal and is not specialized for healthcare waste disposal. The management of Medical waste in Palestine was not given the proper attention. Still there are lacks of legislation and defined policy regarding this issue. The entire Medical waste generated is dumped within general waste. The results also suggested that there is need for sustained cooperation among all key actors (government, hospitals and waste managers) in implementing a safe and reliable medical waste management strategy, not only in legislation and policy formation but also particularly in its monitoring and enforcement.

This according to him can be achieved through the cooperation between the Ministry of Health, Environmental Quality Authority, Ministry of Local Government, and Non-Governmental Organizations working in related fields. Additional remediation measures are proposed to tackle the problematic areas of medical waste management in Jenin district hospitals by proposing some recommendations that will ensure that potential health and environmental risks of medical waste are minimized.

Abor (2012) examined the medical waste management practices of a hospital in Southern Africa using questionnaire. The results revealed that the hospital does not quantify medical waste. Segregation of medical wastes into infectious medical waste and non-infectious medical waste is not conducted according to definite rules and standards. Separation of medical waste and municipal waste is however practiced to a satisfactory extent. Wheeled trolleys are used for on-site transportation of waste from the points of production to the temporary storage area. Staff responsible for collecting medical waste use almost completes personal protective equipment. Offsite transportation of the hospital waste is undertaken by a private waste management company. Small pickups are mainly used to transport waste daily to an off-site area for treatment and disposal. The main treatment method used in the final disposal of infectious waste is incineration. Noninfectious waste is disposed off using land disposal method.

The study also showed that the hospital does not have a policy and plan in place for managing medical waste. There are a number of problems the hospital faces in terms of medical waste management, including; lack of necessary rules, regulations and instructions on the different aspects of collections and disposal of waste, failure to quantify the waste generated in reliable records, lack of use of coloured bags by limiting the bags to only one colour for all waste, the absence of a dedicated waste manager, and no committee responsible for monitoring the management of medical waste. The study finally recommend the use of appropriate means of wastes disposal designed by WHO, (2007) and separation of wastes at point source and treatment in order to reduce spread of infection.

2.4 Generation and Disposal of Healthcare Waste globally

In order to assess the generation and disposal of medical care wastes generated from different countries, several literatures were reviewed and from the reviewed it was observed that the rate of generation of wastes varies from hospital to hospital depending on so many factors.

Stanley, Okpara, Chukwujekwu, Agbozu and Nyenke (2011) carried out a survey to assess the practice of disposing of wastes from the eight dental clinics of Obafemi Awolowo University Teaching Complex, Ile-Ife, Nigeria using questionnaire and survey method. Both the soil and water samples collected for the study were analyzed for chemical properties. From the analyses, the soil and water samples showed a very high content of lead, chromium, mercury, cadmium and manganese in both soil and water samples in comparison with the Nigerian Federal Environmental Protection Agency standards. The study concludes that the use of tooth-coloured restorative materials and digital X-ray facility to serve as alternatives to the generation of these wastes is recommended and that farming activities should not be allowed in the area until an audit of the soil and water have been performed.

To confirm the above, Ogbonna (2011) carried out an investigation to ascertain the characteristics and waste management practices of medical wastes in healthcare institutions in Port Harcourt, Nigeria using questionnaires administered to the hospital staff. From the results, it was noticed that the average waste types generated in the three categories of hospitals for both hazardous and non-hazardous wastes were in the order of 17.66, 7.89 and 2.36 kg/day for large, medium and small hospitals respectively. The percentage waste generation for the large hospitals show that 41% of the waste type are hazardous, 33% are non-hazardous while in the medium size hospitals showed that 35% of the waste generated are hazardous and non- hazardous had 35% and the small scale hospitals had combined waste types as the dominant waste type with 51% followed by non-hazardous with 31% and hazardous had the least with 18% of waste types. Solid waste disposal method adopted by the health institutions showed that open dumpsites are most preferred to other disposal methods while liquid wastes are mostly disposed of by flushing through drains/sinks. However, disposal of solid waste by incineration is recommended except for the environmental problems which have a tendency to pollute the sub-soil and groundwater due to their leaching as well as the health risks it pose to the general public.

In line with the above, health implication associated with incinerating hospital wastes was investigated by (Agnieszka and Edeltrauda, 2010).They assessed the degree of environmental effect of the secondary solid waste generated during the incineration process of medical waste by analyzing the air emissions and leaching from the incinerator. The obtained results allowed that although the hospital waste incineration plant significantly solves the problems of medical waste treatment in Krakow but the generated ashes and slag contained considerable concentrations of heavy metals, mainly zinc, and chloride and sulfate anions. Ashes and slag constituted 10–15% of the mass of incinerated wastes which is more harmful for the environment when compared with untreated wastes. They therefore, suggest that wastes should be treated before disposing.

Furthermore, Obekpa and Ohimain (2011) carried out a thorough and critical investigation of health care wastes generated in some hospital in Nigeria using cross sectional descriptive method. The study was carried out between June and September 2008 at a tertiary health facility (Teaching Hospital) in Nigeria with the aim of assessing the current practices and commitment to sustainable HCW management in a tertiary healthcare facility. The study approach involved the estimation of the quantity of HCW generated, evaluation of the waste segregation practices and determination of the knowledge of healthcare workers regarding HCW management. In doing this, the daily waste inventory of each ward was assessed. A total of 52 health workers, including doctors and nurses were interviewed to determine their knowledge and practice with regards to HCW. The results showed that the average amount of HCW generation rate was 0.62 kg/person/day at the out -patient units and 0.81 kg/bed/day in the inpatient wards. The proportion of respondents who had received specific training in the management of HCW was 11.5% (6/52). The number who understood the importance of HCW management in the provision of safety to the public was 46% (24/52). The level of healthcare waste management practice was found to be 0 (that is, unsustainable). From the result of the analysis, the pitfalls of HCW management in Nigeria were highlighted. It was therefore, concluded by recommending measures to improve the HCW management practices in the country which include treatment, segregation and the use of colour code to show the categories of wastes.

Moreover, Ngouakam, Atanga, Onojeta, Aniekan and Konlak (2012) carried out a detailed survey of the generation and disposal of solid clinical wastes in General Hospital and Infectious Disease Hospital in Ikot Ekpene, Akwa Ibom State using a descriptive survey method and questionnaires. From the results of data analysis, it was observed that general hospital generates 25.25 times much volume of health care waste than Infectious Diseases Hospital

(IDH). It was also found in the course of the study that health care waste management was not given serious attention in the selected hospitals in Ikot Ekpene Local Government Area. The findings showed that the most commonly used waste management method in the hospitals was open dumping. Six categories of health care wastes were identified in the two health facilities, namely; infectious, pathological, sharps, pharmaceutical, chemical and radioactive wastes. Physical, chemical, and biological hazards were also identified. General and Infectious Diseases hospitals (IDH) were respectively made of 14 wards/units, 239 beds and 6 wards/units, 28 beds. An estimated total of 33.4kg/day (0.0334 tons/day) of solid health care wastes were generated in the two hospitals. Open dumping, incineration, burying and open burning were the different methods of waste disposal. In conclusion, the study revealed that health care waste was poorly managed in the selected hospitals in Ikot Ekpene LGA and therefore needs proper management and good environmental disposal method.

In India, hospital wastes generate around 3 million tones every year and the amount is expected to grow at 8.00 per cent annually. Health care wastes if not handled and disposed indiscriminately may cause adverse effects on human health and environment. According to the available information from the State Pollution Control Boards (2007) 52,001 (53.25 %), health care establishments are in operation without obtaining authorization from their respective SPCB/PCC. Approximately 288.20 tons per day (56.87%) out of 506.74 tons per day wastes generated is being treated either through Common Bio Medical Waste Treatment Facilities (159 in number) or captive treatment facilities. There are 602 bio medical waste incinerators (which include both common and captive incinerators), 2218 autoclaves, 192 microwaves, 151 hydroclave and 8,038 shredders in the country. About 424 (70.4%) out of 602 incinerators are provided with air pollution control devices and 178 (29.6 %) incinerators are in operation without air pollution control devices.

In addition, Bansal, Manoj; Mishra, Ashok; Gautam, Praveen; Changulani, Richa; Srivastava, Dhiraj; Singh Gour and Neeraj (2011) drew attention to the fact that routine immunization campaigns in Africa generate large amounts of waste. For example, the 2001 measles mass immunization campaign covering 6 countries in West Africa targeted over 16 million children and generated over 300tons of injection-related waste (Bansal, *et al,* 2011). Estimates by the WHO showed that routine immunization of less than one year old children and women of child bearing age with tetanustoxoid accounted for over one billion injections in 1998, while measles eradication activities accounted for another 200 million injections in the same year (WHO, 1999). Such amount of waste presents treatment and disposal challenges. Besides preventing cross contamination during the management process, selecting a suitable and environmentally friendly method is a top challenge. In developing countries, methods such as dumping in open landfills, surface dumping and use of sub-standard incinerators are common (Coker *et al*. 2009;Hossian *et al*. 2013 and Sawalem *et al*. 2009).

To confirm the above, a survey conducted by the WHO in 22 developing countries reveal that 18% to 64% of health care establishments do not use proper clinical waste treatment and disposal technologies (WHO, 2005a). In the western world, treatment and disposal methods are in conformity with certain international regulations characterized by standard incineration with air pollution control devices (APCD) and the application of a wide range of non-combustion technologies.

2.5 Toxicological and Healthcare Implications of improper Healthcare Waste Disposal and Management

Pratibha, Nupur, Anuradha, Pradeep, Ruchika and Sogani (2014) carried out a study on efficiency analysis of a hospital effluent treatment plant in reducing genotoxicity and cytotoxicity of hospital wastewaters in India using short term microbial bioassays, Ames test and saccharonmyces cerevisiae respiration inhibition assay. From the result of the findings, it shows that in many developing countries including India, the major part of hospital wastewater is discharged in surface watercourses or in public sewers or percolates into underlying groundwater aquifers with no or only partial treatment. The result also showed that some of the substances found in wastewater are genotoxic and are suspected to be a possible contributor to certain cancers observed in last decades. The result also indicates that untreated hospital effluents possessed the potential to contaminate the surface and even underground water, thereby making it unfit for irrigation and drinking. In contrast, the treated water samples were found to be slightly geneotoxic and mildly cytotoxic, thus inferring that genotoxicity is reduced after the treatment process. The study then recommend ETP of the hospital wastes before disposal for effective genotoxicity and cytotoxicity reduction for hospital wastes.

Supporting the above, Okunola and Olutayo (2011) carried out a study on the toxicological effects of hospital wastewater using animal bioassays. The physiochemical analysis of the test sample shows that it contained constituents that are capable of inducing mutation in biological system. The data showed that the hospital wastewater is genotoxic, inducing a dose-dependent, statistically significant ($p<0.05$) increase in the micronuclei, chromosome aberration and sperms with abnormal morphology with observed decrease in mean sperm count. Hospital waste poses a significant impact on health and environment, therefore, proper waste management strategy is needed to ensure health and environmental safety.

Moreover, Long and Williams (2006) carried out a preliminary study of toxicological impact of medical waste in Lagos state, Nigeria using empirical data. The observed MWM practices in all the hospitals indicated an absence of full compliance with the protocol for handling medical wastes as stipulated in the relevant sections of the guidelines and standards for environmental pollution control in Nigeria. The result also showed that there is lack of segregation, treatment and proper management of wastes at various hospitals in Lagos state. They therefore suggest treatment of waste at point source and the use of incineration in all the hospitals.

Shao (2003) carried out a study to investigate the health impact of improper disposal of medical wastes on environment and found out that of the 7550 needle stick and sharp injuries reported by8645 HCWs, 66.7% involved a contaminated hollow-bore needle. In the same study, 1805 blood samples from the HCWs were tested and 16.7% were sero positive for hepatitis B surface antigen, 12.7% were positive for anti-HCV and 0.8% was positive for anti-HIV. The authors estimated, based on their data that 308 to 924 HCWs were at risk for contracting HBV; 334 to836 were at risk for contracting HCV; and, at the most, 2 were at risk for contracting HIV.

In line with the above, Bansal, Manoj, Ashok, Guatam, Praveen, Changulani, Richa, Srivastava, Dhiraj, Singh and Neeraj (2011) identified 73 injuries from needles and other sharp objects in a retrospective survey of all self-reported documents in Buraidah Central Hospital, Saudi Arabia. According to the him, nurses, physicians, technicians and non-clinical support staff were involved in 66%,19%, 10% and 5.5% of the instances respectively. Most of the injuries, according to the result, occurred during recapping of used needles (29%); during surgery (19%); by collision with sharps (14%); disposal related (11%) and as well as through concealed sharps (5%) while handling linens or trash containing improperly disposed needles. Bansal et al (2011) supported the above findings by identifying that the risk of occupationally acquired infection with hepatitis B and hepatitis C among HCWs is as a result of the frequency of needle stick injuries with patient blood contact, the prevalence of patient virus carriers, the probability of transmission and the immune status of the personnel, in the case of HBV mainly the vaccination rate.

Furthermore, in a study of occupational exposure to needle stick injuries and hepatitis B vaccination coverage among HCWs in Egypt, Mohankumar and Kottaiveeran (2011) reported that of the 1485 HCWs interviewed, 529 (35.6%) were exposed to at least 1 needle stick injury during the past 3 months with an estimated annual number of 4.9 needle sticks per worker. According to the authors, 15.8% of HCWs reported receiving 3 doses of hepatitis B vaccine, with vaccination coverage highest among professional staff (38%) and lowest among housekeeping staff (3.5%). The authors estimated that 24,004 HCV and 8617 HBV infections occur each year in Egypt as a result of occupational exposure in the health care environment.

In a similar study in the US, Joseph, Paul, Premkumar, Rabindranath; Paul, and Michael (2015) reported that among HCWs at risk, 75% had received 3 or more doses of the hepatitis B vaccine, corresponding to an estimated 2.5 million vaccinated hospital-based HCWs. According to the authors, the coverage levels was 81% among staff physicians and nurses and significantly lower among phlebotomists (71.1%) and nurses' aides and/or other patient care staff (70.9%).

Understanding the epidemiology of needle stick injuries in the target population is important in designing and implementing control measures according to (Ogbonna, Chindah and Ubani, 2012). Based on that, Pruss-Ustun, Giroult and Rushbrook (2005) suggested that strategies such as education of HCWs on the risks and precautions, reduction of invasive procedures, use of safer devices, and procedure and management of exposures are available to prevent infections due to sharps injuries. According to the researchers, efficient surveillance and monitor of occupational health hazards related to blood borne pathogens in the industrialized world help to reduce the risk of transmission. On the other hand, the researchers noted that, similar surveillance and monitoring systems are weak and dysfunctional and/ or sometimes completely absent in developing countries.

According to Anon (2006), the problems associated with medical waste disposal is aggravated due to rapid and uncontrolled growth of medical care facilities, increase of waste generation rate owing to marked increase in disposable medical care materials, illegal and unsafe methods of recycling of waste due to increased cost of disposable medical care materials. This situation can cause a potential health hazard to public at large, especially health care workers, municipal employees and rag pickers involved recycling of waste. In view of the above, Santappa and Rohikumar (2002) showed that waste handlers and the community that lives in the proximity are at risk of contracting communicable disease arising due to improper handling of hospital wastes. Skin contact, injection and inhalation are possible routes of exposures which could cause chronic effects and acute problem. Containers and plastic materials, likely to be salvaged by scavengers may spread communicable disease in case they are not properly sterilized before recycling or reuse.

Gupta and Boojh (2006) study observed that the personnel working under the occupier were trained to take adequate precautionary measures in handling these bio hazardous waste materials, the process of segregation, collection, transport, storage and final disposal of infectious waste was done in compliance with the standard procedures, the final disposal was by incineration in accordance to Environment Product Act Rules 1998, the non-infectious waste was collected separately in different containers and treated as general waste, and on an average about 520 kg of non-infectious and 101 kg of infectious waste is generated per day about 2.31 kg per day per bed, gross weight comprising both infectious and noninfectious waste. This hospital also extends its facility to the neighboring clinics and hospitals by treating their produced waste for incineration.

According to Department of Health Services (2004) hospital waste management includes all activities involved in waste generation, segregation, transportation, storage, treatment and final disposal of all types of waste generated in the hospital facilities, stages of which require special attention. This will ensure that inputs activities and outputs for the safe handling and disposal of healthcare waste are in place. Contamination of raw food as a result of hospital wastes has been observed to cause health related problems to man. This can been seen from different scholars articles. Green leafy vegetables are popular around the world. They are quick growing crops that are harvested within four to six weeks. Some of the common green leafy vegetables are cabbage (*Brassica oleracea L. var. capitata*), lettuce (*Lactuca sativa L. longifolia*), and spinach (*Beta vulgaris var. cicla*). Tender leaves, and in some cases stems, are consumed raw or cooked. Cultivation of leafy vegetables is a profitable business for farmers; however, these vegetables are highly perishable. Therefore, these vegetables are usually grown in peri-urban production areas Abida *et al*. (2009).

Vegetables play an essential role in humans' diet. They provide and assist the body with a variety of important constituents such as minerals, vitamins, complex carbohydrate, high dietary fiber, low levels of fat and high amount of water. Encouraging vegetables consumption is a major dietary guidance policy. A healthy balanced diet contains vegetables, fruit, animal products and grain products. So increasing consumption of vegetables is a fundamental goal of awareness among population. However, proper care must be taken during irrigation in pre-harvesting and post-harvesting periods to avoid toxicity in vegetables before being supplied to the consumers (Guthrie et al. 1992).

A study on the health impact of the utilization of raw domestic sewage for vegetable cultivation in the suburbs of Asmara, Eritrea, showed heavy contamination of vegetables from fecal coliforms and *Giardia lamblia*, as well as from other pathogens, such as *Shigella* and *Salmonella* bacteria (Srikanth and Naik, 2004). The dietary intake of raw greens (e.g., lettuce, cabbage) grown on the raw sewage appears to cause *giardiasis, amebiasis* and bacterial *diarrhoeas* in the farming community as well as in the surrounding area. This study indicates as well that agricultural use of untreated wastewater was the major cause of the increase in giardiasis and other gastrointestinal diseases (Keraita *et al*. 2003).

Generally, polluted water bears two kinds of economic costs; firstly pollution reduces the total amount of adequate water available for household consumption or agricultural and industrial usage. Thus, there are economic costs of water held back from supply. Secondly, there are costs related to the use of polluted water for consumption and production. The cost of using contaminated water for production refers to the decrease in both quality and quantity of products (World Bank, 2007).

Food borne diseases are multi factorial in origin. It could follow ingestion of food containing infectious organisms or non-infectious substances. Food-borne diseases (FBDs) constitute a serious public health problem worldwide. There is an estimated 2 million deaths in children worldwide (Miller *et al* 2008). Chemicals, heavy metals, parasites, fungi, viruses and bacteria can cause food borne illness. However, bacteria related food poisoning is the most common, but less than 20 of the many thousands of different bacteria actually are the culprits (FAO/WHO, 2001). Sewage water contains pathogenic microorganisms like bacteria, viruses, fungi, algae and parasites, having the potential risks to cause diseases that can result immense harm to public health. The water borne diseases are typhoid, paratyphoid fevers, dysentery and cholera, polio and infectious hepatitis (Srikanth and Naik, 2004).

The majority of diseases associated with fresh fruits and vegetables are primarily those transmitted by the fecal-oral route, and therefore, are a result of contamination at some point in the process (de Roever, 1998). The dominant microflora on fruits and vegetables consists of decomposing molds and yeasts; however pathogens leading to bacterial, viral and parasitic human infections are also reported. Bacteria are the greatest concern in terms of serious illness and number of persons at risk of infection on an international scale. Enteric pathogens can be found in soil, manure, urban wastes and in irrigation water, depending on relative moisture, microbial adhesion, rainfall and sunlight. The numerous genera of pathogenic and spoilage bacteria, yeasts and molds in fresh produce are *Escherichia, Salmonella, Shigella, Pseudomonas, Campylobacter*, *Listeria, Staphylococcus, Bacillus, Aeromonas, Aspergillus Penicillium,* and *Fusarium*. (Mehmet and Ayden, 2008).

In developing countries intestinal parasites are very common and fresh vegetables are an important route of their transmission (Amoah *et al*. 2005). Biologically, the highest health risk is infections due to helminth contamination. Because helminths persist for longer periods than pathogens in the environment, host immunity is also usually low to non-existent and the infective dose is small

(Gaspard *et al*, (1997). Contamination of vegetables may occur in a variety of ways, such as from contact with the soil and pre-harvest handling practices. In most cases, contamination is associated with the water used for irrigation (Porter *et al*. 1990).

Outbreaks of intestinal parasitic infections associated with raw vegetables have been reported from developed and developing countries (Ortega *et al* 1997; Erdogrul and Sener, 2005). As little as 10 or fewer Giardia cysts are sufficient to cause illness (Brooks *et al.*, 1995). Ayres *et al.* 1992) recovered viable *Ascaris* eggs from lettuce irrigated with raw sewage, while (Gaspard and Scwartzbrod, 1993) recovered viable *Ascaris* eggs from both tomatoes and lettuce following raw sewage irrigation. There are very few reports on the microbial quality and the prevalence of food borne pathogens on fresh vegetable products of Ethiopia. Microorganisms may cause diseases such as hepatitis A or E, dysentery, typhoid fever, cholera and diarrhea (MOH, 2005). Pathogenic bacteria can cause infection or disease in humans or even animals if they are introduced in sufficient numbers. Some pathogens may initiate infections in a susceptible host by singly; others may require hundreds to be present before an infection can be initiated. Thus, when reclaimed water or sludge is used on fields producing crops, it is critical to protect public health (Brooks *et al*., 1995).

2.7 Discussion of gaps from the Literature

From the reviewed literature, there is lack of segregation between hazardous and non-hazardous wastes (Oruonye, 2012; Manyele, 2003,2004a and b, Mohankumar and Kottaiveeran, 2011, Ngwuluka, *et al*, 2009) and also there is absence of rules and regulations applying to the collection of wastes from the hospital wards and the on-site transport to a temporary storage location coupled with lack of proper wastes treatment, (Babanyara, 2013; Aremu, 2012, Okore, *et al*, 2009, Abah and Ohimain, 2008, and Abor, 2012).

Due to lack of knowledge concerning the health implications associated with biomedical wastes, hospitals disposed their daily generated wastes along with municipal garbage giving rise to high pollution problems. It was also observed from the reviewed literature that insufficient training of personnel, insufficient personnel protective equipment and lack of knowledge regarding the proper use of such equipment are among the problems amongst the factors contributing to poor medical wastes management in both developed and developing countries of the world (Ogbonna, 2011; Pratibha, *et al*, 2014 and Okunola and Olutayo, 2011).

In Africa, the situation of poor medical wastes management is similar. In Nigeria, South Africa, Mozambique, Swaziland, Kenya and Tanzania according to Leonard, (2003) efficient medical wastes management is a major problem. Wastes are seldom segregated at the point of generation and compatibility and reliability issues abound when it comes to current treatment and disposal practices. Reflecting on this, there is potential for environmental exposure to toxic emission from sub-standard incinerators (poor combustion conditions) and nuisance arising from foul stench, not leaving out attraction and proliferation of vermin. Even though there is some rational agreement that illegal and uncontrolled disposal threatens public health. For instance, frequent outbreaks of typhoid, diarrhea and cholera in Nigeria can be associated with poor handling of such wastes according to (Fongwa, 2002). Moreover, the literature showed that the amount and type of clinical wastes produced by healthcare establishment in Nigeria vary in number depending on the type of medical facilities, clinics, health centers and hospitals and also depending on the size and capacity (number of beds) and types of services on offer (specialist, general and both). The inclusion of other factors such countries, location of the health facility (remote or urban) and accessibility in terms of roads further compounds this variability.

In the reviewed literature, much efforts have been directed toward proper and safe management of hazardous healthcare wastes for less developed countries by different organizations, particularly WHO according to Shinee, Gombajav, Nishimuar and Hamajiam, 2008). However, inadequate management practices are often seen in most healthcare facilities (HCFS) particularly in developing countries as seen in the works of (Shinee, Gombajav, Nishimuar and Hamajiam, 2008), WHO, 2004 and Patwary, O'Hare, Street, Elahi, Hossain and

Sarker, 2009) to mention but few. A number of studies on healthcare wastes management showed that health and environmental risk posed by healthcare waste can be reduced by having careful planning, proper guideline and full participation of HCWs according to scholars like (Silva, Hoppe, Ravanello and Mello, 2004).Scholars in developing counties that assessed healthcare waste management issues such as (Mostafa, Shaxly and Sherief, 2007), Coker, Sangodoyin, Sridhar, Booth, Olomolaiye, and Hammond 2009), and Patwary, O'Hare, Sarker, 2011) revealed that segregation, collection of wastes using recommended color coding container and storage of wastes in isolated area were not satisfactory. Also not in place in most hospitals especially in developing countries like Nigeria. It was also observed from the literature that personal protective equipment and accessories were not provided and used by some of the HCWs in most of the hospitals in Nigeria until the emergence of the deadly virus Ebola which created serious awareness on the need.

Moreover, health care wastes generated from HCFs dumped were noticed to be dumped in the generated hospital backyard in a simple pit or put in open garbage to bins on the roads. Few studied done on healthcare waste management in Anambra by Ndibe, (2014) and Owerri by Okore; Mbanefo,Onyekwere, Onyewenjo, Ozurumba, Nwaehiri and Nwagwu, (2009) indicated that there was no waste segregation in most studied HCFs in the area just as in Nigeria. Most of the findings showed that there is no segregation of wastes generated from the hospitals; and based on that, hospitals wastes are simply disposed using either burying, burning, open dump or landfill in most hospitals, especially in Nigeria.

Gaps in Literature

From the reviewed literature, the following gaps were identified,

1. From the reviewed literature, most of the study done focused on hospital wastes management in developed countries, but only a few was in Nigeria but not in the study area. It includes the one done by Stanley *et al* (2011) at Ile Ife, Ajmotokan and Aremu (2012) at Ilorine, Kwara State, Ogbonna (2011) at Port Harcourt, Ngouakam, *et al* (2012) at Ikot Ekpene, Akwa Ibom and Oruonye (2012) at Kwara State. Little or no work has not been done on Enugu the study area.
2. Most of the reviewed literature did not include the toxicological impact of hospital wastes using bioassay assessment and genotoxicological impact assessment of living things to show human exposure and toxicity but that was captured in this present study.
3. The present study will also show the sublathal and chromosomal aberration induced in the kidney and liver of rat as an evidence to portray the toxicity of hospital wastes on man.
4. From the literature Katoch and Kumar (2008) presented a technique to develop mathematical model in biomedical waste generation in three major hospitals in Shimla town, India. Taghipour and Mosaferi (2009)

and Blackman (1996) also used calculus to assess water dispersion in developed countries but the present study will use triple vector product model to show dispersion of solute at different points in the study areas.

5. The present study will developed a hydrodynamic model using triple vector product to show the dispersion of solute from point to other areas within the study area as a model to be used in cheek-mating and monitoring of solute concentration.
6. The study will also prove the level of toxicity of improper wastes disposal using edible vegetable of which none of the reviewed literature in the study area does.
7. Most of the reviewed literature showed health implications of medical wastes disposal in developed countries not much have been done in south east part of Nigeria in Enugu in particular except the study conducted by Ndibe, 2014 at Awka but little or no one has been done in the study area but this present study will capture it using physiochemical, parasitological and bacteriological analysis as a risk factor.

It is these gaps found in literature that form the core of this study.

CHAPTER THREE

This chapter discusses the study areas. It was done under the following sub-headings; location of the study, physical and human characteristics of the study areas.

3.1 Location of the Study Area

Enugu is the capital of Enugu State of Nigeria. It is located at the North-Eastern fringes of South-Eastern Nigeria (fig. 3.1) and occupies an area of about 12,000km^2(Fig. 3.2). It has previously served as capital city for Eastern Region, East Central State, the former Anambra State and presently Enugu state. The town lies approximately between latitude $06^0$21`N and $06^0$21`N and longitude $7^0$25`E and $7^0$38`E.

The town owes its origin to coal mining activities. Between 1915 and 1920, the town developed as a by-product of coal mining activities, hence the nickname “Coal City”. The coal mining activities led to the early development of Ogbete layout, Coal Camp which is one of the oldest planned residential areas built for miners. In 1923, China Town was developed as a special industrial area for African Railway workers and the European Reservation Area now called Government Reservation Area (GRA).

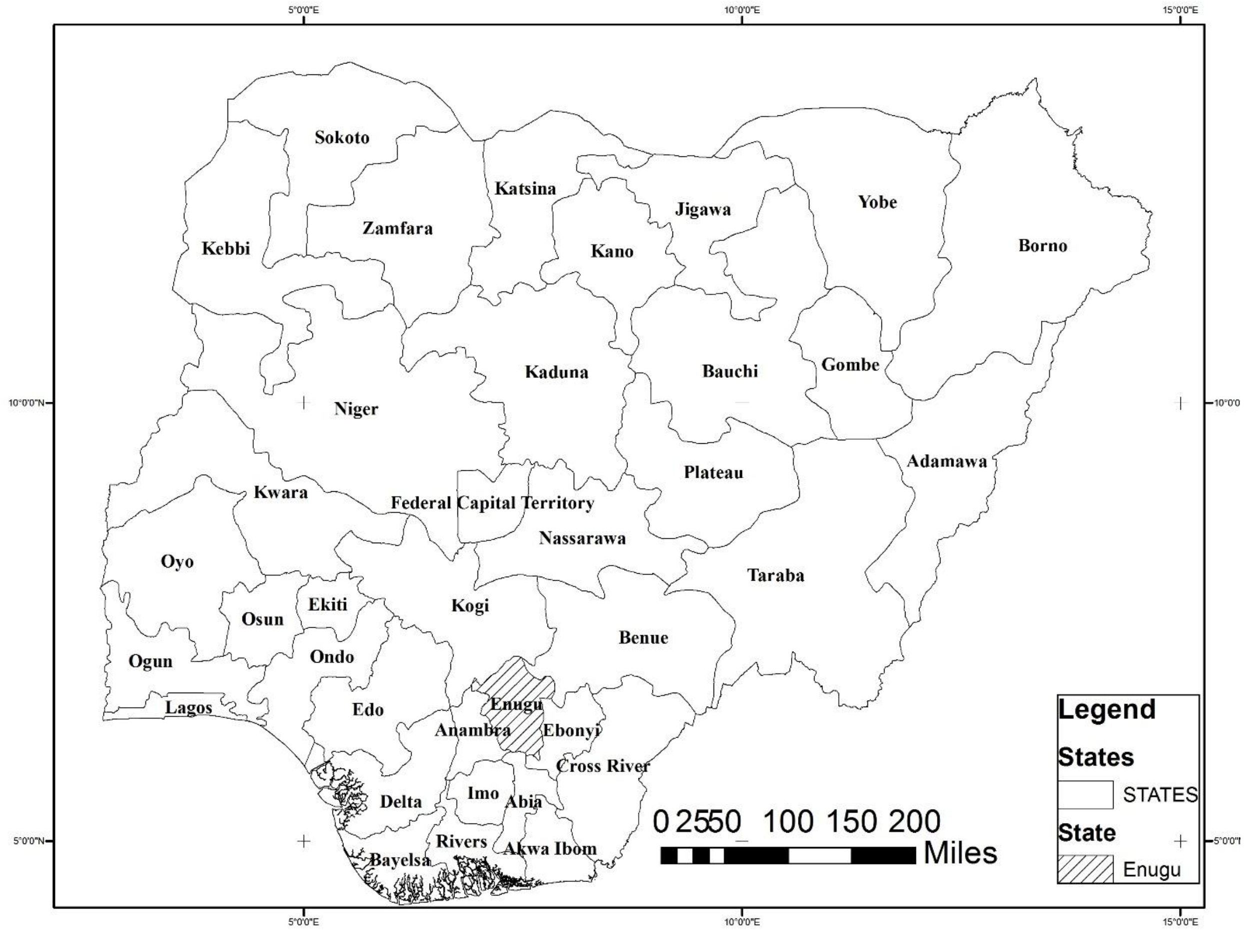


Fig. 3.1: Nigeria showing Enugu State the study area

Source: Survey Department, Nnamdi Azikiwe University, Awka.

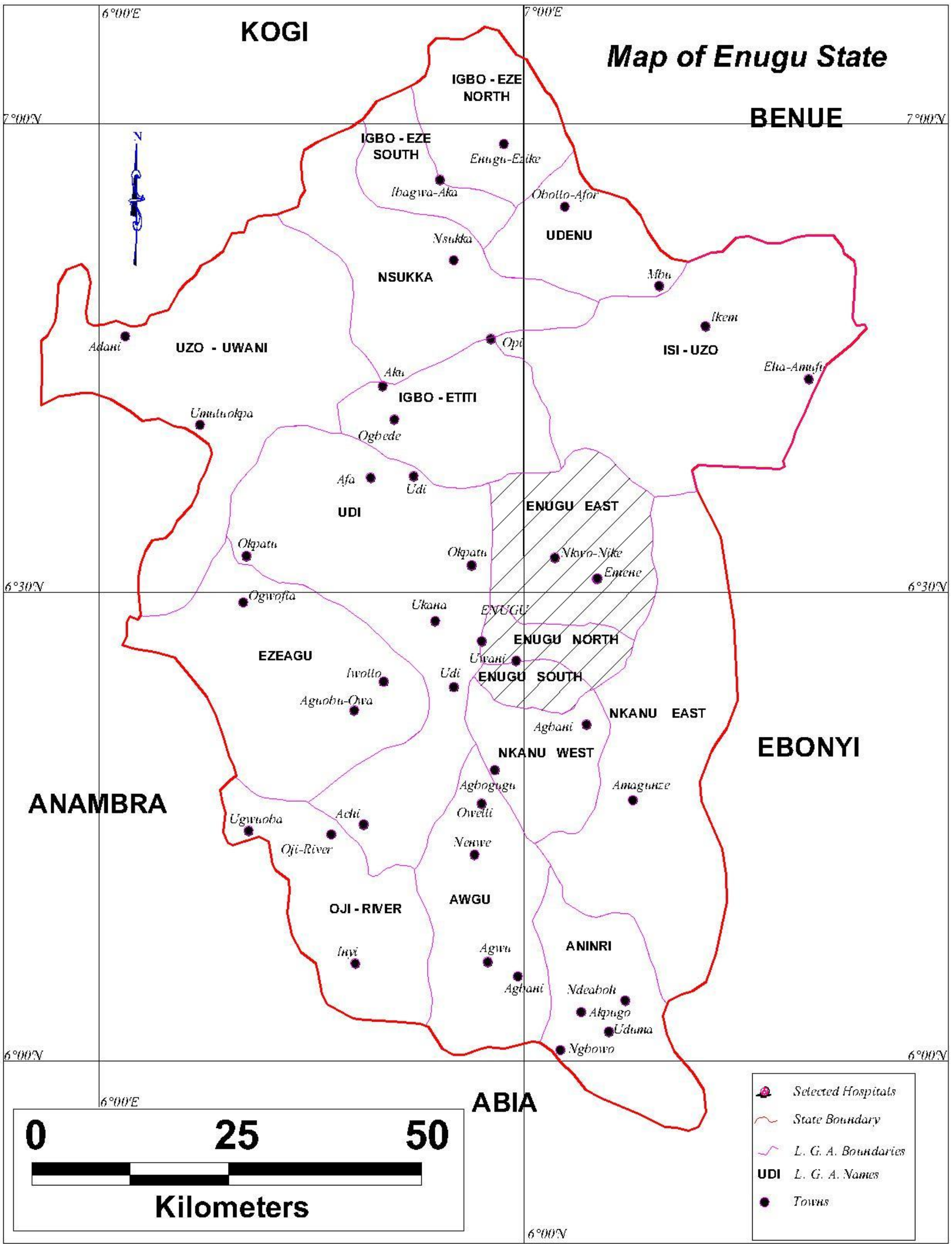


Fig. 3.2: Enugu State showing the study area
Source: Survey Department, NnamdiAzikiwe University, Awka

As Enugu town grew in commerce and industry, having been earlier attracted by coal mining activities so did its population; with the attendant establishment of hospitals and healthcare facilities. The inevitable development in the study area made it compulsory for other residential areas to emerge.

These residential areas span from Abakpa Nike towards Ugwuogo Nike in the North East side, from New Haven towards Thinkers Corner to Emene in the Eastern side, and from Uwani towards Achara Layout to Idaw River and Gariki in the Southern side of the city. The pattern of growth of residential areas calls for an integrated approach involving the planning, development and management of healthcare facilities.

3.2 Physical characteristics of the study area

The era contains about nine geological formations. From east to west, and in terms of age and sequence of exposure of the Formations are: The Asu River Group of the Albian (Lower Cretaceous) Age, made up of shales, sandstones and siltstones. The sediments later became folded, giving rise to the Abakaliki anticlinorium and the related Afrikpo synclinorium both within the present Ebonyi State, as well as the synclinal basin lying between the Niger and Eze-Aku Shales Formation of the Turonian Age which contains shales, siltstones, of sandstones and limestones. Agwu Ndeaaboh shale Formation of the Coniacian Santonia Age. Enugu Shales (to the North) and Awgu Sandstones (to the South) along the same axis. They were laid in the Campania sub stage. Lower Coal Measures Formation (Mamu Formation) of the Meastrichtian Age. This is the coal bearing Formation. False bedded Sanstones Formation is Ajali Sandstones also of the Meastrichtain Age. The body of the Sandstone is thick, friable and poorly sorted. Upper Coal Measures Formation is Nsukka Formation of the Nadian Age. The Formation consists of coarse sandstones or with shale intercalations and fragments of iron stones and ferruginized shales and sandstones. It abounds extensively on the Udi-Nsukka Plateau where different erosion has left the resistant portions standing out as rounded, conical, domey, cuesta like, elongated and sometimes a flat topped hills, some hundreds of meters above the general level.

These Upper Cretaceous Sediments were probably uplifted during the tertiary Formation, giving rise to the Enugu-Okigwe escarpment and Imo Shale-Clay Formation of the Pleistocene Age. It is about 1,000 meters in thick and overlies the Upper Coal measures conformably, Alluvium Deposits which belong the recent age. In Enugu State, this Formation occurs fastest in the North-West and belongs to the Niger Anambra flood plain (Ofomata, 1975).

3.3. Topography of the study area

Enugu state occupies much of the highlands of Awgu, Udi and Nsukka. The hills are flanked by the rolling lowlands of Oji River, Agbada and Anambra Basins to the west, and the Ebonyi (Aboine) River Basin to the east. The selected hospitals: National Orthopaedic and University of Nigeria Teaching Hospital were located in Enugu State and the topographic maps shown in figures 3.3 (a,b) and 3.4(a,b) respectively. The map shows that the area is tilted down the valley. It is characterized by gentle landform. This could be the reason for easy percolation of pollutant into the environment.

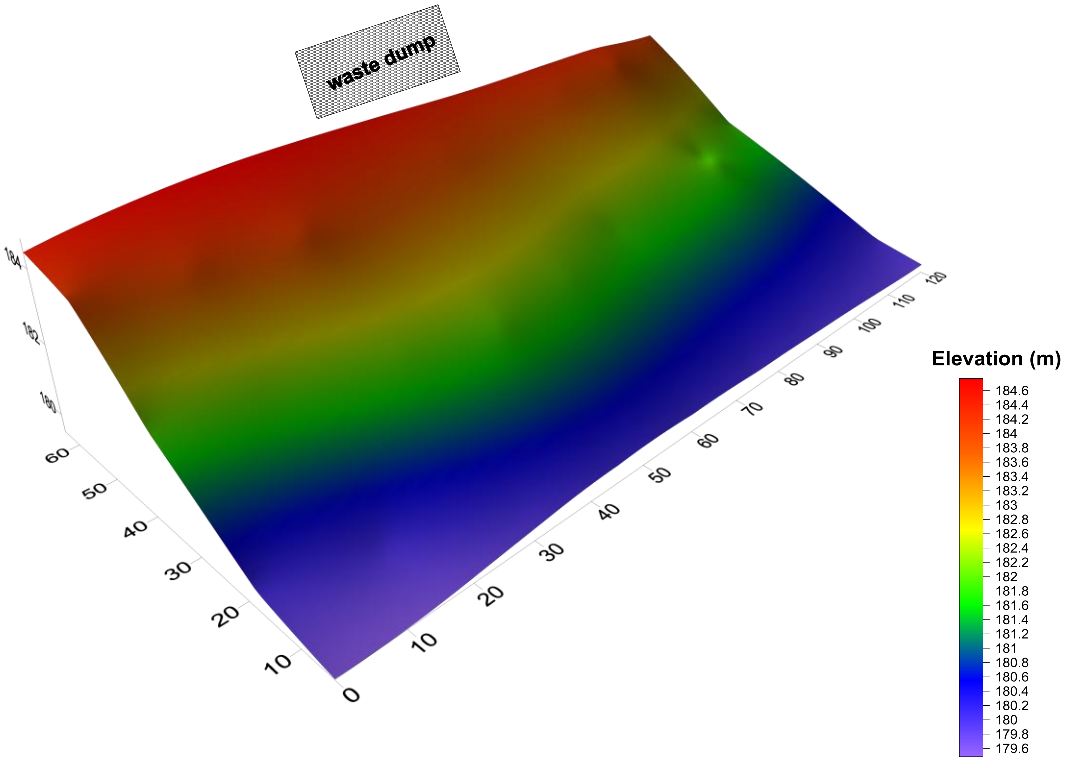


Fig. 3.3(a) 3D Topographic Base map of the National Orthopaedic Hospital Enu

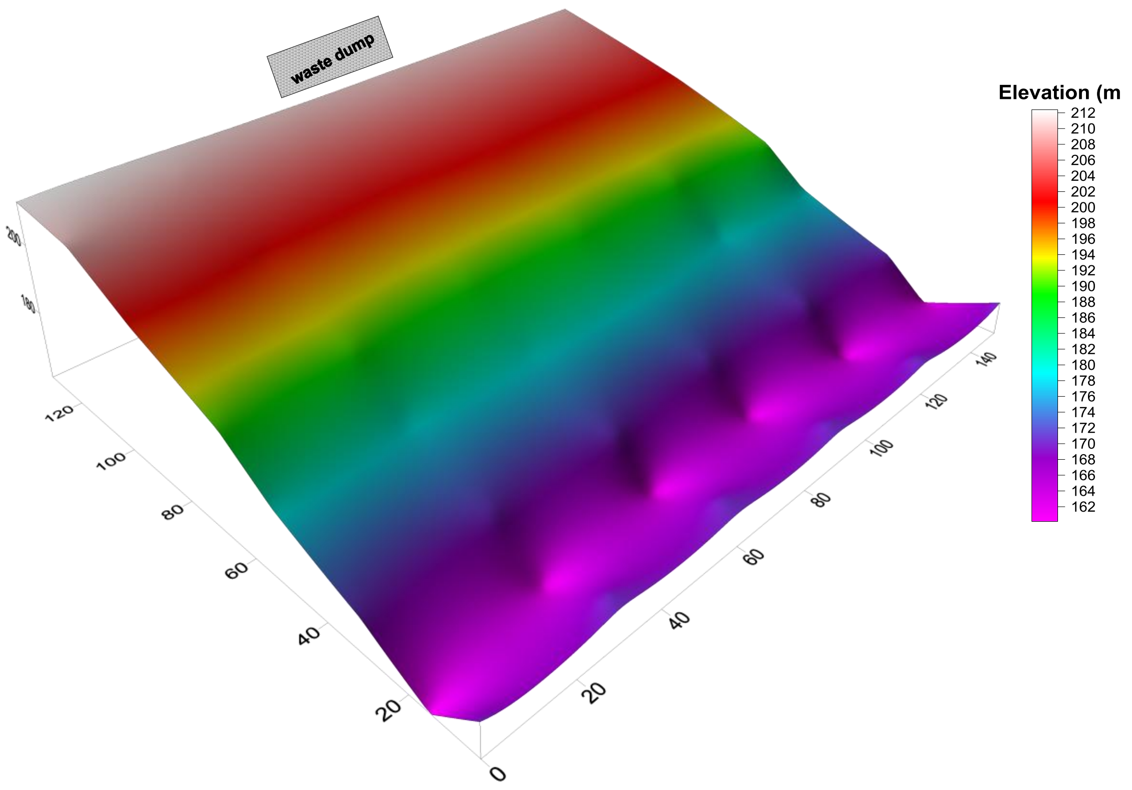


Fig. 3.4 (a) 3D Topographic Base map of the University of Nigeria Teaching Hospital Ituku Ozall

3.3.1 Hydrology of the Study Area

The study area is underlain predominantly by both unconfined and confined aquifers. The unconfined aquifer is in contact with the soil zone but varies in depth from one part of the area to the other. The depth to watertable varies from one season to the other, being shallow during the raining season and deeper during the dry season. The depth to watertable in the study area is shallow due to the shaly Formation of the area. The hydrology of the study area is greatly influenced by its geology, soil type, topography and climate. These factors enhance high infiltration that encourages great recharge of the aquifer. The sedimentary rock of the Enugu contains mostly shale with little interactions of sand giving rise to its low permeability and porosity rate according to Jones and Hockey, (1964).

3.3.3 Climate of the Study Area

The study area lies within the tropical rainforest climatic zone. Two distinct seasons mark the climate of the areas, namely, dry season and wet season. The dry season lasts from November to March, while the rainy season lasts from April to October (sometimes it extends to between March and November). The peak period is always accompanied by flashes of lightning and thunder storms, flooding, soil leaching, extensive set outwash, ground infiltration and percolation (Officha, 2017). The annual rainfall of the area is over 2000mm, (Federal Republic of Nigeria, 2007). Temperature is fairly uniform in the study area throughout the year. The temperature is slightly higher during the dry season (February and March, and November to December). The months of February and March have monthly mean maximum and minimum temperatures of 35^0C and 25^0C respectively, while November to December have monthly mean temperatures of 33.9^0C and 23.7^0C respectively, (Federal Republic of Nigeria, 2007). The months of December and January mark the Harmattan period, which is usually cool in the morning hours, hot in the afternoon hours and cool again during the night hours. The month of August is the coolest period in the area, with monthly mean maximum and minimum temperatures of 29^0C and 23.10^0C respectively (Federal Republic of Nigeria, 2007).

3.4 Human Characteristics

3.4.1 Population Growth of the Study Area

According to the 2006 Nigerian census, Enugu had an estimated population of 722,664 (Federal Republic of Nigeria Official Gazette, 2007). This estimate along with population estimates of other Nigerian cities have been disputed with accusations of population inflation and deflation in favour of the northern part of the country (Ahemba, 2007). The population of Enugu is predominately Christian, (Ike, 1998) as is the rest of southeastern Nigeria. The growth in population of Enugu is shown in Table 3.1.

Table 3.1: Population Growth of Enugu

Year	Population
1931	3,170
1953	12,959
1963	62,764
1982	138,457
1983	349,873
1982	367,567
1983	349,873
1984	367,567
1987	385,735
1991	46,535
2002	07,756
2006	95,000
2016	896,652

Source: Federal Republic of Nigeria Official Gazette (2007).

The indigenous people of Enugu include the Ogui Nike who live in the areas surrounding Hotel Presidential, Obiagu, Ama-Igbo, Ihewuzi and Onu-Asata. Other groups include the Awkunanaw people, who live mainly in the Achara Layout and Uwani areas. The Enugwu Ngwo people live in Hilltop on the west of the city with their farm lands sprawling all over the valley. The Nike people live around the Abakpa, Iji-Nike, and Emene areas of the city (Ilogu, 1974).

3.4.2 The Growth and Development of the Study Area

The Enugu urban originated from the discovery of coal in 1909 in Enugu Ngwo, a village situated at the top of Udi Plateux. With the commencement of the taping of the coal resources in 1915, settlers began to settle on the foot of the hills and on the wide plains that currently constitute the centre of Enugu urban (Iyi, 2007). It was classified a second class Township in 1917 by the Township Ordinance No. 19 of 1917 (Nigerian Institute of Town Planners, 2011). As a town, Enugu had a checkered history. It started from when it took over from Calabar as the headquarters of Eastern Nigeria, capital of the defunct Republic of Biafra, capital of East central State, Capital of Old Anambra State, and Capital of Old Enugu State, up to 26th August, 1996, when it became and is currently the capital of the new Enugu State (Iyi, 2007).

The original coal mine was at Udi in 1913, but later operations were moved to coal camp area (Concept Ecodesign International, 1981). In 1916, the first coal train left Enugu for Port Harcourt. Over the years, the political seat of power in Enugu urban took precedence over industrial development with the exception of the rail maintenance yards and coal mining. Older residential sections included Ogbete, Ogui, Asata Uwani and G.R.A. (Government Residential Area). These areas, apart from housing included small business establishments.

Enugu urban began as a coal mining town. After sometime, mining activities declined but being an administrative centre, it gained importance over the years. Residential districts sprang-up to absorb the rapid growth in population. The earlier districts comprise Riverside, Independence Layout, New Haven Layout, Ekulu Layout, Abakpa-Nike, Aria River Layout, Ogui Nike Layout, Uwani Southern and Northern extensions, Republic layout, Maryland layout, New Era layout, Idaw River Extension and others. It was as a result of the increase in growth pattern that several healthcare facilities where establish to meet the health need of the state, hence the huge amount of waste generation and improper disposal in the study area.

3.4.3 Settlement pattern of the Study Area

The first settlement in the Enugu area was the small Nike village of Ogui, which was present since the era of the Atlantic Slave Trade (Udo, 1988). Nike in the Igbo language means "with strength or power. It was through slave raiding that the Nike people acquired most of their lands, which were mostly unsettled. The Nike used slaves for a defence strategy, placing slave camps at the edge of their territories so that it was harder for an enemy to access the free born (Ekechi, 1972). The Nike people were allied to the Aro people who formed the Aro Confederacy (1690-1901) (Nwauwa,1995) which was an Igbo organization that controlled slave trading in the Enugu area. Along with the Aro people who came to trade from Arochukwu in the south were the Hausa people who came to trade from the north. The Hausa traders provided horses to the Nike which was used for rituals by the Igbo. Both the Aro and Hausa migrated back and forth to what is now the city of Enugu and were considered foreigners to the area (Odoemene, 2000). Enugu State have more developed and equipped healthcare facilities in East but due to growth in population and development without legislation and policy on waste disposal and management, its environment has seriously be affected and call for urgent attention.

3.5 Hospital Facilities in Enugu

Enugu state has several hospital, dispensary, veterinary homes, clinics and maternity homes. These include the Enugu State University Teaching Hospital, University of Nigeria Teaching Hospital, ParkLane General Hospital, Peenok Medical Center located at Ziks Avenue in Uwani, Hansa Clinic on Awolowo street in Uwani, Niger Foundation Hospital and Diagnostic Centre on Presidential Close in Independent Layout, and the Ntasi Obi no n"Afufu Hospital Organization located on Enuguabor Street in the Trans-Ekulu layout, among others.

Some of the specialist hospital in Enugu state includes Psychiatric Hospital Enugu, and the National Orthopaedic Hospital Enugu (NOHE). Many of the hospital in Enugu are privately run but the UNTH the National Orthopaedic Hospital and Parklane Hospital are among some of the government controlled hospitals in the city. The medical equipment for the UNTH was upgraded in 2009 as well as parts of the hospital which were renovated in the same year. Most hospitals in the city suffer from poor standard of medical facilities available to them. Many of the city's citizen travel abroad for medical care. However, hospitals have been aided by foreign organizations and by Enugu's community at home and abroad who have donated medicine and other medical equipment. National Orthopaedic Hospital and UNTH Hospital was chosen because they gave the researcher approval to conduct the research. The two hospital are also amongst the major big government hospitals in Enugu state hence, generates huge amount of wastes on daily bases during patient's healthcare.

3.5.1 Location of the Sampled Hospitals

Enugu metropolis is in the capital of Enugu State of Nigeria. The study area is Enugu Metropolis comprising Enugu City and the wider Enugu Metropolis within which is located the HCFs of interest namely: the University of Nigeria Teaching Hospital (UNTH) located formerly near the Prisons but now relocated at the new permanent site at Ituku Ozalla and the National Orthopaedic Hospital Enugu (NOHE) located at Nike. Enugu city covers an area of 113km^2 while Enugu Metropolis cover an area of 200km^2 and by implication the UNTH at Ituku Ozalla falls within the Metropolis.

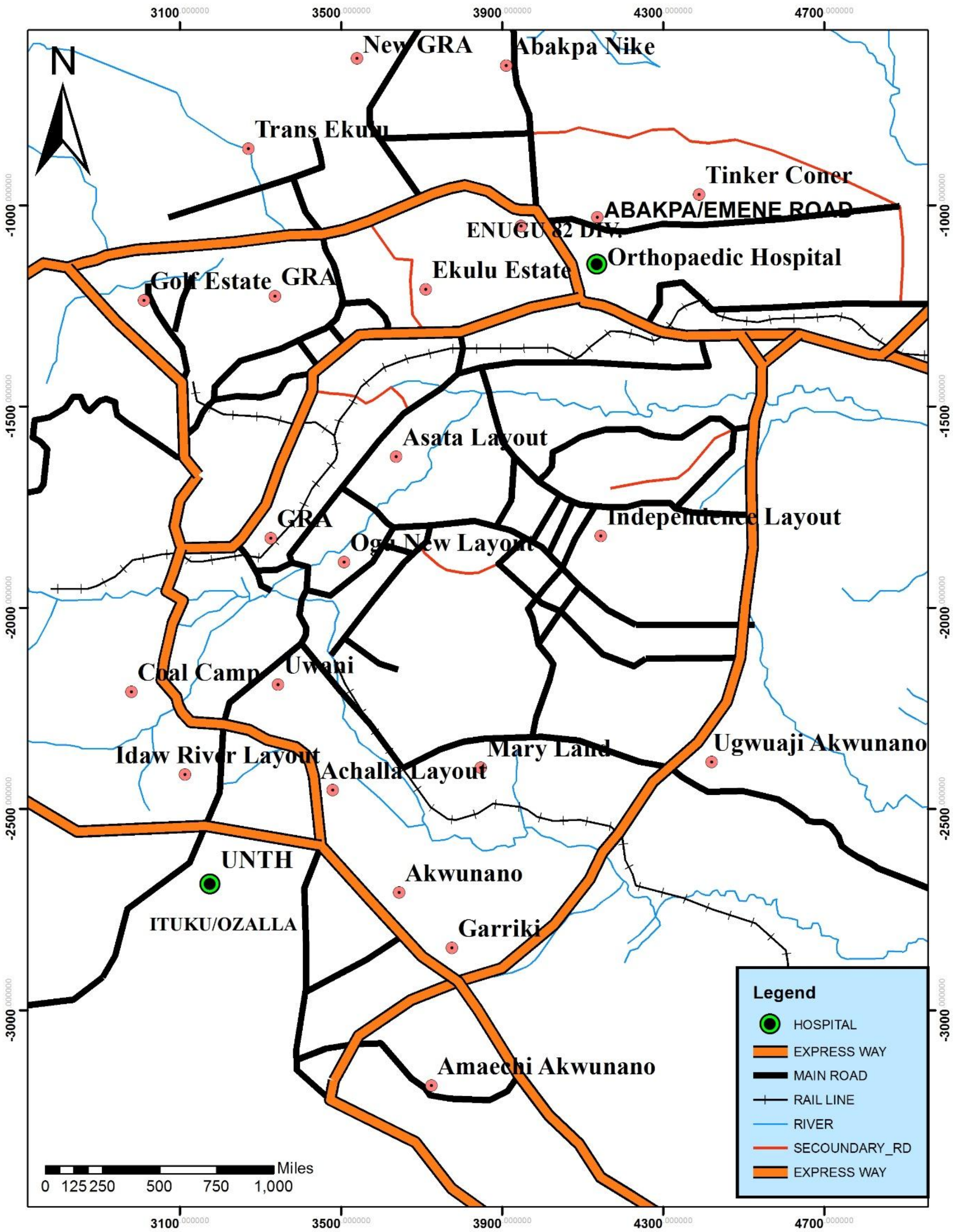


Fig. 3.5 Map of Enugu metropolitan area showing the selected Hospitals.
(Source, Adopted from Geologic Map of Enugu State sheet 2)

The vegetation is generally losing its original forest to savannah type. Thick green belt's running down along riverline and rivulets that cross-cross the city have insured that the city scrape is entirely metropolitan. The city has a moderately undulating terrain with slopes ranging between 1% and 25%, thus enhancing effective drainage as runoffs easily empty into the network of natural drainage channels cross-crossing the city. It is, however important to note that relative to the position of the dominant escarpment, Enugu a depression. This has made the city relatively susceptible to pollution from effluent disposal from biomedical centers in the area.

As a result of the geological feature of Enugu environment, pollutants easily find their ways into the water body to pollute the domestic water resources in the study area. It was based on the geology and socio-economic activities coupled with numerous hospitals in the study area that forms the present study in order to find out the level of toxicity of disposed hospital wastes in Enugu state environment using two specialist selected hospitals: University of Nigeria Teaching Hospital and National Orthopaedic Hospital.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.0. Introduction

This chapter discusses the methodology adopted for this dissertation. It discusses the research design, sources of data, data need, sample size and sampling techniques, target population of the study, sampling techniques, statistical techniques and data analysis, instrument use for data collection, instrument validity and reliability and validity of the research instrument.

4.1 Research design

The type of research design adopted for this study is both survey and experimental methods of investigation. The survey method involved the use of questionnaire, while the experimental investigated the hydrodynamic modelling of solute dispersion, estimated the toxic heavy metal concentrations in soil, water, vegetable and rat organs. According to Osuala (2005), the purpose of experimentation is to derive verified functional relationships among phenomena under controlled conditions. The study sought opinions and perception of the occupants, staff of the selected hospitals, healthcare waste handlers, patients, nurses, doctors, healthcare workers (auxiliary workers) and the general public in Enugu on the health implications of improper disposal of biomedical wastes in the area. The study portrayed the current physical and environmental management of biomedical wastes with challenges facing the healthcare management in the management of wastes in Enugu. It was also employed in order to assess the heavy metal load of well water and surface water from the studied hospitals and also to analyze the water samples collected from wells within and across the hospitals location, which formed the background for the basis of comparison to determine the acceptability of such water in the area with World Health Organization Standard. This was done using Atomic Absorption Spectrophotometer (AAS), while eight (8) rats were analyzed using chromosomal aberration induced in the rat liver, kidney and blood in order to test the mutagenicity of the heavy metals ability to induce changes in the chromosomes of the rats.

4.2 Survey Design

Well-structured questionnaire was prepared and distributed. The questionnaire was structured to reflect the bio-data of the respondents as well as information on health implications of improper disposal of biomedical wastes on environment. Two hundred copies of the questionnaire (100 copies each) were distributed to the staff of the hospitals in order to seek opinions and perception of the staff of the two hospitals, healthcare waste handlers, patients and healthcare workers (auxiliary workers) on the health implications of improper disposal of hospital wastes in the area. The study portrayed the current physical and environmental management of hospital wastes with challenges facing the healthcare management in the management of wastes in Enugu. Exactly 100% of the questionnaire was filled and collected. The questionnaire was precoded using the Likert scale of measurements of Strongly Agree (SA), Agree (A), Not Sure (NS), Disagree (D) and Strongly Disagree (SD) for question 7 and 17 while Very High (VH), High (H), Moderate (M), Low (L) and Very Low (VL) were use in question 18-23 (Appendix A).

4.3 Laboratory Design

In laboratory design,

- Five (5) water samples were collected from four sampling stations each from the two Hospitals in Enugu and one (1) above the point source as the control, to determine the heavy metal concentrations. At University of Nigeria Teaching Hospital Ituku/Ozalla, the water samples were collected from Ufam River located very close to waste dumps and at National Orthopaedic Hospital, the water were collected from Nvuna Stream at the hospitals also located close the hospital dumpsite as can be seen from figures 4.1 and 4.2 respectively.

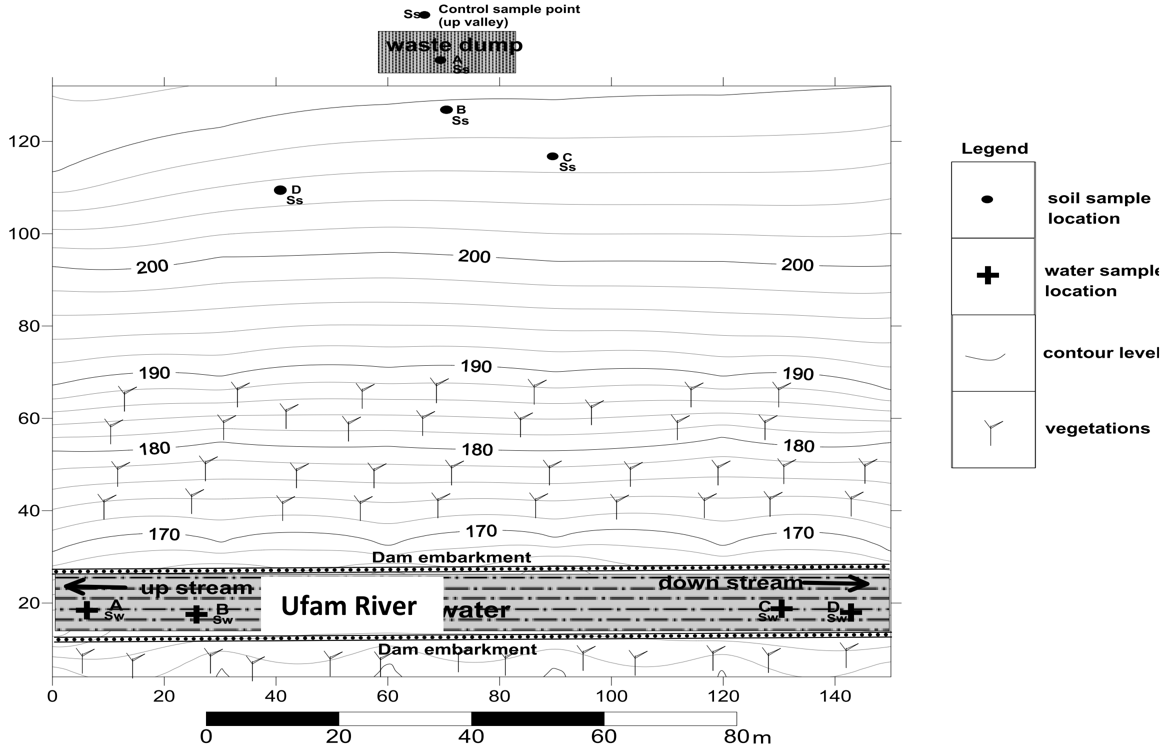


Fig. 4.1: Map showing the location of water, soil and vegetable sample for University of Nigeria Teaching Hospital Ituku/Ozalla.
Source: Researchers field work, 2017

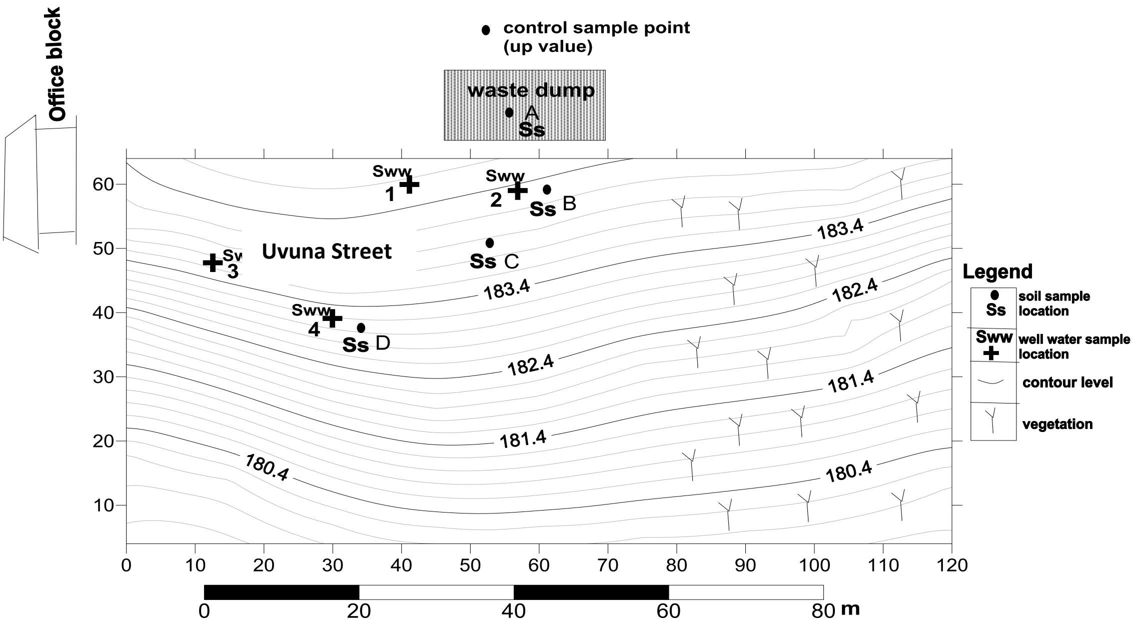


Fig. 4.2: Map showing the location of water, soil and vegetable sample at National Orthopaedic Hospital Enugu.
Source: Researchers field work, 2017

- Water samples were analyzed at Spring Board Laboratory, Awka and Biotechnology laboratory at Nnamdi Azikiwe University, for the physiological, physiochemical, parasitological and bacteriological parameters. The values obtained were compared with the permissible limits as stated by the standard water quality test provided by the World Health Organization (2006).

- Chromosomal Aberration test in eight (8) rats, four from each of the hospital. The rat samples were bought from University of Nigeria Nuskka, Department of Animal Husbandry. The rats were fed with effluents from the hospital and wastes for the period of two weeks prior to disserting and analyses and the rat for the control was fed with saline water for the same period of two (2) weeks.

- In addition to the chromosomal aberration test, heavy metal concentrations on liver and kidney of the rats were also examined to ascertain the level of contamination of the rats by heavy metals, which is an indicator of its bioaccumulation and bioconcentration of the heavy metals on the rats.

- Moreover, 8 samples of three different types of edible vegetable (cucumber, water melon and garden egg leave) cultivated were collected from gardens located very close to the hospitals waste dumpsite. The vegetable used for the control was collected above the located dumpsite at five (5)m away from the sampling site. The vegetable were analyzed to ascertain the heavy metal concentration on the raw vegetable in order to determine the bioconcentration of the metals on the vegetable, a pointer to its possible bioaccumulation in human.

- hydrodynamic dispersion model was developed using triple vector model to show the dispersion of heavy metals in soil and water of the hospital vicinity and around the study areas.

- for the soil sample, the samples were collected from different locations within the sample site. The sampling was done starting from the point source (waste dump) using hand auger tool. The second sample was taken from 10m away from the first sampling, while the third and fourth samples were taken at 15m and 20m respectively. The samples were taken to laboratory for analysis at Spring Board Laboratory Awka.

4.4 Data Needs

The data needed include information on the following;

- The procedures of healthcare waste disposal/handling.
- The environmental problems encountered in the healthcare waste disposal.
- The legislative and regulatory aspect of healthcare waste management.
- Data from GPS to locate the dump site, soil sample and water sample points.

- Hand Auger for soil collection, box and waterproof.
- A tape for measurement and calculator.
- Hand gloves and nose mask
- 1 liter of water can for water samples
- Rat mats embedded with special glue for catching of rats, fish and bread as rat food and cage for transportation of the rats to the laboratory.
- Data on maps from urban planning units to determine the base map for the sampling points.
- Data on population of hospitals in Enugu State and the population of the chosen hospitals.
- Data on chromosomal aberration and mutagenicity using rats.
- Data on the health implications of improper disposal of hospital wastes using questionnaire and chromosomal aberration tests.
- Quality of soil samples for agricultural purposes using vegetable samples.

4.5 Sources of Data

The sources of data used in this research include primary and secondary data.

4.5.1 Primary Sources of Data

1. **Oral Interview:** the hospital workers of the two hospitals were interviewed. The interview was conducted on already structured questions in order to allow free discussions and view expressions. The main aim of this interview was to elicit information on existing

community organizations (men and women), how to get their co-operations and their efforts to bring about change in methods of biomedical wastes disposal and management. To ascertain the proximity of farmland and garden to the hospitals and possibly to get information on how and where the hospitals dispose their waste.

In line with the above, to understand the overall healthcare waste management of the facilities studied, a face to face interview was held with the head of the administration of the facilities. The main question asked includes; (a) procedures used in waste collection, disposal and management in their facilities, (b) hospital waste management policy, (c) special budget for waste management (d) training of waste management staff.

Moreover, waste management performances of the hospitals were assessed using a list consisting of six characteristics waste management descriptors namely; general management strategy (b) waste collection (c) waste segregation (d) waste recycling (e) waste storage and (f) offsite disposal

In addition, a field reconnaissance survey was carried out in order to seek for permission to carry out the study in the two hospitals and to have a clear observations as in the method of waste disposal, method of handling of wastes, the techniques, and instrument for the disposal. This information helped in formulating the questionnaire for the study.

4.5.2 Secondary Sources of Data:

Secondary data were sourced from materials obtained from publications in text books, journals, conference papers and workshops regarding the topic of discussion. It also includes unpublished work like projects and seminars. Other sources includes;

1. Maps:

The maps which helped the researcher to ascertain the locations and distributions of hospitals in Enugu State were sourced by the researcher with the use of Mobile Global Position System (GPS) which was later transferred into computer system for digitalization using Surfer 13 program. The digitalization was done and base map, contour map and distribution trend data analysis produced.

4.6 The study population

The population of the study includes all the workers available in the hospital at the point of data collection. This includes the medical doctors, nurses, waste handlers and adhoc staff of the hospitals. These groups were selected because they would make relevant contributions to the study.

From the recognizance survey at the Ethical Clearance Committee of the hospitals, the sample frame for the study comprises total healthcare staff of the hospitals which is 2577, including the nurses, medical doctors and biomedical wastes managers. These people were chosen because they form the vulnerable population and are direct users of the biomedical facilities. The sample frame for the wastes nurses, medical doctors, scavengers and waste managers and handlers including the senior and junior staff and other administrative staff were three hundred and forty six (346) from which the respondents were selected.

Morealso, two hospitals were purposively selected for the study, one from teaching hospital and the other from specialist hospital. The hospitals were selected based on the degree of patronage, method of waste disposal, specialization, and size of the hospital. This was because, the hospital with the highest patronage such as University of Nigeria Teaching Hospital will inevitably generates huge quantity of waste.

4.6.1 Sampling size and techniques

The sampling techniques used in selecting the hospitals were based on purposive sampling. The hospitals were selected based on their specialization, size and quality of waste generated. According to Enugu State Ministry of Health, Enugu State has about 366 hospitals, 2 Specialist Hospitals, two Teaching Hospitals, 36 healthcare centers and clinics. The hospital selected for this study is University of Nigeria Teaching Hospital and National Orthopaedic Hospitals Ituku/Ozalla. University of Nigeria Teaching Hospital Ituku/Ozalla was selected because it was one of the Teaching Hospital in the study area having huge healthcare facilities and hence, generated huge quantity of wastes on daily bases. This is as a result of constant patronage of patients to the hospital on daily bases while the National Orthopaedic Hospital Enugu was chosen because it was one of the Specialist Hospitals in the study area and they also generate a special type of hazardous waste which must be disposed with care in order not to constitute danger to the general public.

4.6.2 Sample Size Determination

The sample size is determined using the Yaro Yamane's formula

where $$n = \frac{N}{1+N(e)^2} \qquad (4.1)$$

n = Sample size

N = Population size

e = margin of error (5%; 0.05)

$$n = \frac{2577}{1+2577(0.05)^2} = \frac{2577}{1+2577(0.0025)} \qquad (4.2)$$

$$n = \frac{2577}{7.4425} = 346\,respondents$$

Using the Yaro Yamane's Formula, Sample size is approximated to 346 respondents.

4.6.3 Questionnaire Distribution

Using the information from the ethical clearance committee of the hospital via Ministry of Health, Enugu Chapter, the selected hospitals have a total of 2577 Healthcare Staff. Using the Yaro Yamane's formula, a population of 346 was deduced approximately. Then, copies of 346 questionnaires were administered to healthcare staff, comprising of 89 administrators, 104 Doctors/Nurses, 87 scavengers/waste handlers and 66 other healthcare staff. The questionnaire were administered by the researcher and it consists of questions of their knowledge and practice of health care waste disposal and management, hospital waste management policy, special budget for waste management, training of waste management staff, knowledge and practice of waste handling, segregation, color coding, waste treatment and waste management.

Stratified random sampling techniques was used to select the respondents. Out of the 346 administered questionnaire, 26% of the total number administered samples (346) representing 89 administrators, 30% representing 104 doctors/nurses, 25% representing 87 orderlies/waste handlers and 19% representing 66 other healthcare staff. The choice of percentage distribution used was as a result of unequal distribution of the respondents.

For proper assessment on the toxicological and health impact of improper disposal and management of healthcare waste of the selected hospitals, the researcher interviewed the various heads of Departments of the hospitals administration face to face. Oral methods assessment was used to obtain accurate information on the researcher topic while laboratory analysis were carried out to confirm the accuracy of the information given by the healthcare management of the chosen hospitals.

4.7 Research Instruments/Statistical Tools

One-Way Analysis of Variance (ANOVA) was used to test for the interaction between the leachate and soil, plants and water of the study area. **One-way analysis of variance** was also use to compare the difference between genotoxicity and mutagenicity of biomedical wastes and wastes disposal. Linear trend analysis was used to determine the hydrodynamic solute dispersion trend of the heavy metals in soil and water samples in the study area. Moreover, One Way Analysis of Variance was used to test for the physiological and bacteriological parameters of heavy metals on vegetable grown around the hospital waste dump. And also to test for the interaction between the leachate and rats from the hospital vicinity. While Kruskal-Wallis test was used to compare the health implications of improper disposal of hospitals waste and method of waste disposal in the study area.

4.8 Validity/Reliability of Research Instrument

Instrument validity involves the truthfulness of an instrument in measuring what the researcher wishes or attempts to measure, while instrument reliability involves the consistency of an instrument in ensuring that subsequent measurement give approximately the same numerical status (Green, 1975). In this research, a pilot survey was carried out in order to garner relevant information for the study to validate the instrument. Validity of the instrument was ensured with my supervisor that who assessed and approve the instrument as being capable of measuring what the researcher attempts to study before final copies were distributed.

In the same vein, the recorder ensured adequate guideline to the respondents during the distribution of the questionnaire; this increased accuracy of the information gathered, the cooperation of the respondent with the researcher ensured immediate completion of questionnaire and as such made the information obtained reliable.

Reliability was achieved by adopting the test-retest method (sampling the same respondent with the same question twice). This involves administering the same instrument twice to the subjects (evaluation of toxicological and health implication of improper healthcare wastes disposal and management) during data collection to assess and ensure consistency in their responses. In the test of reliability, Cronbach Alpha was used to determine the level of internal consistency of the responses of respondents. This was used to determine the consistency of the respondents for decision making. Inconsistent responses cannot be used for decision making as may lead to wrong conclusion. Using Cronbach Alpha at 5% level of significance, Alpha value less than 0.60 is said to be weak and value greater than 0.60 is said to be strong.

4.9 Methods of Data Collection

4.9.1 Collection of Surface Water Sample

The surface water samples were collected from four sampling points designated Sample A, Sample B, Sample C, Sample D and control. The water sample was collected from Ufom river which is located at Ozalla at University of Nigeria Teaching Hospital Enugu. For the National Orthopaedic Hospital Enugu the water was taken from Nvuna stream behind the hospital but very close to the dumpsite. Surface water samples for bacteriological, parasitological and physicochemical analyses were collected in clean sterile containers of 1liter. The samples were collected following the sampling method by standard for water collection as stipulated by (WHO, 2001). The method means sampling from the upper stream, middle stream, downstream and close to the dump with a control. The control water was taken above the waste dump at 5m away.

4.9.2 Collection of Soil Samples for the study

The samples were collected from different locations within the waste dump using hand auger tool at 20cm depth each according to (Obiakor and Okonkwo 2010). This will make it possible to get the actual pollutant and its level. The first soil sample was taken from the point source i.e. where the wastes were dumped. The second samples was taken at 5m away from the point source, the third sample taken at10m away from point source, the fourth taken 20m away from the point source. The whole samples were collected down slope from the waste dump in each of the study sites.

Based on the location, pollutants find their way down slope to the water supply of the study area and hence, polluting the water, soil and vegetables.

4.9.3 Collection of Vegetable Samples for the study

A total of 24 samples comprising three types of fresh vegetables each (water melon, garden egg leave and cucumber) were collected using simple random sampling technique from vegetable farms cultivated around the two Hospitals dump. Eight (8) recently matured leaves of water melon, garden egg leave and cucumber from three (3) different plants each were sampled following the method of Fisseha (1998). All the samples were collected in sterile universal containers and sterile plastic bags. The samples were immediately transported to Spring Board Laboratory Awka and Institute of Research Center, Zaria for the determination of heavy metals. The samples were cooled during transportation with ice box to keep the normal conditions of the microflora of vegetables.

4.9.4 Collection of Rat Samples for the study

Eight (8) rats were purchased at Zoology Department, University of Nigeria Nsukka. One of the rats was used as control. The rats were transported to the laboratory for acclimatization and analysis. During the period of acclimatization, the rats were fed with waste dump and water samples from each of the hospitals while the control was fed with sterile water for two week prior to the dissertation and analysis.

4.10 Method of Data Analysis

4.10.1. Bacteriological Analysis of Vegetables

The homogenate from sample preparation in buffered peptone water was used for the following procedures: total aerobic count, total coliform counts, and feacal coliform count using APHA standard analysis methods.

4. 10.2. Total aerobic count

Total viable count of all the vegetable samples was determined by plate count as described by APHA using standard plate count agar medium. Serial dilutions of the samples were done with 0.1% buffered peptone water; 1ml from each dilution (10^{-3} to 10^{-6}) was pour plated on standard plate count agar medium in duplicates. The samples were mixed by rotating, and then the samples were incubated at $37^{O}C$ for 24hr. After incubation, plates with colonies between 30-300 were counted and the readings recorded (Roberts and Greenwood, 2003).

4.10.3. Total coliform count

Total coliform count of vegetable samples were also determined by direct plate count as described in the standard method (APHA) using Eosin Methylene Blue Agar and Levine. Serial dilutions of the samples were made in 0.1% buffered peptone water; 1ml from each dilution (10^{-1} to 10^{-5}) was plated in duplicates. The plates were incubated at $37^{o}C$ for 24h. After incubation, plates with colonies between 30-300 were counted and recorded (Roberts and Greenwood, 2003).

4.10.4 Fecal coliform count

Serial dilutions of the homogenate were plated on Violet Red Bile Agar for fecal coliforms count (Oxoid). Plates were incubated at 30^{o}C for 24 hours. Then red to pink colonies, surrounded by precipitated bile, were counted as coliforms (Downes, 2001).

4.10.5 Parasitological Analyses of Vegetables

A portion of vegetables was weighted (100g for all cases) into plastic bags and washed with physiological saline solution (0.87% NaCl) and the washing water or saline was left for about 24hrs for sedimentation to take place. The supernatant was discarded and leaving 5ml of the residual. The solution containing the residual was centrifuged at 2000g for 5min. The supernatant was discarded and the residue carefully collected. The samples were agitated gently in physiological saline solution containing iodine, the samples were also examined in iodine stained (three for each sample) through light microscopy following the method of Erdogrul and Sener, (2005).

4.10.6 Determination of Heavy Metals in Vegetables Samples

Vegetable samples were washed in running tap water then with distilled water and carefully dried in oven at 70^{o}C for 24hr. Pre-weighed samples (200g for each) were ground in a pestle and mortar followed by wet digestion with HNO_3 and H_2O_2 (Tappi, 1999) in the ratio of 3:1.The samples were digested on a hot plate at a temperature of 93^{o}C for 4 hrs. Heating was done such that it did not boil. Heating was done till it dried up completely and whitish brown dry mass was obtained. It was then cooled and the digest mixture was extracted in acid water mixture (HCl: distilled water, ratio 3:1) and filtered through whatman filter paper. The filtrate was analyzed for the heavy metal content using AAS (GBC 932AA).

The recorded data were subjected to Analysis of Variance (ANOVA, appendixes 2a and b) to assess the influence of different variables on the concentrations of heavy metals and microbial contaminants in the vegetables tested. Significant difference between the values were evaluated at 95% confidence, $p<0.05$.

4.10.7 Chromosomal Preparation and Analysis

Chromosome preparations were made following the procedure described by Okonkwo and Obiakor (2010) using the liver and kidney, since they represent the first target organ for contaminant. More than 100 well- spread metaphase plates were analyzed for chromosomal aberrations at magnification of X400 oil immersion for all the groups, selecting 10-20 metaphases from each slide.

Eight (8) rat samples were collected from the hospital waste dump using cage trap and rat mat embedded with a glue. The rats were housed in stainless steel wire bottom cages and kept under constant environmental conditions. They were fed on fresh standard pellet and tap water throughout the study. All the rats were acclimatized for 1 week before the beginning of the experiment. The rats were divided in to five groups namely Group A, B, C and D. The four Groups were administrated with water polluted with the heavy metal at the range of 0.01 and 0.02 respectively. Group D was kept as the control and no administration was made except that the rat was constantly fed with distilled water prior to analysis.

4.10.8 Determination of the bioaccumulation factor of heavy metals

Bioaccumulation is a function of the bioavailability of contaminants in combination with organism specific uptake and elimination processes. Toxicity is determined by the exposure of an animal (rat) to bio-available contaminants in concert with the animal's sensitivity to the contaminant. These processes have been shown to be a function of the organism's lipid content, size, growth rate, gender, diet, and ability to metabolize or transform a given contaminant, as well as the chemical conditions of the surrounding medium. Other biological factors that can affect contaminant bioavailability include the burrowing and feeding behavior of the individual organism or species. The depth to which an organism burrows, the type of feeding mechanism it uses (filter feeding, particle ingestion), the size range of sediment particles it consumes, and its diet all have a large influence on the concentration of contaminant to which the organism will be exposed.

Bioaccumulation of metals in different water samples can be quantified by a bioaccumulation factor (BAF), which is the ratio of a substance's concentration in liver and kidney of the test organism (rats) to its concentration in the ambient water. Bioaccumulation factors (rates) were calculated for all rats collected and analyzed for joint concentrations during the study.

$$BAF = \frac{concentraton\ of\ metal\ in\ rats}{concentration\ of\ metal\ in\ water} \qquad (4.3)$$

Bioaccumulation factor help to tell us that the rates of bioaccumulation of pollutant by animal (rat) varies depending on the biological factors such as those mentioned above. From different scholars, rat bioaccumulate pollutant more than other animals and based on that they are often used as bio-indicator in monitoring of bioaccumulation effects of pollutant by animals Onwuemesi, (2012) and Obiakor, and Okonkwo, (2010).

4.10.9 Determination of the Pollution Index

Pollution Index (PI) is a way of assessing pollution levels by putting into considerations the joint effect of all polluting metals, Onwuemesi, (2012). The pollution index is calculated by finding the average ratios of metal concentration to the tolerance levels (Oje, 2008) or above the level that it causes or become unsafe for human health (Oje, 2008 quoting Ezeh *et al.*, 2008). It is calculated thus:

$$pollution\ Index\ (PI) = \frac{1}{n}\left(\frac{M_1}{(TL_1)}\right) + \left(\frac{M_2}{(TL_2)}\right) + \left(\frac{M_n}{(TL_n)}\right) \ldots (Oje, 2009) \qquad (4.4)$$

where

M_1, M_2 …..Mn are the average concentrations of the polluting metals

TL_1, TL_2 ….TLn are the tolerable levels for each metal

“n” is the number of polluting metal considered.

A pollution index of more than 1.0 indicates that average metal concentration are above the permissible limit and therefore toxic.

4.10.10 Determination of bioconcentration of heavy metals

Bioconcentration is the uptake of a contaminant from water by test organisms where water is the only pathway. Bioconcentration factors (BCFs, expressed as L/kg of tissue) are based on laboratory studies of organisms exposed to water containing a chemical of concern. It is calculated thus;

$$BCF = \frac{Ct}{Cw} \tag{4.5}$$

Where

Ct is the concentration of a contaminant in the organs of the organism

and Cw is the concentration in water (mg/L).

4.10.11 Hydrodynamic Dispersion of Solute (Heavy Metal) in soil using Triple Vector Product Model

Hydrodynamic dispersion is the transportation of solute such as heavy metals by advective fluid flowing through the solute point source. The solute is dispersed through the porous media of the soil which depends on the permeability (effective porosity) of the soil containing the solute. The advective fluid which is water in the study area depletes the solute concentration from the point source down the valley flow direction.

A mathematical model of the depleted solute (heavy metal) concentration is modelled using triple vector product. Numerous authors used differential calculus involving time, depleted solute concentration, and porosity of the soil medium to model hydrodynamic solute dispersion, (Berkowitz, 2002, Duriez, 20005 and Chou and Wyseure (2009), but in this model, the depleted solute (heavy metal) concentration and Cartesian plane are used for the modelling. A boundary limit condition is also imposed on the upstream side of the Cartesian coordinate plane containing the solute point source to show the background value of the solute. The hydrodynamic dispersion of the solute (heavy metals) can therefore be modelled using a linear trend surface down the topographic valley of the study area. The mathematical equation of the solute trend surface is obtained using Triple Vector Product model. A Triple Vector product gives a volume of a parallepiped (extended parallelogram) with three sides. However, if the volume of the parallelpided is equated to zero, it gives a plane surface which defines the base of the parallelpided.

Let the Triple Vector Product be expressed by:

$$\vec{u} \cdot \left(\vec{v}\; x\; \vec{w} \right) = 0$$ (Murrayy, 1974) equation (4.6)

Where

$\underset{U}{\rightarrow}$ = is any tangent position vector $\underset{U}{\rightarrow} [x, y, c]$ on the trend surface.

$\vec{v}$ = is a positon vector with components (x_1, y_1, c_1)

$\vec{w}$ = is a positon vector with components (x_2,y_2,c_2)

Where c_1 and c_2 are depleted solute concentrations and x_1,y_1,x_2,y_2 are the Cartesian coordinates of the depleted solute concentrations.

In determinant form the triple vector product $\vec{u} \cdot (\vec{v}\, x\, \vec{w})$ is expressed as

$$\vec{u} \cdot (\vec{v}\, x\, \vec{w}) = \begin{vmatrix} x & y & c \\ x_1 & y_1 & c_1 \\ x_2 & y_2 & c_2 \end{vmatrix} = 0 \qquad (4.7)$$

$$\therefore\ x\ (y_1 - c_1 y_2) - y(x_1 c_2 - c_1 x_2) + c\,(x_1 y_2 - y_1 x_2) = 0 \qquad (4.8)$$

Rewriting equation 4.8 we have:

$$c\,(x_1 y_2 - y_1 x_2) = -x(y_1 c_2 - c_1 y_2) + y(x_1 c_2 - c_1 x_2) = 0 \qquad (4.9)$$

solving for solute concentration C in the determinant form, the solute concentration are obtained as;

$$\therefore \quad c = -x\left(\frac{y_1 c_2 - c_1 y_2}{x_1 y_2 - y_1 x_2}\right) + y\left(\frac{x_1 c_2 - c_1 x_2}{x_1 y_2 - y_1 x_2}\right) = 0 \qquad (4.10)$$

Equation 4.10 is the fitted trend surface of the depleted solute concentration in the study area. The calculated values of the solute concentration C for different heavy metals (Pb and Cr) were contoured using surfer 14 version to produce 3D and surface dispersion distribution in the areas, as shown in figures 5.1 to 5.8.

Differentiating equation 4.10 we obtain the solute concentration gradient ∇c.

$$\nabla c = \frac{i\,dc}{dx} + j\frac{dc}{dy} \qquad (4.11)$$

Where i and j are unit vectors in x and y directions.

$$|\nabla c| = \sqrt{\left(\frac{dc}{dx}\right)^2 + \left(\frac{dc}{dy}\right)^2} \qquad (4.12)$$

Where ∇c = solute concentration gradient vector.

$|\nabla c|$ = modulus of the solute concentration gradient vector.

The solute concentration c in equation 4.7 is therefore calculated at different points in the study area. The results are tabulated in Appendices A and B and they are also used to produce concentration contour levels in the study areas.

4.10.12: Boundary Conditions of the Hydrodynamic solute dispersion model developed in this dissertation.

Boundary conditions are used to fixed field boundaries for which a model is valid. In this dissertation, two boundaries were imposed for the validity of the hydrodynamic solute dispersion in soil in the study areas of National Orthopaedic Hospital Enugu and University of Nigeria Teaching Hospital Ituku Ozalla.

For National Orthopaedic Hospital:

(i) The solute concentration c = 2.60ppm (concentration at point source).

When y = 75m.

(ii) The solute concentration c = 0.06ppm (concentration at the control points

when y = ≥ 82m.

at the up valley behind the point source).

For University of Nigeria Teaching Hospital Ituku Ozalla:

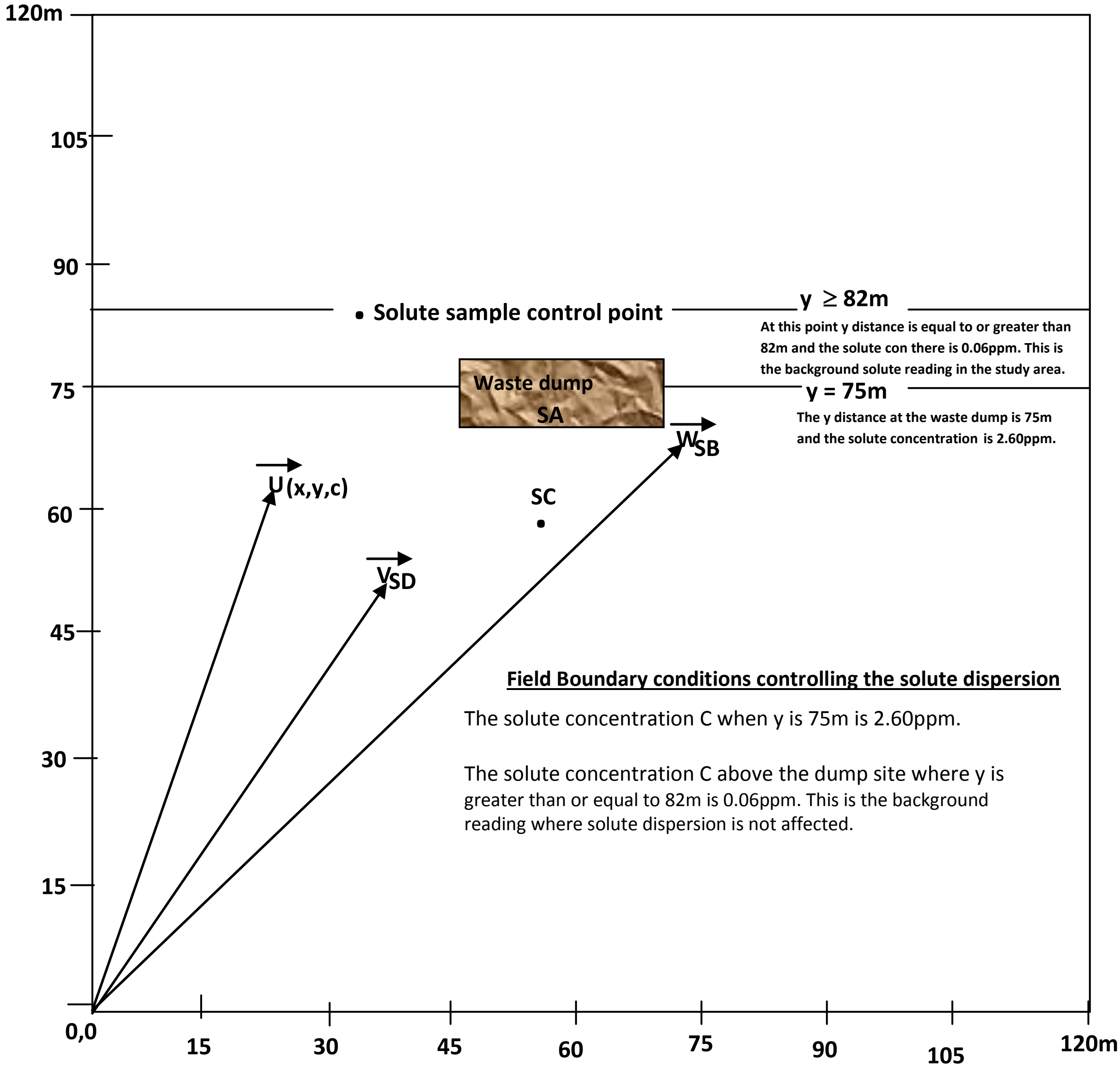
(i) The solute concentration c = 1.95ppm (concentration at point source).

When y = 140m.

(ii) The solute concentration c = 0.001ppm (concentration at the control points

when y = ≥ 150m.

at the up valley behind the point source).



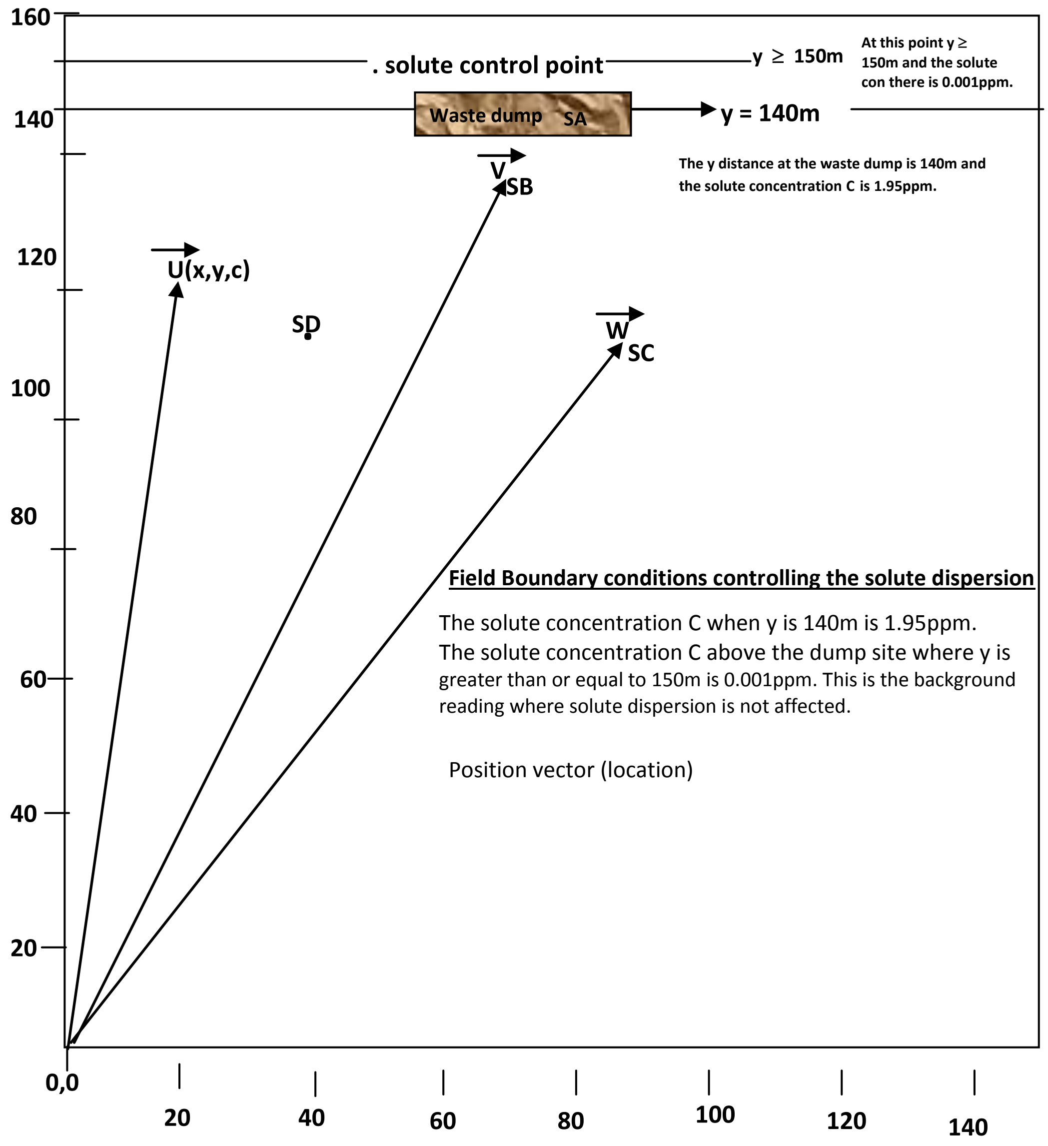
Source: Author's computation, 2017

Where:

$\vec{V}$ and $\vec{W}$ are position vectors from the origin (0,0) at sample locations containing specific value components of x and y coordinates and solute concentration C.

$\vec{U}$ is arbitrary tangent vector containing components x and y coordinates and concentration C. SA, SB, SC and SD are soil sample locations.

Fig. 4.4 Mathematical model for Triple Vector Product computation of the Hydrodynamic dispersion of Pb in water at National Orthopaedic Hospital Enugu



Source: Author's computation, 2017

Where:

$\vec{V}$ and $\vec{W}$ are position vectors from the origin (0,0) at sample locations containing specific value components of x and y coordinates and solute concentration C.

$\vec{U}$ is arbitrary tangent vector containing components x and y coordinates and concentration C.

SA, SB, SC and SD are soil sample locations.

Fig. 4.5 Mathematical model for Triple Vector Product computation of the Hydrodynamic dispersion of Pb in soil at University of Nigeria Teaching Hospital, Ituku/Ozalla, Enugu.

4.11 Statistical Analysis

The statistical tests used in this dissertation include One Way Analysis of Variance, Principal Component Analysis, Inter-Variable Covariance and Correlation.

4.11.1 Analysis of Variance (ANOVA)

This statistical tool were employed to test hypotheses 1,2,3 and 4. Objective 1,2, 3 and 4 which were derived from research questions 1,2,3 and 4. They were translated into null hypotheses. These hypotheses includes:

1.6 Research Hypotheses

Ho: There is no significant interaction among the leachate, soil, plants and water of the study area.

Ho: The hydrodynamic solute dispersion trend of the heavy metals in soil and water samples in the study area do not significantly differ.

Ho: The parasitological and bacteriological parameters of heavy metals on vegetable grown around the hospital waste dump do not vary significantly.

Ho: there is no significant difference between the leachate and rats from the hospital vicinity.

ANOVA is a statistical technique utilized in partitioning of variations in an observed data into its various sources. It breaks down the total variation occurring in a dependent variable into various separate factors causing the variation. This technique does not stipulate any functional differences between the dependent and the independent variable.

Assumptions: Each group is an independent random sample from a normal population. Analysis of variance is robust to departures from normality, although the data should be symmetric. The groups should come from populations with equal variances.

The equation for simple ANOVA is stated as follow:

$$SST = \sum(X^2) - \sum(X^2) \qquad (4.13)$$

$$SSB = \frac{\sum(X_1)^2}{N} + \frac{\sum(X_2)^2}{N} + \frac{\sum(X_3)^2}{N} + \frac{\sum(X_4)^2}{N} \qquad (4.14)$$

Where

SST = Total Sum of Squares (perception of residents on effect of improper disposal of biomedical wastes on environment).

SSB = Between Sum of Squares (perception of residents on effect of improper disposal and management of biomedical wastes on environment from the two selected hospitals).

SSW = Within Sum of squares (perception from different locations within groups)

4.12 Global Positioning System (GPS)

Global Positioning System was operated by the researcher by holding the GPS facing the sky as the power button unit is turned on. At a spot close to the dumpsite, water and rat sampling with a distance not less than 1 meter data were captured. The sky view page showed the graphical tracking satellites and the strength of the satellite signals, the coordinates and depths measurement was also displayed. This is recorded as the power button is turn off. The same procedure was repeated in subsequent spots to record the measurement. It were turned off to enable the initial records to be wiped off completely without interfering with other subsequent measurement.

4.12.1 Procedure for Processing Imagery

Appropriate remote sensed data was processed by a GIS expert using digital image processing technique, and finally produced the land use map of the study area. The GIS expert also did a visual interpretation of the land-use map which was followed by supervised interpretation and classification of the land-use features.

4.12.2 Land-use/ Land-cover classification

For this study, supervised classification was adopted for definition of clusters because of the researcher's knowledge of the study area. This knowledge can be obtained from general knowledge of the area using aerial photographs or map or field visit.

Igbokwe (1996) summarizes the operation of carrying out supervised classification into the following:

i. Adoption of suitable object categories.
ii. Training over representative areas.
iii. Extraction of statistics of the training areas.
iv. Feature selection.
v. Selection of suitable classification algorithm.
vi. Classification of the image into object categories.
vii. Accuracy assessments.

Adoption of suitable object categories: The adoption of suitable object categories depend on the area being mapped, the spectral resolution of the image data, as well as the knowledge of the land cover of the area. After a pre-classification visits to the site and based on these factors, the following classes were adopted as given in Table 4.1.

Table 4.1 Description of classes adopted.

S/N	Type of Land cover	Descriptions	Colour Assigned
1.	Built-up Areas	This includes industrial, Commercial Residential and other related built-up areas	Red
2.	Open Spaces	Sand deposit, unpaved roads, excavation sites	White
3.	Vegetation	This includes coniferocius and deciduous trees, forest covers e.t.c. It also includes green urban areas such as cultivated crops	Green
4.	Waterbodies	Water related features such as water course, estuaries, Rivers	Blue

Source: Researchers field work, 2017.

Training over representative areas: Training fields are areas of known identity delineated on the digital image, usually by specifying the corner points of a rectangular or polygonal area using line and column numbers within the coordinate system of the digital image.

Enugu State street guide map was used as a reference data in selecting the sample set prior to field visit. The researcher's knowledge of the study area also assisted in the selection of the sample sets. Several sites were visited (ground truthing) in the study area with respect to the four of the classes of landuse. Water bodies were not visited as the class is easily discernible from the image. A Garmin 76S handheld GPS was used to obtain the coordinates of the sample sites for the other landuse classes. These sample sites were used to define the training pixels in the computer using Erdas Imagine 9.2 software.

To begin the classification proper in Erdas Imagine 9.2, The LandSat-7ETM+ was classified using Erdas Imagine 9.2 software. The image to be classified was opened using the viewer menu bar of the Erdas Imagine 9.2. The Area of Interest (AOI) tool was used to collect signatures from the image to be classified. A signature is a set of statistics that defines a training sample or cluster. The signatures collected were added to the signature editor window. Efforts were made to ensure that the training areas or number of pixels are large enough to provide accurate estimate of the properties of each class and that they are not too large to include undesirable pixels of other class.

The computer was instructed to classify using maximum likelihood classifier as the classification algorithm. The algorithm computes the probability with which a given feature vector belongs to every feature class. That feature vector is assigned to the class which has the highest probability.

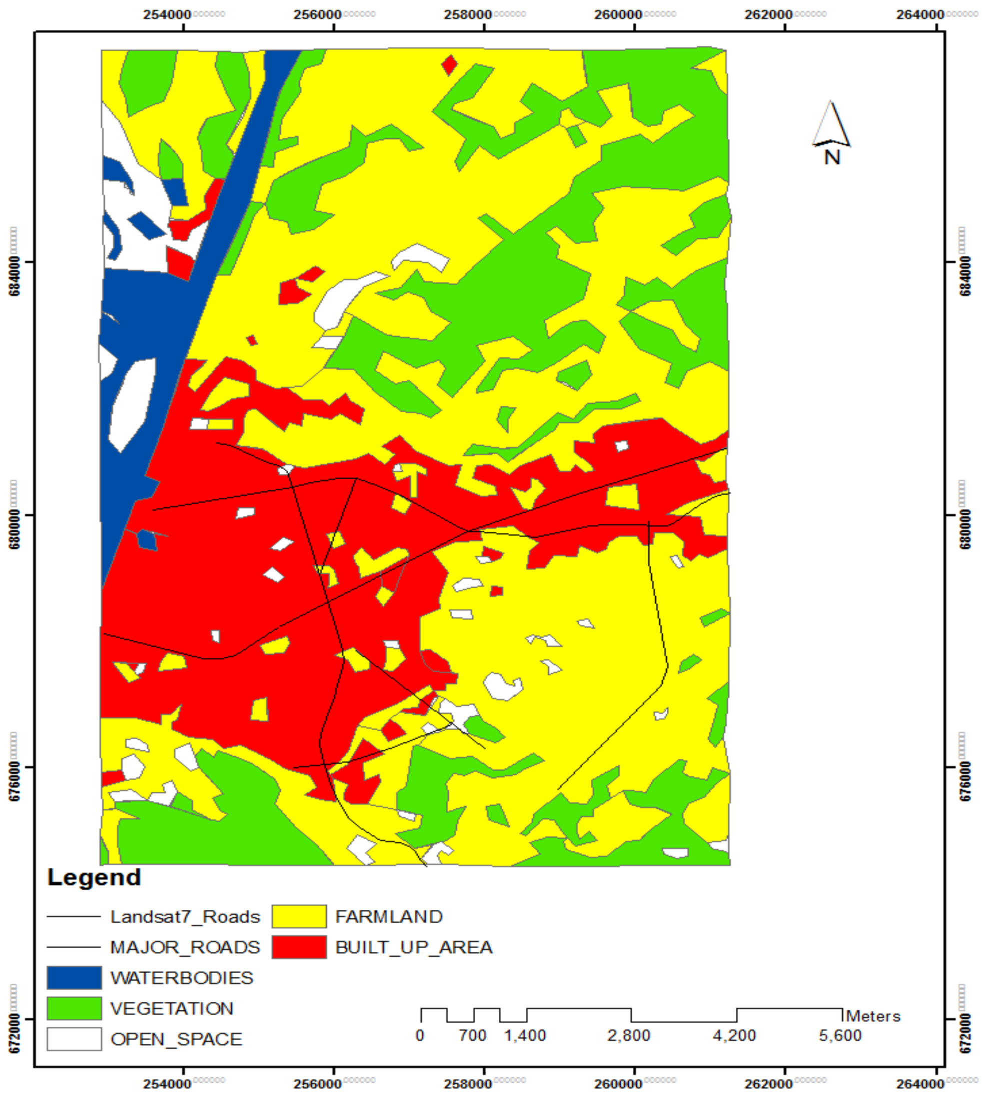


Fig. 4.6: Land-use land cover map of the study area.

Map 4.6 shows the landuse and land cover of the study area. It shows the physical characteristic of the study area where the samples were taken. It also showed the activities in use in the study area.

4.13 Methods of Data Analysis and Presentations

In this study, various methods of data display were employed in order to present the data obtained from field work in such a way that a layman can easily understand. Based on that, the researcher used graphs, tables, charts, bars and pictures to present the field data.

4.9 Ethical Clearance

The ethical committee of the two hospitals and healthcare workers were made to understand the purpose of the study which was purely for academic use. They were assured of utmost confidentiality of the data or information given for the success of the study. Approval to enable the conduct of the research at the selected hospitals were sort from the management of the two hospitals through the ethical clearance committee of the hospitals and it was granted (appendix 3).

CHAPTER FIVE

PRESENTATION AND DISCUSSION OF RESULTS

The discussions in this chapter were based on the laboratory analysis and information generated from the questionnaire. The computations from the raw data and the statistical tables were presented in Tables 5.1 to 5.15 where they were discussed in detail. However, the questionnaire in this study was presented in Appendix A while the raw data were discussed in the text, and the statistical analyses of the hypotheses presented in Appendices B and C respectively.

5.1 Data from the Questionnaire (Information on bio data):

Table 5.1 showed the percentage responses on the bio data of the respondents. From the table it was observed that the majority of respondents were men, representing 52.88% and men with 47.12%.

Table 5.1: Gender description

Options on gender	**Frequencies of respondents**	**Percentage**
Male	183	52.88
Female	163	47.12
Total	**346**	**100**

Source: Authors computation (2017)

Table 5.2: Age of the Respondents

Options on age interval	Frequencies of respondents	Percentage
20-24	28	8.09
25-29	38	10.98
30-34	102	29.47
35-39	48	13.87
40-44	57	16.47
45-49	39	11.27
50-54	19	5.49
55-59	10	2.89
60 and above	5	1.45
Total	**346**	**100**

Source: Authors computation, (2017)

Table 5.2 also showed information on the age bracket of the people in the area. It shows that majority of the sampled people fall within the active age group of 20 to 29 years accounting for 57.5%. This was followed by 30-49 years with 71.08% and 50 upwards with 9.83%.

Table 5.3: Literacy Status of the Respondents

S/No	Literacy option	Percentage	
1	No formal education	37	10.69
2	FSLC	61	17.63
3	GCE/WAEC/WASSC	73	21.09
4	OND	42	12.14
5	HND/DEGREE	59	17.05
6	Higher Degree (M.B.A., Ph.D)	74	21.39
7	**Total**	**346**	**100**

Source: Authors computation (2017)

The educational background level of the respondents were also ascertained using Table 5.3 to be tertiary group, 50.58%, secondary level

21.09%, informal group 17.63%, and others 10.69%. The implications of this are that majority of the respondents are educated which means that the level of awareness of the health consequences of pollution of groundwater with hospital waste is very high; and based on the awareness, they should be against illegal dumping of hospital waste with municipal wastes on the environment without prior treatment which could lead to various health problems.

TABLE 5.4 Duration of stay

S/No	**Duration**	**Percentage**	
1	1-5 years	140	40.46
2	6-10 years	105	30.35
3	11-15 years	68	19.65
4	16-20 years	22	6.39
5	21years and above	11	3.18
6	**Total**	**346**	**100**

Source: Authors computation (2017)

The duration of stay at the study area was ascertained to be more than 5 to 6 years (Table 5.4), which is also a good point that indiscriminate disposal of hospital waste has effect on the populace of Enugu state due to long stay in the environment.

TABLE 5.5: Data on the Profession

S/No	Profession option	Percentage	
1	Medical Doctor	79	22.83
2	Nurse	94	27.17
3	Medical lab scientist	43	12.42
4	Pharmacist	53	15.31
5	Waste manager/handler	58	16.76
6	Others	19	5.49
7	**Total**	**346**	**100**

Source: Authors computation (2017)

Table 5.5 showed information on the occupation of the resident of Enugu area. Moreover, Table 5.5 showed that the study area had more doctors and nurses representing 50.0% of the respondents with waste handlers representing 16.76%. It also shows that majority of the dwellers are civil servants and waste handlers 5.49% with medical lab scientist and pharmacist have the value of 27.73%.

5.2 Surface water Quality of University of Nigeria Teaching Hospital Ufam River:

This section discusses the quality of surface water collected from University of Nigeria Teaching Hospital Enugu (UNTH). The result is shown in Table 5.7 and the discussion presented.

In Table 5.7 the major source of domestic water in UNTH hospital were ascertained from the responses of the respondents to be surface water and it was testified that the residents used the water for domestic purposes. If this water are not treated before use, it could lead to water borne diseases in the area. The presence of heavy metal deposit in the water samples could be as a result of deposition of wastes on the environment which flows down into the dam especially during the rainy season.

The respondents' response include; 89% of the respondents strongly agreed that surface water is the major source of drinking water in the study area. Among the respondents, 6% were not sure of the sources of drinking water in the area while 4.7% disagree to surface water as the major source of their drinking water. Table 5.7 also show that there are noticeable changes in the water quality from the laboratory result. It showed that the taste and colour of the water changes as a result of the presence of contaminants. The colour changes from dark brown to light brown, this was further studied in the laboratory to confirm the authenticity of the findings as shown in Table 5.7.

TABLE 5.6: Physicochemical Parameter of Surface Water from UNTH Enugu in (ppm).

Parameters (ppm)	Sample A Point source	Sample B 5m away	Sample C 10m away	Sample D 20m away	Control sample	WHO Std.
Ph	7.70	7.35	7.25	6.90	68.1	7.0
DO (mg/l)	1.40	1.16	1.13	1.11	1.03	1.07
BOD (mg/l)	0.80	0.40	0.23	0.20	0.06	0.22
COD(mg/l)	3.71	3.10	1.72	1.10	1.22	1.45
Turbidity (NTU)	9.70	7.00	3.90	3.10	6.00	6.5
Nitrate (mg/l)	9.10	5.90	3.50	3.00	26.05	4.0
Sulphate (mg/l)	6.50	3.90	2.50	2.30	1.46	2.76
Phosphate (mg/l)	3.30	3.10	1.00	0.90	0.27	1.7
Temperature (^{0}C)	26	24	24	22	16	23.5
Color	Dark	Light	Brown	Light	Light	-
Ammonia(mg/l)	1.41	1.36	1.26	1.21	1.21	1.35
Chloride (mg/l)	27.53	27.44	27.31	27.11	18.03	20.4
Alkalinity (mg/l)	67	66	62	61	57	60
Copper (mg/l)	0.08	0.08	0.07	0.06	0.002	0.03
Iron	0.48	0.43	0.31	0.20	0.01	0.02

Source: Authors computation, (2017).

The physicochemical parameters of UNTH dam water was shown in Table 5.6. The water collected from the dam were noticed to be alkaline with the pH values between the ranges of 7.25 to 7.35. The water sample from Sample A and B showed deviations in high concentration levels of turbidity than the acceptable standards with 9.70 except the level of turbidity in sample C and D was below the recommended standard. Moreover, the level of sulphate were also shown to be very high in Sample A and B but a slight reduction in Sample C and D, while the level of phosphate showed deviation in high concentration levels in A, B and C but Sample D was below the control. The level of ammonia was also ascertain, and Table 5.6 shows that the level of ammonia were high in all the groups. In line with the above, the level of alkalinity was observed to be higher in the whole samples as well as copper and iron concentrations. This was in agreement with work of different scholars like Oje, (2008); Aroh, (2003); Onyedika, (2008) and Nduka *et al.*, (2006). The implication of the above findings shows that the water from the study area should be sterilized or boiled before drinking and using for other domestic purposes.

TABLE 5.7 Heavy Metal Concentrations in surface water from Uvuna stream at NOHE in (ppm).

Parameters (ppm)	Sample A Point source	Sample B 5m away	Sample C 10m away	Sample D 20m away	Control sample	WHO Std.	Health Impact
Chromium (Cr^{6+})	0.58	0.41	0.29	0.16	0.005	0.019	Cancer
Lead (Pb)	0.10	0.08	0.04	0.02	0.001	0.001	Cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems
Cadmium (Cd)	0.07	0.05	0.03	0.01	0.002	0.003	Cancer
Iron (Fe^{+2})	0.20	0.13	0.10	0.6	0.2	0.3	None
Manganese (Mn^{+2})	0.63	0.43	0.31	0.09	0.001	0.02	Neurological disorder
Nickel (Ni)	0.06	0.04	0.03	0.03	0.01	0.002	Possible cancer
Copper (Cu^{+2})	0.50	0.32	0.24	0.21	0.10	0.01	Gastrointestinal disorder
Aluminum	0.078	0.064	0.060	0.023	0.014	0.2	Potential Neuro-degenerative disorders
Cobalt	0.0245	0.0217	0.0153	0.0141	0.003	0.050	None
Arsenic (As)	0.091	0.0177	0.0154	0.0131	0.0027	0.01	Cancer

Source: Author's computation (2017).

Table 5.7 shows the level of pollutant migration from the point source to the last sampling point. It showed that as the sampling moves away from the point source, the reading reduces, showing that the source of the pollutant is from the site of the dump. Table 5.7 also showed that the concentration of Pb at point A (point source) was higher than the other points and that the concentrations of Pb at the whole sampling point were above the permissible limit of 0.01ppm by World Health Organization, (2006). Moreover, chromium (Cr) at both points were higher than the permissible limit of 0.05ppm. Virtually, most of the heavy metals analyzed exceeded the world health organization recommended limit and above the control samples, hence, the above water need to treated before use in order to reduce the health implications.

The above results was in line with the findings of Onwuemesi, (2012), the concentration of heavy metals in surface water of Ivo River as a result of mining activities in the area is a pointer that man is at risk of being infected with water borne diseases if the water is not treated before consumption. Moreover, Akanwa, (2011) carried out a study at Obosi dumpsite and found out that pollutant migrates as it moves away from the point source. She also supported the findings that the level of pollutant in water and soil samples from the study area could be as a result of indiscriminate dumping of wastes on Obosi environment. Based on the above, there is need for proper treatment of hospital wastes before disposing to the general waste dump site in order to eliminate the impact on the environment.

From Table 5.7 it can be clearly observed that Cr at point A was very high and start decreasing from point B which was sampled at 5m away from the point source. The decrease in concentration follows the same trend at point C, 15 meters away and point C, 20 meters. The result of the laboratory shows that the tested metals were higher than the permissible limit of metal concentration by WHO, (2006). The above result was in line with the work of Onwuemesi, (2012) which showed that Cr at the concentration of 0.01 at Ishiagu mining station was very high to compare with the standard. Moreover, Akanwa, (2014) also showed that the presence of Cr in water samples of Obosi area was as a result of wastes dump in the vicinity. The waters of UNTH, Ituku Ozalla should be treated before consumption and there is need for strict law against dumping of waste especially in water flow channel to minimize the consequence of health related problems that could result from such art. Health implications associated with indiscriminate dumping of wastes on environment have been observed by many scholars to include; cross infection, HIV, AIDs, hepatitis A and B, ebola virus and other deadly diseases, WHO, (2010). Hazardous wastes according to World Health Organization are special wastes that needs urgent, careful and serious attention by the general public and generators WHO, (2006). These type of wastes must be handled with care and disposed in the best manner for sustainability and to reduce its health risk to human and environment.

5. 4 Heavy metal concentration in surface water from UNTH

TABLE 5.8: Heavy metal concentration in surface water from UNTH

Parameters (ppm)	**Sample A** **Point source**	**Sample B** **5m away**	**Sample C 10m away**	**Sample D 20m away**	**Control sample**	**WHO Std.**	**Health Impact**
Chromium (Cr^{6+})	0.25	0.14	0.12	0.10	0.04	0.019	Toxic to kidney
Lead (Pb)	1.00	0.20	0.16	0.11	0.00	0.001	Cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems
Cadmium (Cd)	0.10	0.05	0.04	0.03	0.002	0.003	Cancer
Iron (Fe^{+2})	0.36	0.21	0.10	0.06	0.01	0.3	none
Manganese (Mn^{+2})	0.50	0.24	0.11	0.03	0.02	0.2	Neurological disorder
Nickel (Ni)	0.012	0.010	0.006	0.005	0.001	0.02	Possible carcinogenic
Copper (Cu^{+2})	0.3	0.29	0.25	0.21	0.00	0.01	Gastrointestinal disorder
Aluminum	0.201	0.144	0.033	0.026	0.004	0.02	Potential Neuro-degenerative disorders
Cobalt	0.311	0.226	0.171	0.162	0.003	0.050	None
Arsenic (As)	0.08	0.06	0.03	0.02	0.001	0.001	Cancer

Source: Author's computation (2017)

Table 5.8 showed the result of analysis from water samples collected from NOHE. Table 5.8 showed that the metal concentrations of the water samples analyzed were above permissible limit. The level of chromium concentration in the tested water sample from the National Orthopaedic Hospital showed that the dispersion of metals from the point sources decreases as the solute moves away. At the point source, the level of chromium concentrations was recorded to be 0.25ppm and at B,C, and D it decreases from 0.14 to 0.10 respectively. The level of concentration at the control was relatively higher than the permissible limit of 0.05ppm set by WHO, (2010). This was in line with the findings of Onwuemesi, (2012). Heavy metal disperses as the sampling moves away from the point source. It has been reported that exposure to chromium over an elevated period causes high blood pressure and kidney and DNA damage, and has been linked to asthma and bronchitis Onwuemesi, (2012). In support of the above, WHO (2006) showed that accumulation of Cr over period of time is very toxic to kidney. This according to WHO could lead to kidney damage and enlargement. Based on that, the disposal of hospital waste should be done using modern engineering technology of land line method where the dump site is cemented to prevent flow of leachate to water body.

The major pathways of this metal in the study area is from landfill leachates at the hospital dumpsite. This dumpsite was located cracked zone at the uphill valley to the flow of water direction. As a result water flows from the wastes through geologic unit of the area down the valley to the water body causing pollution of the water resources of the study area.

Furthermore, the Cd concentration in Table 5.8 showed that the four samples analyzed exceeded the 0.003 limit of the World Health Organization but the control sample was below the permissible limit. The concentration was observed to be highest at point A and B. This is of particular concern due to the strategic location of the well water and its use in diverse forms by respondents for consumption and for domestic animals. The elevated level of metals in the well water further implicates the magnitude of metal input from leachates resulting from National Orthopaedic hospital that deposited their wastes without treatment. In fact, significant levels of Cd were found in well tested at the dumpsite, although the concentrations of heavy metals in the sample decreased when the sampling distances from the dumpsite decreased.

In addition, the Pb concentration was ascertain to be higher than the standard with sample A, B and C recording higher with 1.00ppm, 0.20ppm and 0.16ppm respectively, while sample D and the control was slightly different with 0.11 and 0.001 for control. The above result showed that the disposal of hospital wastes on NOHE environment may affect water quality of the vicinity and hence make the water unfit for human consumption. This was in line with the work of (Oje, 2008, Onwuemesi, 2012 and Akanwa, 2014). Water for consumption should not contain trace of heavy metals because bioaccumulation of heavy metal in the body system is dangerous as it causes health related problems to the consumers. According to WHO (2006) accumulation of water polluted with Pb over a period of time could cause cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems. Based on this, the location of hospital waste at the study area should be changed to another confined area.

5.5 Heavy Metal Contamination of Vegetables

Three different types of vegetables water melon(*citrullus lanatus*), garden egg leave (*s. macrocarpon*) and cucumber (*cucumis sativus*) were analyzed for heavy metals content. Difference in metal concentration in vegetables seems to imply that different types of vegetables have different abilities to accumulate metals. Different types of vegetable species accumulate different metals depending on environmental conditions, metal species and plant available forms of heavy metals (Lokeshwari and Chandrappa, 2006).

TABLE 5.9: heavy metals in vegetable from the two hospitals in ppm

Parameters (ppm)	Type of plants	UNTH	NOHE	Control	FAO STD 2010
Pb	Water melon garden egg leave Cucumber	0.87 0.74 0.27	0.62 0.89 0.05	0.15 0.33 0.01	0.30
Cr	Water melon garden egg leave Cucumber	1.16 0.13 0.15	0.18 0.14 0.12	0.09 0.10 0.08	0.10
Mn	Water melon garden egg leave Cucumber	0.17 0.14 0.12	0.15 0.13 0.10	0.11 0.10 0.06	500.00
Ni	Water melon garden egg leave Cucumber	0.33 0.20 0.16	2.06 2.04 2.02	0.28 0.02 0.10	67.00
Co	Water melon garden egg leave Cucumber	0.16 0.24 0.36	1.27 2.08 2.05	0.14 1.00	50.00
Arsenic	Water melon garden egg leave Cucumber	0.04 0.01 0.03	0.01 0.01 0.02	0.001 0.001 0.002	0.10
Aluminum	Water melon garden egg leave Cucumber	0.06 0.29 0.23	0.02 0.11 0.23	0.001 0.09 0.19	-
Chromium	Water melon garden egg leave Cucumber	0.04 0.21 0.36	0.45 0.34 0.23	0.03 0.17 0.11	0.06 -
Cd	Water melon garden egg leave Cucumber	0.04 0.38 0.45	0.22 0.27 0.31	0.002 0.14	0.10
Calcium	Water melon garden egg leave Cucumber	0.161 0.145 0.026	0.132 0.111 0.140	0.121 0.010	-

Source: Author's computation (2017)

From Table 5.9, the analyzed samples showed that the concentration of Pb in cucumber ranges from 0.27-0.05ppm of wet samples. The concentration of Pb in water melon and garden egg leave was more than the maximum limit recommended by (FAO, 2010) in both hospitals with 0.87-0.62 and 0.74-0.89ppm of dry samples respectively. A similar study by Chove, 2006) showed that Pb concentrations ranged from 0.15 to 0.41 $mgKg^{-1}$ dry weight samples which was closer to the data obtained in this study. Other scholars like Yu, (2006) Miller (2004) and Farooq (2008) showed that high level of Pb concentration in samples could be deadly to human and hence, unfit for human consumption.

In contrast the concentration of Pb in the study was below the maximum limits. In agreement with the result, Fisscha (1998) reported that cucumber, garden egg leave and water melon were generally the least accumulator of heavy metals as compared to other vegetable. The amount of Pb in the leaves of these vegetable could be explained to be as a result of Pb uptake by the pH of soil and level of organic matter in the study area where these vegetables were grown.

The heavy metal concentration of chromium (Cr) was also ascertained in the table. The table further showed that samples contain traces of Cr in the two hospitals samples with water melon ranging from 1.16- 0.18ppm, garden egg leave 0.13-0.14ppm and cucumber 0.15-0.12ppm of the wet samples respectively. Comparing the concentration levels at National Orthopaedic Hospital and University of Nigeria Teaching Hospital Ituku/Ozalla, the result showed that water melon concentration at UNTH was 1.16ppm and at NOHE is 0.18ppm. This showed that the concentration was higher at NOHE but the vegetable cultivated at close to the two hospital dump contains heavy metal (pb) above the permissible limit and based on that, farming at the area should be discouraged and wastes treated before disposal.

In a similar study by Sharma (2006), it confirmed that heavy metal contents in different vegetables grown in the land irrigated with wastewater contains heavy metals as a result of wastewater. In the present study, the level of Cr in the samples from the hospitals dumpsite were observed to be within the permissible limits of 0.10 by FAO/WHO. The possible explanation of the above result is that the transportation of Cr in root is very slow. This was in agreement with the works of Skeffington (1996) and Baltrenaite and Butkus, (2004) accounting for the low levels of Cr in the tops of plant. The absorption of chromium to soil depends primarily on the clay content of the soil and, to a lesser extent, on waste and the organic content of soil according to them.

In line with the above, the concentration of cadmium in the samples were also ascertained. The table showed that the level of cadmium observed to be varying between 0.234 to 0.375ppm. From the table, it was observed that the concentration of Cd was higher in watermelon and lower in garden egg leave and cucumber. The concentration of Cr was relatively higher than the permissible limit in the three vegetables. In agreement with the present study findings, Prabu (2009) found that the Cd accumulation was more in leafy vegetables such as garden egg leave, lettuce, swiss chard and spinach. Similarly, Jamali (2007) also reported that the concentration of Cd in vegetable grown from domestic waste water was ranging between 0.14mgkg^{-1} spinach and

0.30mgkg^{-1} brinjal. Moreover, Demirezen and Ahmed (2006) analyzed various vegetables (cucumber, tomato, green pepper, lettuce, parseley, onion, bean, egg-plant, pepper mint, pumpkin and okra) from Turkey and reported that the Cd content (0.24-0.97mgkg^{-1}) was in high concentration and not suitable for human consumption in all the vegetables under study.

In addition, the level of Mn, Ni, Co, Arsenic, Aluminum, and Cobalt was investigated in the study. Table 5.9 further showed that accumulation of these metals in leafy vegetable could possibly lead to human health problems. From the table, the concentration of these metals were slightly above the recommended limit by FAO (2010). Table 5.9 further showed that the concentration of the heavy metals in the samples could be as a result of disposal of hospital wastes on the environment where the study vegetables were grown.

Furthermore, the bacteriological content of vegetable from the study hospitals were also analyzed in the Table 5.10 in order to show the concentrations of some bacteria in the leafy vegetable.

5.5 Bacteriological Content of Vegetables

The bacteriological content of vegetables from the studied hospitals were analyzed in Table 5.10.

TABLE 5.10: Bacteriological mean contamination of vegetable samples from NOHE and UNTH

Type of plant	No of examined sample	Total aerobic count (fµx10^6g-^{1}) in vegetables		Total coliform count (fµx10^5g-^{1}) in vegetables		Fecal coliform count (fµx10^4g-^{1}) in vegetables	
		NOHE	UNTH	NOHE	UNTH	NOHE	UNTH
Water melon	8	98.16	85.10	44.46	30.09	52.26	67.32
Garden egg leave	8	95.34	101.00	51.48	32.51	46.18	56.97
Cucumber	8	85.43	61.10	58.54	27.18	49.41	33.48

Source: Author's computation (2017)

Table 5.10 showed the bacterial mean concentration indicators in randomly selected samples of green leafy vegetables (water melon, garden egg leave and cucumber). This was done in order to check for total coliforms, feacal coliforms and total aerobic count. These bacterial indicators were enumerated on Eosine methyline blue Agar, Violet red bile agar and Plate count agar, respectively. The result showed high percentages of total aerobic count and total coliform counts in water melon collected from garden grown very close to the hospitals waste dump site. In addition, fecal coliforms in cucumber collected from the same site with garden egg leave have the least concentration of 85.43, 61.10, 58.54, 27.18, 49. 41 and 33.48 fµx10^4g^{-1} respectively. This can be attributed to improper disposal of hospital wastes on environment as can be observed in some scholars studies like Chiroma et al, (2014); Anjula, and L.

Sangeeta (2011), Dan'azumi and Bichi (2010) and Christopher, Miranda and Bassey (2009).

The implications of the result is that the bacterial counts recorded in the selected vegetables exceeded the International Commission on Microbiological Specifications for Food limits of 10^3 to 10^5 coliforms 100^{g-1} wet weight of vegetables usually consumed raw (ICMSF, 1998) and therefore, the vegetable from the study area should be cooked very well before consumption and not to be taken raw.

In line with the above, Cornish (1999), Keraita (2003) and Amoah (2005) reported high bacterial counts on lettuce produced in farms within Kumasi. The result was closer to the findings of Thunberg (2004) who showed a total viable count as $5.0x10^8$, $3.10x10^7$, and $2.0x10^6CFUg^{-1}$ for some selected leafy vegetables collected from various farm sites located very close to waste dump. This was in agreement with the present study as can been seen. Aerobic organisms reflect the exposure of the sample to contamination and the existence of favourable conditions for multiplication of microorganisms (Tortora, 1995). It was also noted by WHO/FAO that vegetables should not have a total aerobic count exceeding $4.9x10^6CFUg^{-1}$ which is the acceptable limit by some countries, Nigeria inclusive. The above result confirmed the present of bacterial contamination in the vegetable is as a result of increasing amount of hospital wastes dumped on the environment and also cultivation of vegetable very close to the dump site as a means of getting manure to the crops.

Supporting the above findings, the parasitological examination of the vegetables from the two hospitals were investigated as shown in Tables 5.11 and 5.12 respectively in order to further ascertain the level of contamination of the selected vegetables.

5.6 Parasitological content of vegetables

TABLE 5.11: Parasitological mean contamination of vegetables from UNTH Enugu

Type of plant	**No of samples examined**	***Ascaris lumbricaides* eggs (%)**	***Giardia cyst* (%)**
Water melon	8	1.6	1.86
Garden egg leave	8	2.18	1.78
Cucumber	8	1.37	1.76

Source: Authors computation (2017)

TABLE 5.12: Parasitological mean contamination of vegetables from NOHE

Type of plant	**No of samples examined**	***Ascaris lumbricaides eggs* (%)**	***Giardia cyst* (%)**
Water melon	8	3.33	1.35
Garden egg leave	8	4.00	2.18
Cucumber	8	2.25	1.46

Source: Authors computation (2017)

In the Tables 5.11 and 5.12, samples of vegetable collected from the two hospitals were examined and they showed positive for *Ascaris lumbricoides* eggs and *Giardia* spp. cysts. The result shows that the eggs of *Ascaris* were detected in 9.60% of the vegetables examined. These include 33.3% water melon, 4.0% garden egg leave and 2.25% cucumber. *Giardia* cysts were detected in 4.99% of fresh vegetables examined. These include 1.35% of water melon, 2.18% of garden egg leave and 1.46% cucumber samples. The implication of the result is that the percentages of these parasites on the vegetables sampled suggests a risk of human infection, since parasites which exist in association with these vegetables are capable of infecting human; especially *Ascaris lumbricoides* eggs that are highly prevalent. This was in line with the study carried out by Robertson and Gjerde, (2000). Choi and Lee (1992) in Korea reported that *ascaris* eggs were found to be the highest (49.0%) among lettuce (*Lactuca sativa*), young radish(*Raphanus sapivus*) and Chinese cabbage (*Brassica pekinensis*) where Chinese cabbage showed the highest degree of contamination (91.1%) and lettuce being next(49.0%) in positivity of *ascarid* eggs. A study from Saudi Arabia also reported the detection of *Ascaris lumbricoides* in 16% of leafy vegetables examined which was lower than the present study (Al-Binali, 2006). The result reveled that in both hospitals, wastes are dumped very close to the garden site and that most inhabitants ignorantly use the sites as a means of getting manure to their vegetables and hence the increase in the number of intestinal parasites.

In order to further verify the health implications of these metals from the study area, the concentration of the metals were tested in the liver and kidney of the eight selected rats for the study. The rats were fed with waters from the study area and waste from the hospitals for the period of two (2) weeks. This was shown in Tables 5.13 to 5.16 respectively.

5.7 Bacteriological examination of Rat Liver

From literature, examination of effects of heavy metals on human can be easily ascertained by the use of some animals that have the same physiological characteristics with man. Again, rats are capable of transmitting diseases to man through food chain, hence, the use of rat for this study.

TABLE 5.13: Bacteriological content of heavy metals in the Liver of rat samples fed with water from NOHE

Parameters (ppm)	RAT A	RAT B	RAT C	RAT D	CONTROL
Pb	0.03	0.02	0.02	0.01	0.01
Cr	0.147	0.144	0.136	0.132	0.045
Hg	37.159	34.39	32.362	30.33	26.65
Ni	0.986	0.869	0.698	0.692	0.365
Cu	18.5	18.5	17.6	16.9	10.65
Mg	6.20	6.17	6.13	5.50	4.76
Cd	0.190	0.189	0.188	0.186	0.087
Co	0.198	0.196	0.188	0.186	0.155
Al	0.428	0.320	0.211	0.174	0.043
As	2.59	2.57	2.50	2.49	2.43

Source: Authors computation (2017).

Table 5.13 showed the level of metal concentrations in the liver of rats analyzed for the present of bacteriological contamination from NOHE. From Table 5.13, the level of Pb was slightly above the permissible limit with sample A rating highest and sample D rating lowest. The presence of Cr in the liver of the rats also showed some traces of contamination with all the samples exceeding the limit. It was again observed that the concentration of Hg in sample A was higher to compare the other groups. Ni was also ascertained to have traces of heavy metal concentrations in both samples. Cu, Mg, Cd, Co, Al, and As were also found to be contained in the samples. Since the heavy metal levels in the body of the tested rats increased when fed with water from around the waste dumpsite, it implies that if man ingests water from around the dumpsite, the heavy metal concentration of his body will also increase. Based on the findings, sitting of hospital wastes close to water body (UNTH) or in a porous media/fractured zone (NOHE) should be discouraged and prohibited. Again, illegal and indiscriminate dumping of hospital wastes in an open environment should discouraged and monitored.

TABLE 5.14: Bacteriological content of heavy metals in the Liver of Rat samples fed with water from university of Nigeria Teaching Hospital, Enugu

Parameters (ppm)	RAT A	RAT B	RAT C	RAT D	CONTROL
Pb	1.06	1.05	1.03	1.01	0.02
Cr	0.149	0.147	0.142	0.139	0.045
Hg	38.26	36.87	34.32	33.24	26.65
Ni	0.831	0.810	0.761	0.697	0.365
Cu	18.9	17.8	16.9	16.3	10.65
Mg	6.72	5.86	5.69	5.61	4.76
Cd	0.198	0.192	0.179	0.137	0.087
Co	0.199	0.198	0.196	0.192	0.155
Al	0.174	0.176	0.092	0.052	0.043
As	2.81	2.62	2.59	2.12	2.43

Source: Authors computation (2017).

Table 5.14 shows the level of metal concentrations in the liver of rats analyzed for the present of bacteriological contamination from UNTH. From the table, the level of Pb was slightly above the permissible limit with sample A rating highest and sample D rating lowest with 0.139. The presence of Cr in the liver of the rats also showed some traces of contamination with all the samples exceeding the limit 0.045 set by WHO. It was again observed that the concentration of Hg in sample A (38.26) was higher to compare the other groups with 36.87, 34.32. 33.24 and 26.65 respectively. Ni was also ascertained to have traces of heavy metal concentrations in both samples. The concentration of Cu at the samples were examined and found out that the four samples were above the control with 18.9, 17.8, 16.9 and 16.3 respectively and the concentration for the control is 10.65. Mg, Cd, Co, Al, and As also follow the same trend in the tested samples. Since the heavy metal levels in the body of the tested rats increased when fed with water from around the waste dumpsite, it implies that if man ingests water from around the dumpsite, the heavy metal concentration of his body will also increase. Based on that, consumption of water contaminated with heavy metal is unfit for human since it could lead to health problems.

5.8 Bacteriological examination of Rat Kidney

The kidney of the selected rats were further investigated to further verify the concentrations and also compare the results. From Tables 5.15 and 5.16, the level of heavy metals from the samples also exceeded the recommended limit showing that when man ingested water from the study area, the presence of the heavy metal in the water could have adverse effect on human.

TABLE 5.15: Bacteriological content of heavy metal in the Kidney of Rat samples fed with water from National Orthopaedic Hospital, Enugu

Parameters	RAT A	RAT B	RAT C	RAT D	CONTROL
Pb	3.98	3.97	3.91	3.67	0.02
Cr	0.376	0.375	0.371	0.370	0.045
Hg	39.281	39.020	38.238	33.266	26.65
Ni	2.02	2.01	2.01	2.00	0.365
Cu	14.40	13.21	13.09	13.02	10.65
Mn	4.06	4.05	4.00	0.03	4.76
Cd	1.47	1.42	1.41	1.39	0.087
Co	0.388	0.382	0.381	0.361	0.155
Al	0.184	0.171	0.169	0.163	0.043
As	1.91	1.86	1.83	1.86	2.43

Source: Authors computation (2017)

Bacteriological examination of kidney in the rat samples fed with effluents from NOHE and UNTH was ascertained to support the result of the above findings which showed an indicator that contamination of environment with hospital wastes could lead to disruption of body system of an organisms (rat) and hence its possible effects on human. This was verified using Tables 4.15 and 5.16 respectively.

TABLE 5.16: Bacteriological content of heavy metal in the Kidney of Rat samples fed with waters from University of Nigeria Teaching Hospital, Enugu

Parameters	RAT A	RAT B	RAT C	RAT D	CONTROL
Pb	3.99	3.86	3.69	3.57	0.02
Cr	0.398	0.392	0.377	0.369	0.045
Hg	33.216	34.129	34.127	32.236	26.65
Ni	2.04	2.02	2.01	2.00	0.365
Cu	15.01	14.01	14.03	13.22	10.65
Mn	4.02	4.09	4.07	4.05	4.76
Cd	1.42	1.40	1.36	1.31	0.087
Co	0.380	0.371	0.369	0.361	0.155
Al	0.202	0.112	0.100	0.082	0.043
As	1.91	1.88	1.86	1.83	2.43

Source: Authors computation (2017)

Tables 5.15 and 5.16 showed the bacteriological content of selected heavy metals for the study. The findings from the tables showed that Pb, Cr, Hg, Ni, Cu, Mn, Cd, Co, Al and As were above the permissible limit of FAO (2010) while the controls showed no content of the tested metals. Kidney and liver are the first target organs by metals in animal, hence, the use of kidney and liver for the determination of level of metals concentration and effects. The above findings was in line with the study of Bala *et al* (2012) and Bala *et al* (2013) respectively. The results were also coincide with those reported by many investigators (Gunn et al., 1963, Gibbiani, 1966, WHO, 1992, Karl *et al*., 2005). A possible explanations for heavy metal induced damage via production of free radicals that alter mitochondrial activity and genetic information could be as a result of ingestion of the metals by the rat and deposition of the particles in the kidney of the organism.

The study further examined the soil samples from the two hospitals in order to further verify the presence of heavy metal in the samples and their possible health related issues on man as can be seen in Tables 5.17 and 5.18 respectively. The samples were collected at the interval of 5m each with the control taken above the up valley of the dump at 20m away from the dumpsite.

5.9 Heavy Metal Concentration of Soil Samples (ppm)

TABLE 5.17: Heavy metal concentration in Soil Samples collected from NOHE

Parameters (ppm)	Point source at 2cm	10m away from point source at 2cm	15m from point source at 2cm	20m from point source at 2cm	Control mean at 2cm	WHO STD (2006)
Nickel	1.090	1.006	0.956	0.938	0.003	0.005
Lead	2.132	2.121	2.070	2.055	2.01	0.001
Magnesium	37.159	34.934	33.238	32.362	2.10	2.20
Copper	1.079	1.016	0.716	0.595	0.17	0.27
Calcium	5.761	3.432	2.111	1.709	1.13	1.43
Arsenic	1.130	1.003	0.979	0.672	0.030	0.040
Phosphorus	27.00	10.01	8.02	6.00	1.01	1.00
Cadmium	0.777	0.338	0.091	0.080	0.001	0.06
Chromium	1.920	1.618	1.178	0.336	0.001	0.02
Zinc	0.317	0.277	0.187	0.163	0.143	5.00

Source: Authors computation (2017)

From Table 5.17, the findings of the analysis show that Nickel at point source were higher than the other samples. The values of the sample concentrations decreases as the sampling moves away from the point source. From the Table 5.17, the samples collected at the point source (5m), 10m, 15m and 20m were all above the limit of 0.003ppm of WHO (2001) while the control was below the limit. Pb concentration were also ascertained and it showed slight increase at the point source and decrease from 10m sampling, yet above the recommended limit of 300ppm. Lead (Pb) concentration levels in soil of point source and 10m to 20m ranges from 2.132ppm 2.055ppm and the concentration at the control is 2.10ppm.

Moreover, the level of magnesium concentration levels ranged from 37.159ppm at the point source to 32.362ppm at 20m away from the point source. At the control site, the concentration level of Mn was 2.40ppm. Much lower concentration of Mn was recorded at the control site than the tested soils (Table 5.17). With respect to contamination/pollution index, Mn concentration levels in the tested soils were observed to slightly above the permissible limit of WHO. This was in line with the findings of Tahar and Keltoum, (2011) whose result showed Mn concentration in soils obtained to be higher than the permissible limit with values of 79.03-244.94ppm for heavy metal pollution in soil and plants in the industrial area of west Algeria.

Supporting the above, copper and calcium shows deviation from the control which means that there is also traces of metal in the sample showing contamination by hospital waste. It was further noted that copper at sampling point of 15m and 20m where slightly different from the control. This shows that as the sampling moves away from the point source, the concentration decreases showing a point that the pollutant is from the hospital waste dumpsite.

The level of concentration of As, phosphorus, Cd and Cr was examined in the samples and the results showed that at the point site, the level of concentrations was very high more than the control and also decreases as the samples move forwards. The above findings were in support with the findings of some authors like Onwuka, (2012) and Onwuemesi, (2014) that shows the concentration of pollutant decreases as the pollutant is transported forward from the point source. Akanwa, (2012) also showed that the rate of migration of pollution could be determined with the level of pollutant when moving from one point to the other through the rate of flow of pollutant. The indication of pollutant migration in the study showed that hospital waste dumped at the point source could migrate to pollute other environment if not checked more especially during rainy season.

Furthermore, the concentrations of Zn ranged from 0.317–0.163ppm respectively. The control site soil recorded lower Zn concentration level of 143ppm which indicated variation in the level of Zinc between the tested soil and the control soil. The variation in concentration level of Zinc in these soils showed the impact of pollution from hospital waste dump. The concentration of the Zn exceeded the permissible standard of 50ppm set out by WHO in soil indicating the extent of Zn pollution in this soil.

TABLE 5.18: Heavy metal concentration in soil samples collected from UNTH (ppm)

Parameters (ppm)	Point source at 2cm	10m away from point source at 2cm	15m from point source at 2cm	20m from point source at 2cm	Control mean at 2cm	WHO STD
Calcium	6.850	2.820	2.814	2.810	0.001	-
Copper	66.0	35.0	31.2	28.6	0.27	2.00
Lead	1.95	0.05	0.03	0.01	0.001	1.00
Magnesium	6.42	4.12	4.09	1.86	2.40	2.00
Nickel	42.0	21.0	18.98	14.11	0.03	5.00
Phosphate	21.0	8.0	6.1	4.0	0.240	1.00
Arsenic	3.230	2.140	2.138	2.121	1.040	2.00
Cadmium	1.005	1.003	1.001	1.00	0.001	0.06
Chromium	0.003	0.002	0.002	0.001	0.001	0.2
Zinc	0.165`	1.162	1.157	1.148	0.143	5

Source: Authors computation (2017)

Table 5.18 further showed the level of concentration of heavy metal in soil samples at UNTH Ituku/Ozalla. From Table 5.18, the level of pollutant kept reducing as the sampling moved away from the sampling point showing that the pollutant is from the dumpsite. Virtually, all the tested metals slightly exceeded the World Health Organization Standard. This suggests that the soil should be treated properly before farming or growing vegetables on it. Cadmium and Pb at 20m were within the recommended limit.

The examined concentration of Cd in soil point source and 10m to 20m showed a range of 1.005-1.003ppm and 1.001 to 1.00ppm respectively while the control site has the value of 0.001ppm. The point source significantly exhibited higher Cd concentration value of 1.005ppm than the control site soil. The observed Cd concentration recorded at all sampling points and the control site are all above the maximum permissible concentration of 0.06ppm set by WHO Standard for Cd concentration in soil. The values of Cd concentration level recorded in this study was observed to be below than the Cd concentration values of 115.27ppm and 9.11ppm reported by Jagtap *et al*, (2010); Babatunde and Steve, (2014) for Cd concentration in soil irrigated with urban wastewaters and soils around NNPC oil depot in India and Jos in Nigeria.

Moreover, Pb concentration levels in soil of point source and 10m to 20m are in the range of 1.95-0.05ppm and 0.03-0.01ppm with values of 0.001ppm at the control site soil. At the point source, the concentration of Pb showed significantly higher Pb concentration value than site 10m and 20m with the control site. The above findings were in line with the studies of Liang and Liang, (2011); Osakwe, (2013); Bichi and Bello, (2013); Majolagbe and Duru, (2014), indicating the high impact of Pb pollution in the studied soils. Cadmium concentration level was also examined. The samples from point source, 10m, 15m, and 20m were slightly different from the control. This finding is in line with the works of scholars like Hunter, Johnson, and Thompson, (1989) and Radim, Vlastimil and Frantisek (2003). Their works confirmed that illegal dumping of untreated wastes on the soil could lead to pollution of soil meant for agricultural activities hence such soil remain unfit for agricultural purposes and can be regenerated by the use of trees and plants that will absorb the pollutant.

Supporting the above, the application of pig and poultry manure which contain Cu and Zn at higher concentrations on agricultural lands as fertilizer could also result in metal pollution of agricultural lands Poulsen, (1998) which may have an eventual effect on the grazing cattle. Through the polluted water sources, the aquatic animals and agricultural livestock and rats have been infected with pathogenic microorganisms and as well accumulate chemical pollutants. The heavy metals and organic pollutants could have a detrimental effect on aquatic and farmland animals, Van de Merwe *et al*., (2010). If agricultural lands are close to hospital wastes dump, deposition of metal-containing particulates from incineration could occur and eventual uptake by crops and soil Garcia and Millan, (1998). Medvedev (1995) inferred some indications of industrial pollution in the forest ecosystems by determining the concentrations of cadmium, lead and sulphur in the tissues of wild, forest reindeer from North-West Russia. In the determination of the levels of some heavy metals in urban run-off sediments in Ilorin and Lagos, Nigeria, by Adekola *et al.* (2002), very high concentrations of Zn, Fe and Cd were found in the urban sediment from these cities.

Miranda *et al.* (2005) studied the effects of moderate pollution on toxic and trace metal levels in calves from a polluted area of northern Spain; Cd and Pb contents in the liver were moderately and significantly higher in calves from industrialized area. In the findings of Atayese *et al*, (2008) for Lagos environment, Amaranthus grown along major highways accumulated Pb and Cd at concentrations above the normal limit for plants, suggesting pollution by aerial deposition. Asonye *et al,* (2007) reported the concentrations of Pb, Cr, Cd, Fe, Zn, Mn and Cu in water samples of rivers, streams and waterways in southern Nigeria, exceeding the guidelines of WHO. Kpee *et al,* (2009) evaluated seasonal variation of Cd, Ni, Cu and Pb pollution in catfish, sediment and water samples from Ipo stream in Ikwere district of Rivers state, Nigeria. The above findings was in line with the present study which shows that high concentrations of heavy metals as a result of indiscriminate dumping of hospital wastes could be dangerous to human especially when the dump were sited close to residential areas. In order to find out the dispersion level of the heavy metals observed in this study, hydrodynamic dispersion model was used. This model try to show how pollutant/solute move from point source to lower region in the study area.

5.10 Hydrodynamic Dispersion Determination Using Triple Product Vector

Hydrodynamic dispersion of solute (heavy metals) in soil of the study area was calculated using triple product vector model which shows that the concentration of heavy metals from the study areas decreases from North to South which is in agreement with topography (figures 3.3 and 3.4) of the study area. The values of concentrations at different points within the study areas were calculated and contoured in figures 5.1(a and b) to figures 5.8(a and b) respectively for the two hospitals while maintaining a boundary conditions. For National Orthopaedic Hospital:

(iii) The solute concentration c = 2.60ppm (concentration at point source).

When y = 75m.

(iv) The solute concentration c = 0.06ppm (concentration at the control points when y = ≥ 82m.

at the up valley behind the point source).

And for University of Nigeria Teaching Hospital Ituku Ozalla:

(iii) The solute concentration c = 1.95ppm (concentration at point source).

When y = 140m.

(iv) The solute concentration c = 0.001ppm (concentration at the control points when y = ≥ 150m.

at the up valley behind the point source).

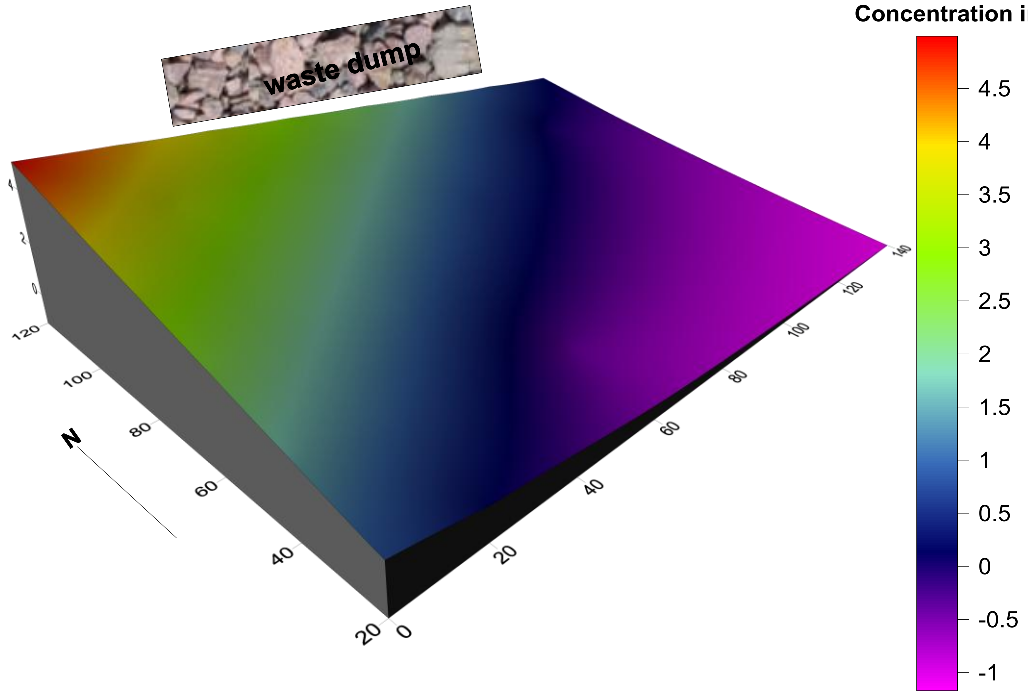


Fig. 5.1 (a) 3D contour map for dispersed lead in water at University of Nigeria Teaching Hospital Ituku Oz

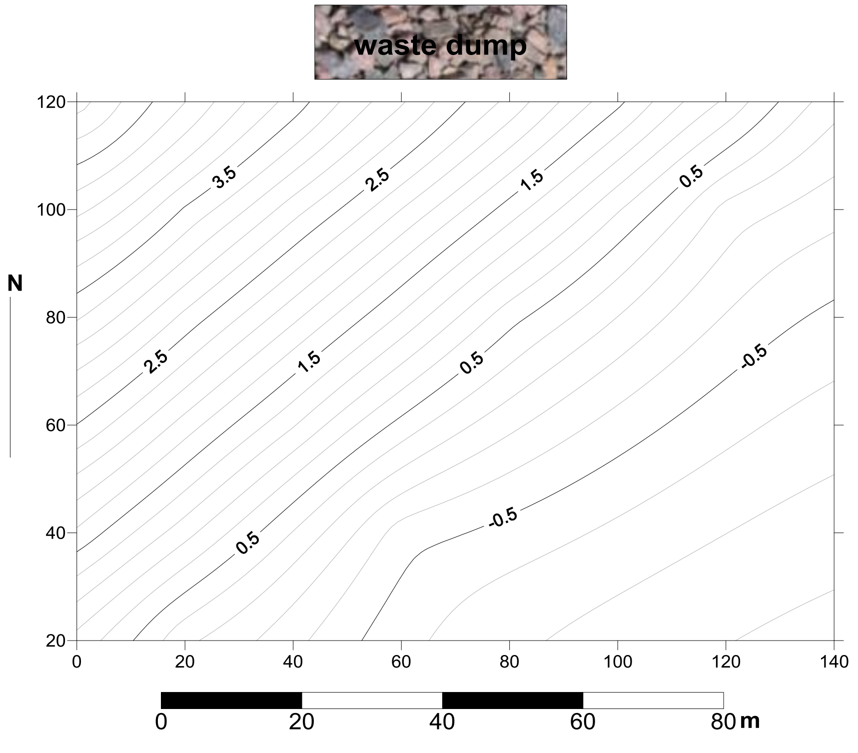


Fig. 5.1 (b) contour map of dispersed lead in water at University of Nigeria Teaching Hospital Ituku Ozalla

Contour interval 1ppm

Source: Researchers field computation, 2017

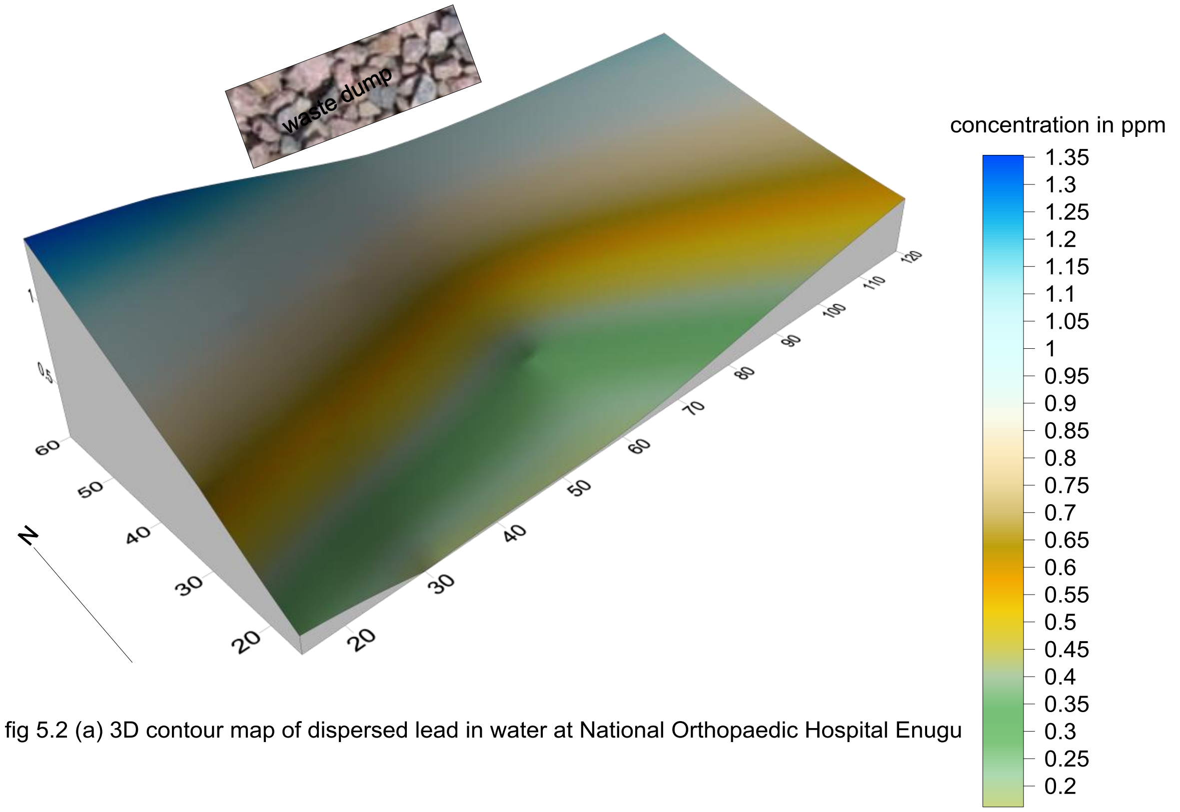


fig 5.2 (a) 3D contour map of dispersed lead in water at National Orthopaedic Hospital Enugu

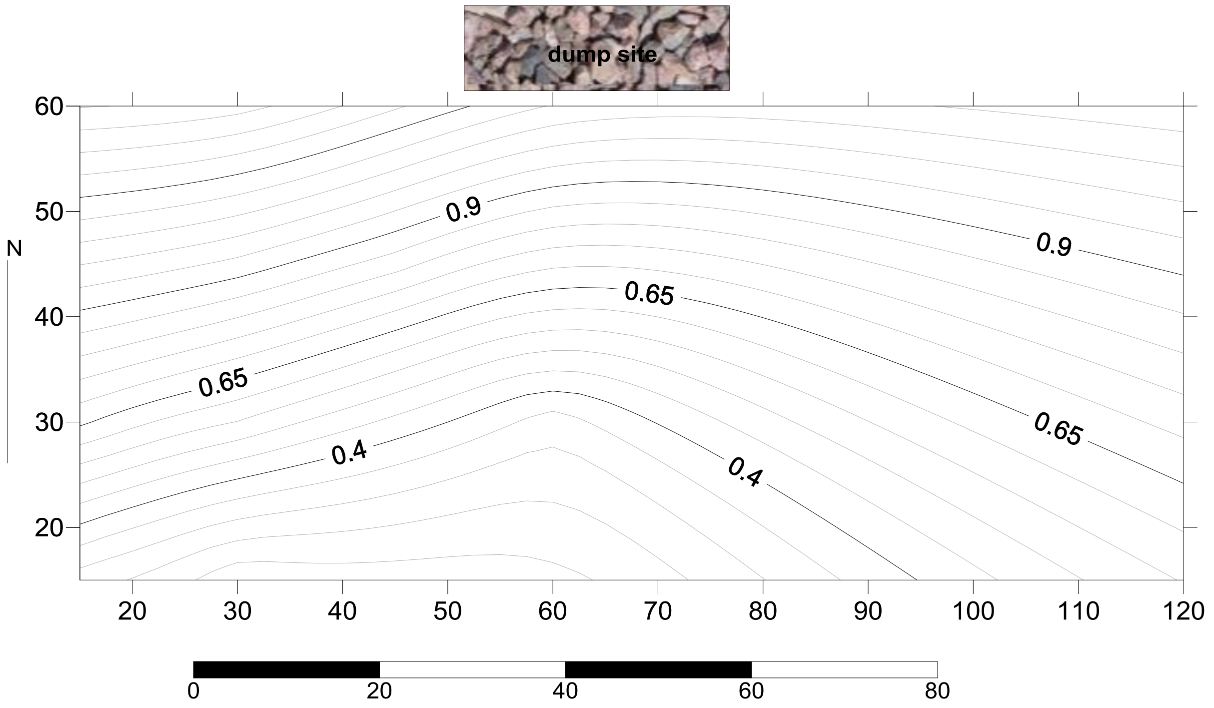


Fig.5.2 (b) contour map of dispersed lead in water at National Orthopaedic Hospital Enugu

Contour interval 0.25ppm

Source: Researchers field computation, 2017

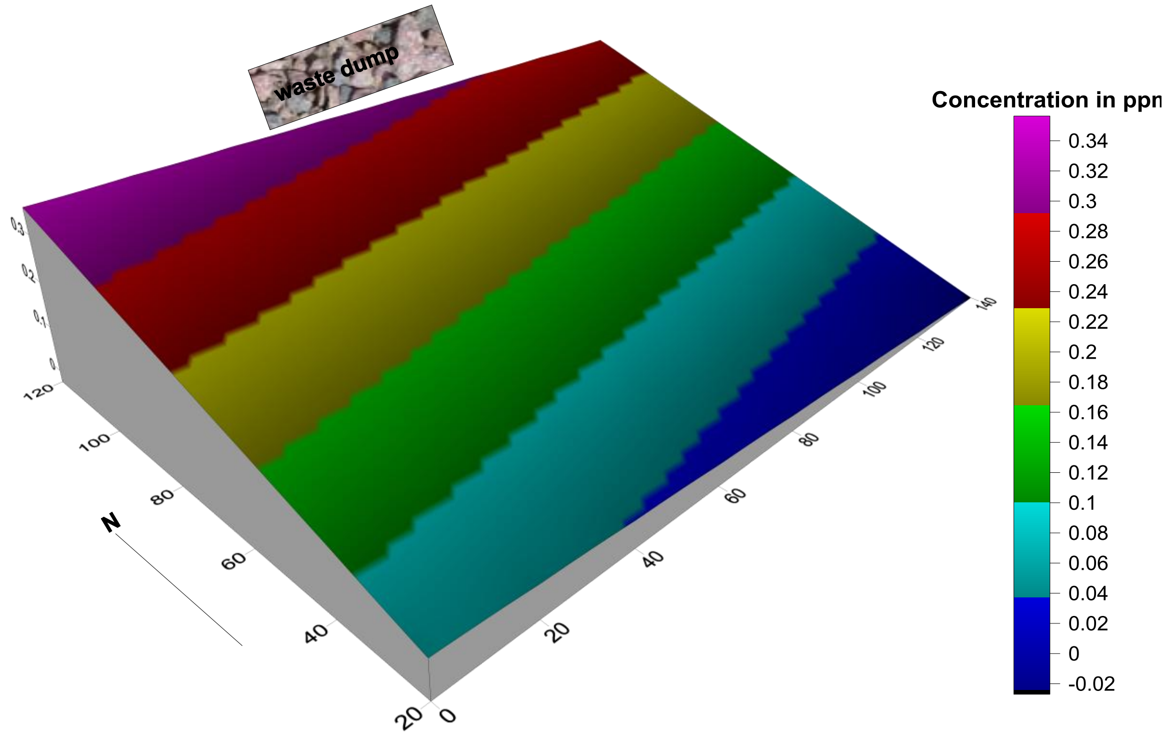


Fig.5.3 (a) 3D contour map for dispersed lead in soil at University of Nigeria Teaching Hospital Ituku Ozalla

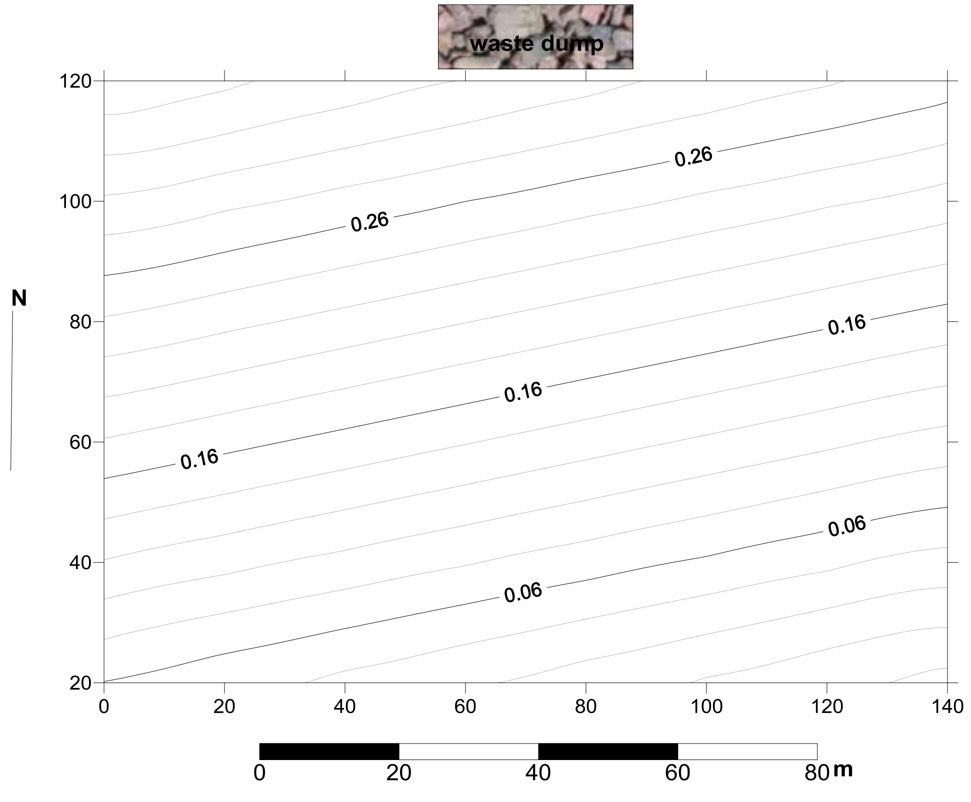


Fig. 5.3(b) Contour map of dispersed lead in soil at University of Nigeria Teaching Hospital Ituku Ozalla

Contour interval 1ppm

Source: Researchers field computation, 2017

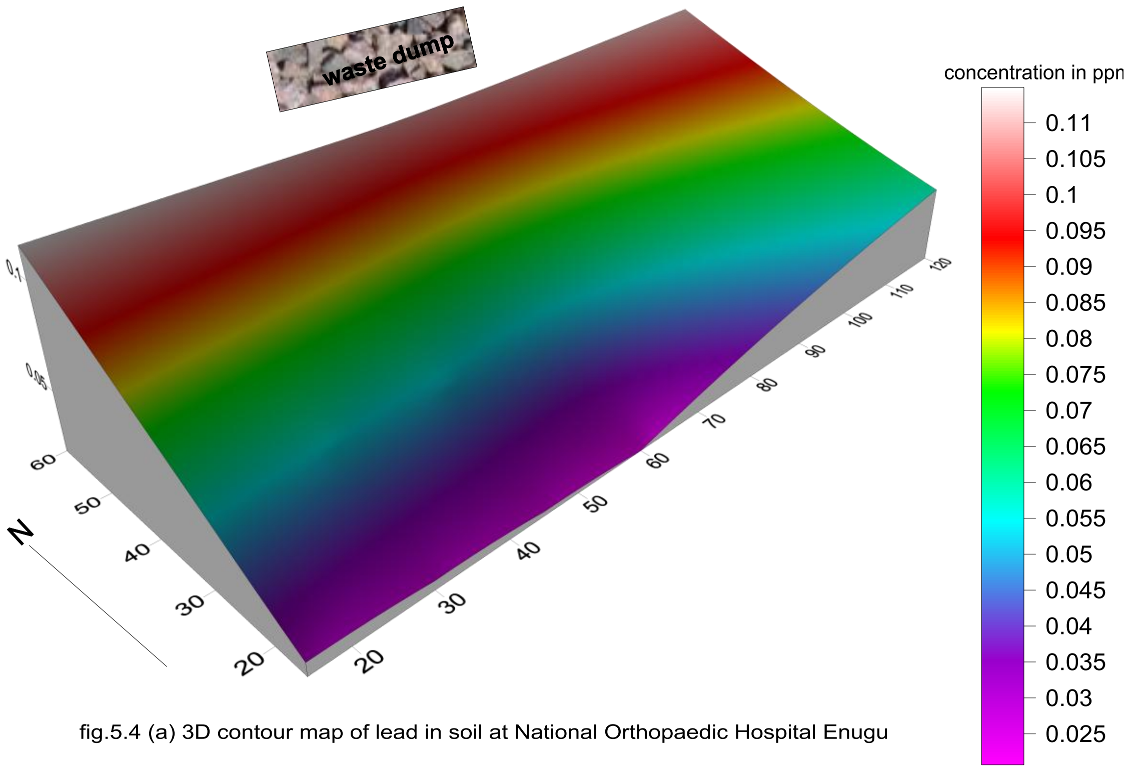


fig.5.4 (a) 3D contour map of lead in soil at National Orthopaedic Hospital Enugu

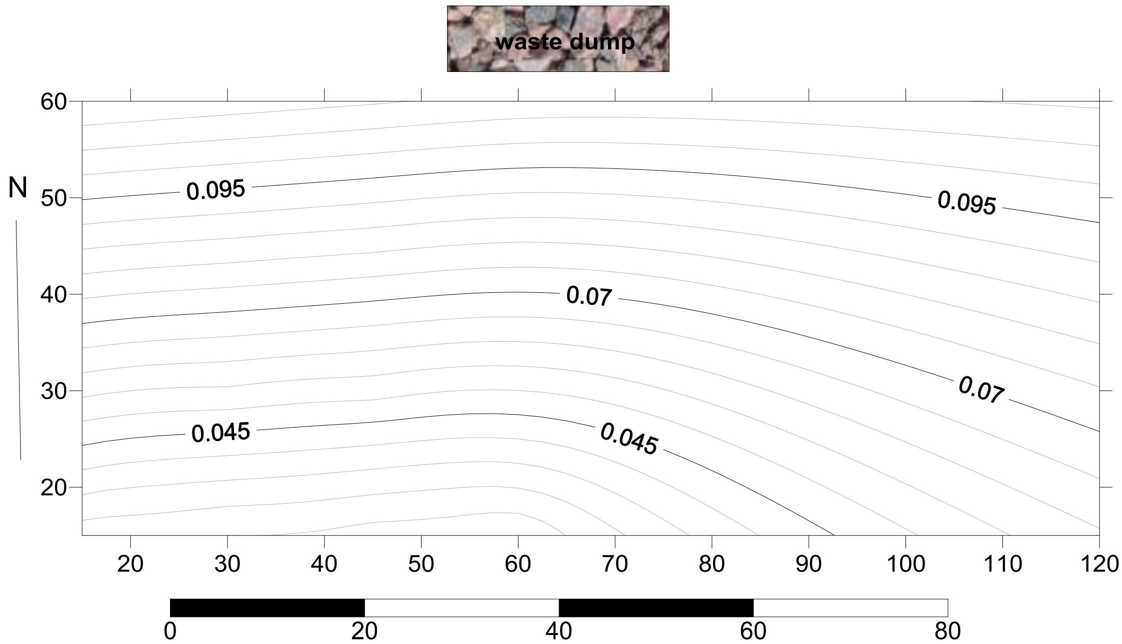


fig.5.4 (b) contour map of lead in soil at National Orthopaedic Hospital Enugu

Contour interval .015ppm

Source: Researchers field computation, 2017

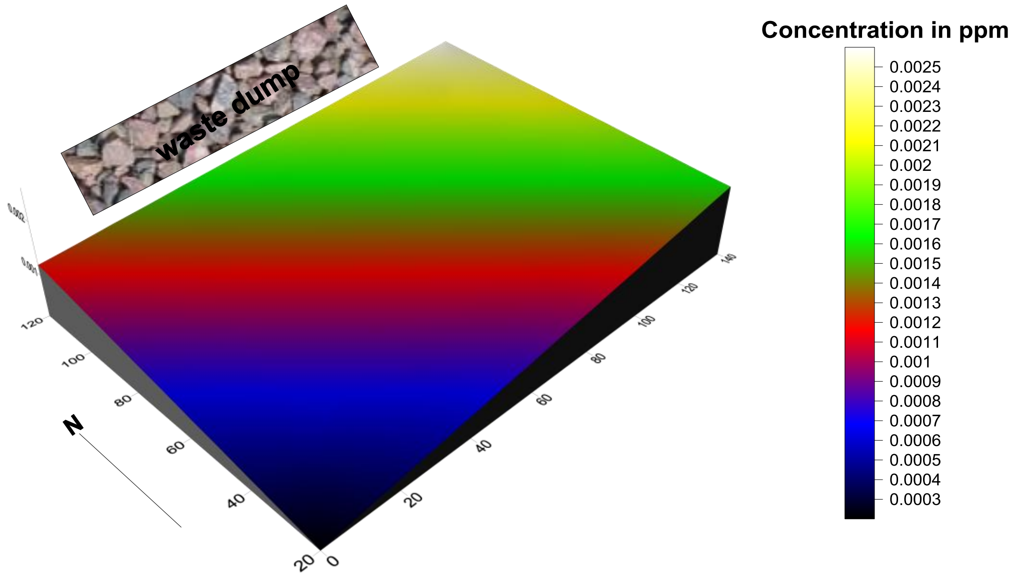


Fig.5.5 (a) 3D contour map for dispersed chromuim in soil at University of Nigeria Teaching Hospital Ituku/Oz

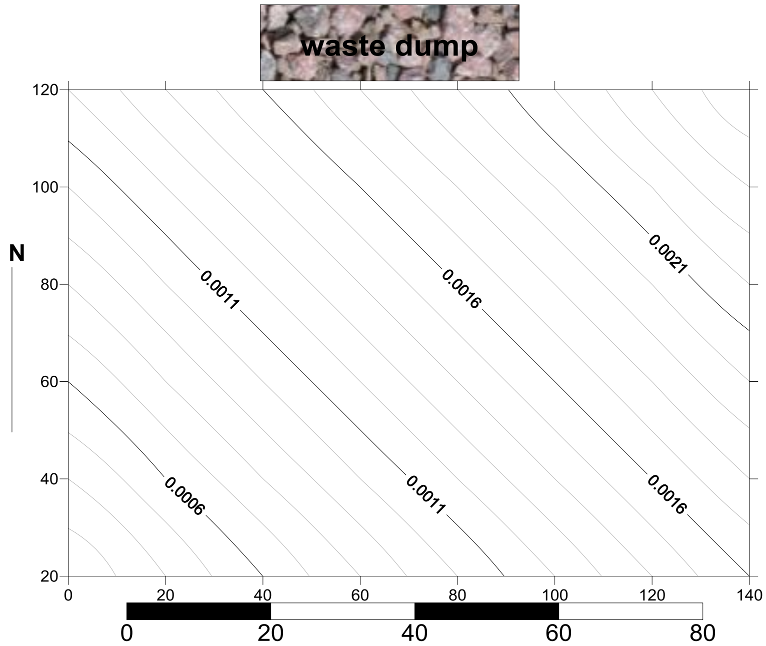


Fig. 5.5(b) contour map of dispersed chromuim in soil at University of Nigeria Teaching Hospital Ituku/Ozalla

Contour interval 0.0005ppm

Source: Researchers field computation, 2017

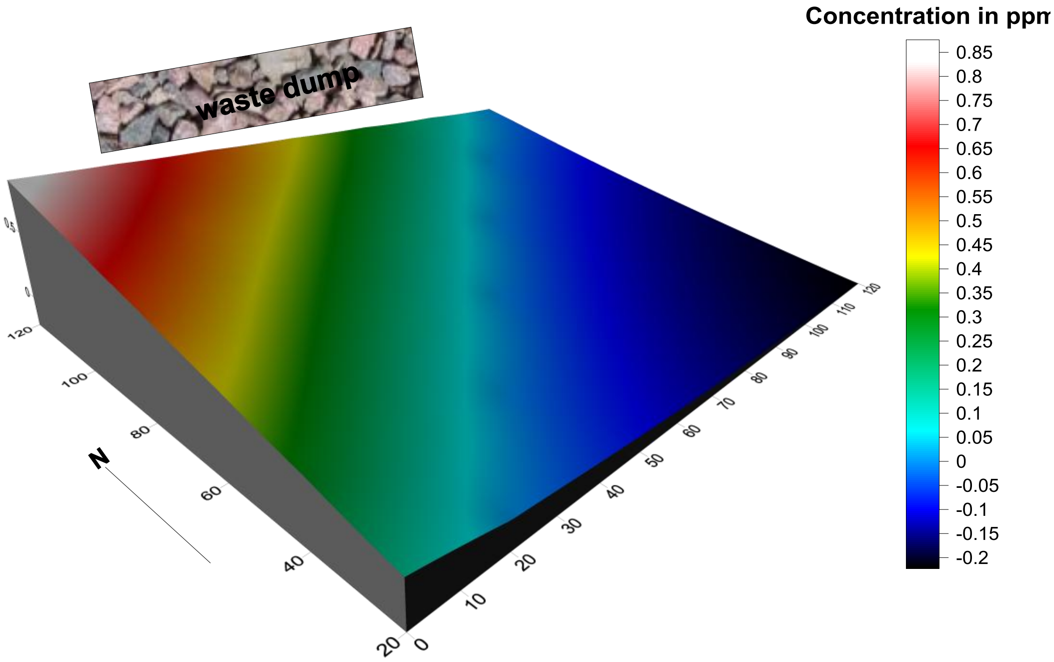


Fig.5.6(a) 3D contour map for dispersed chromium in water at University of Nigeria Teaching Hospital Ituku Ozalla

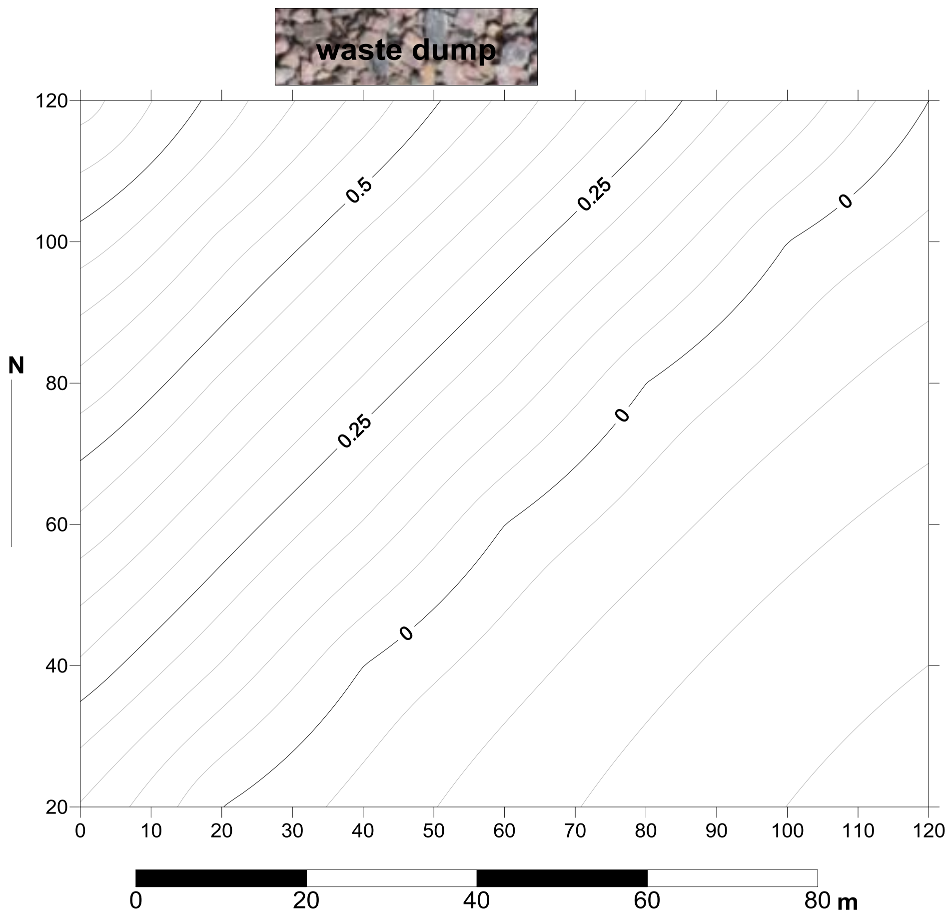


Fig.5.6 (b) contour map of dispersed chromium in water at University of Nigeria Teaching Hospital Ituku Oza

Contour interval 0.25ppm

Source: Researchers field computation, 2017

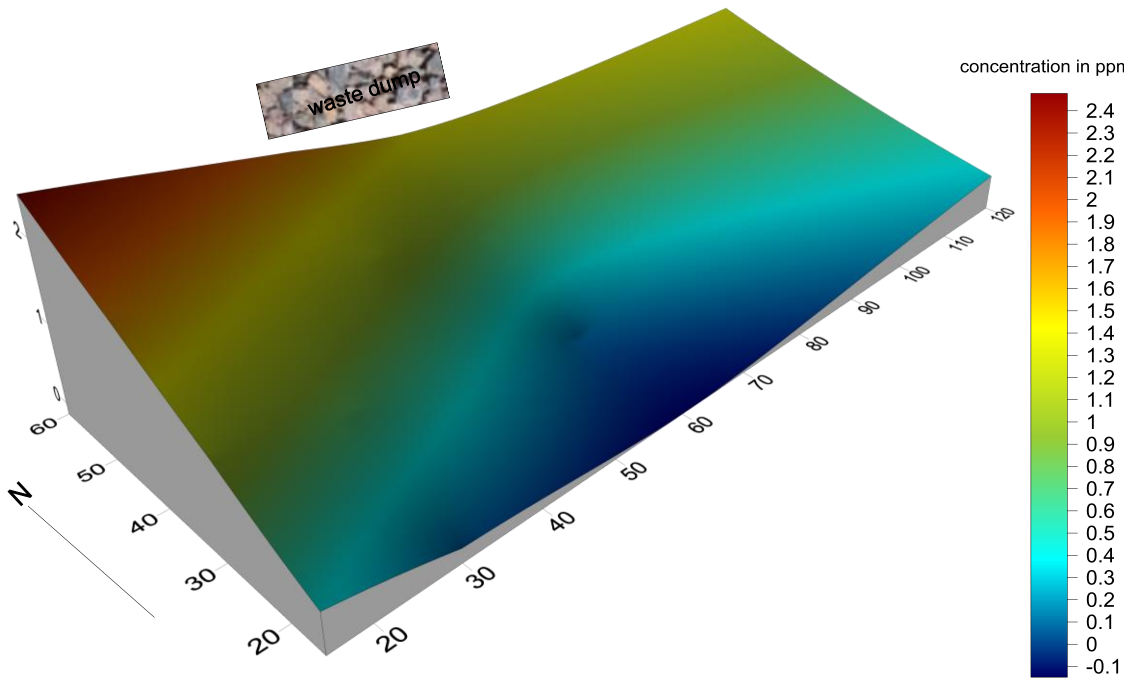


fig. 5.7 (a) 3D contour map of chromium in soil at National Orthopaedic Hospital Enugu

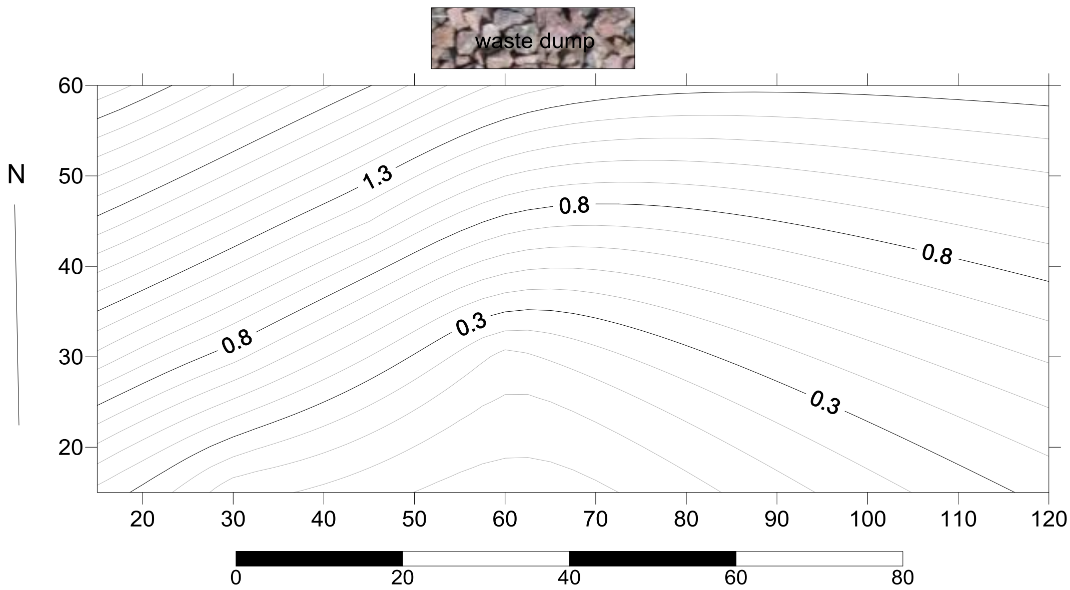


fig. 5.7 (b) contour map of chromium in soil at National Orthopaedic Hospital Enugu

Contour interval 0.5ppm

Source: Researchers field computation, 2017

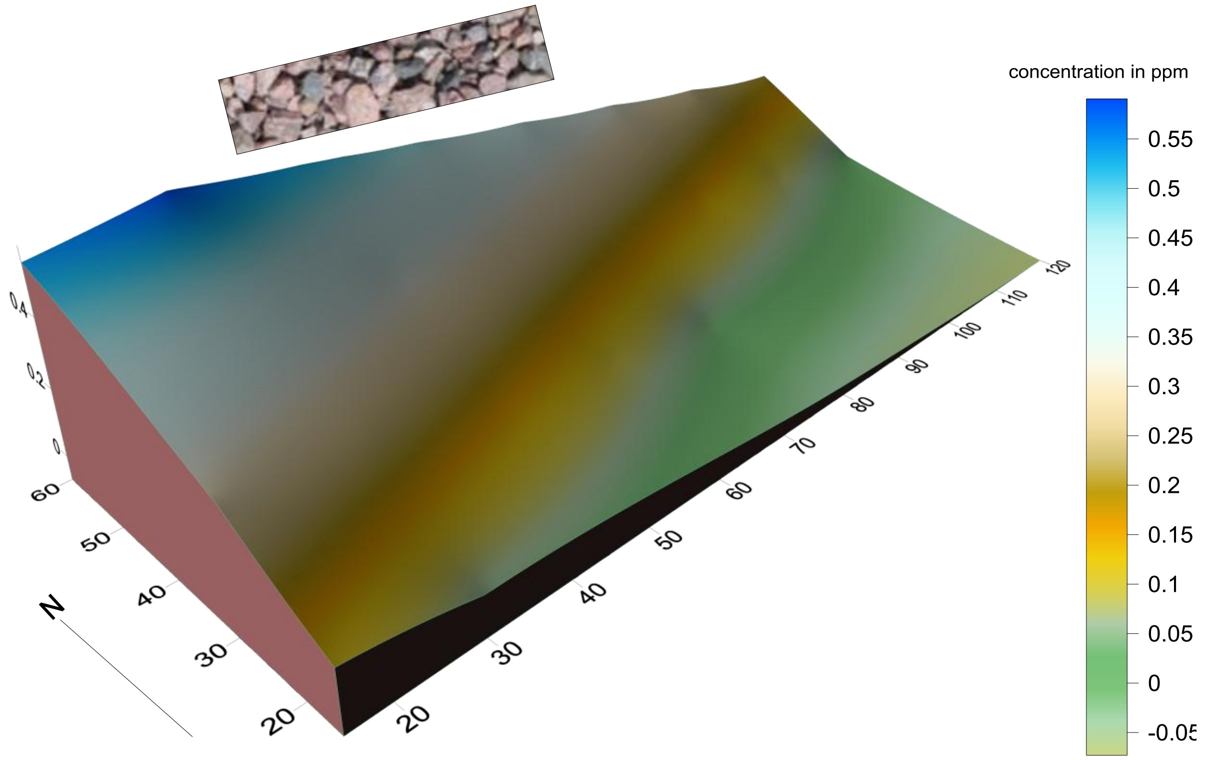


fig. 5.8(a)3D contour map of dispersed chromium in water at Nationa Orthopaedic Hospital Enugu

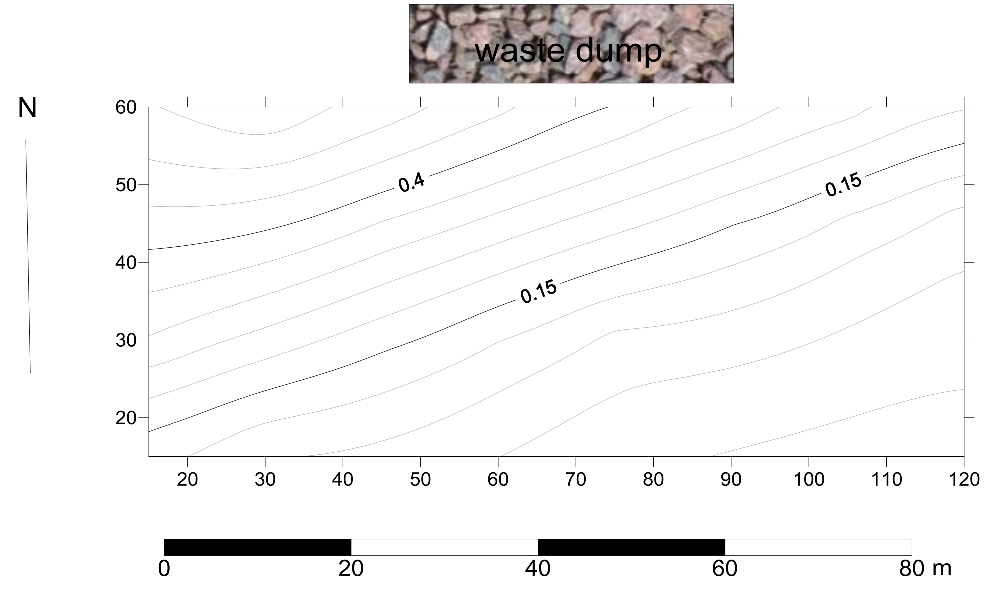


fig. 5.8 (b) Contour map of dispersed chromium in water at Nationa Orthopaedic Hospital Enugu

Contour interval 0.25ppm

Source: Researchers field computation, 2017

Hydrodynamic dispersion of the selected metals from the study areas were analyzed and plotted using triple vector product that showed the concentrations C of these heavy metals. Hydrodynamic dispersion is the transportation of solute (heavy metals like Pb, As, Cr, Cd, Zn and Co) by advective fluid flowing through the solute point source down the valley as earlier stated. The transportation of these metals is down the valley because water does not flow up valley or up hill. The ease of transportation of these metals depends on the porosity and permeability of the soil. The figures 5.1to 5.8 showed the calculated values of different heavy metals (Pb and chromium) in water and soil.

The 3D contour map of lead in soil at National Orthopaedic Hospital Enugu and at University of Nigeria Teaching Hospital Ituku/Ozalla were plotted using Surfer 14 model software as shown in figures 5.1 to 5.8. The result showed that the dispersion of Pb decreases from the point source (waste dump) down the surface valley. Figure 5.2(a and b) showed the 3D contour map of the dispersed Pb in water and the contour map of the dispersed Pb in water at University of Nigeria Teaching Hospital Ituku/Ozalla. From the figures, the concentration of Pb was observed to be trending down to south. This implies that the concentration decreases as the solute moves down from the point source. The findings was in line with the topography of the study area. Moreover, figure 5.3(a and b) confirm the dispersion level in soil. From the figures, it was also revealed that the concentration of Pb in soil follow the same trend in water but that the concentration in water was slightly higher than in soil. This could be attributed to the geology of the study area and location of the dumps. From the calculated values, the hospital dumps were located at the fractured zone in the study area. This made the possible for the high porosity of the rate of permeability of solute in the area.

Sequel to the above, the 3D contour map of chromium at the University of Nigeria Teaching Hospital were also examined. The figures (5.5 a and b) confirmed the results, that the waste dump were located at flow direction in the study area. The figures showed that the concentration of chromium in water was slightly below than that of soil. The above findings were in line with the studies of scholars like Berkowitz (2002) and Chou and Wyseure (2009).

In addition, the level of hydrodynamic dispersion of Pb and Cr at the National Orthopaedic Hospital Enugu was investigated using 3D contour map. From the figures (5.6a and b) and (5.7a and b) the concentration of Pb in water was slightly below the concentration of in soil but was found to exceed the permissible limit of WHO (2006). This was because as water moves with the pollutant, it dilute it thereby reducing the concentration. The figures also showed that the concentration of chromium in soil and water was below the permissible limit. This was in accordance with the findings of Onwuemesi, (2012) at Ishiagu, Ebonyi State Nigeria and Onwuka, (2010) at Anambra State.

5.11 Data from the Hospital Records

TABLE 5.19 Number of patient per day

S/No	No of patient per day(out and in patients)	UNTH	Percentage	NOHE	Percentage
1	10-59	78	39.0	65	32.5
2	51-60	41	20.5	37	18.5
3	61-70	37	18.5	49	24.5
4	71-80	27	13.5	39	19.5
5	81-90	15	7.5	4	2.0
6	91 and above	2	1.0	6	3.0

Source: Author's computation (2017)

Table 5.19 shows the number of patient that comes to NOHE and UNTH on daily bases according to the hospital record from the two hospitals. The information help to determine the quantity of wastes generated from each hospital on daily basis and to determine the volume of waste that goes to the wastes dumpsite.

From Table 5.19, the number of patients varies from 20% to 30% respectively. This range shows that the number of patient determines the volume of waste from these hospital and it showed that UNTH generates more wastes on daily basis more than NOHE due to the nature of cases (illness) treated in at the hospital while NOHE as specialist hospital deals with treatment of a special type of illness, hence the decrease in the number of people that visit the hospital on daily basis.

The above findings led to the next table, Table 5.20. Table 5.20 further showed the disposal and management of the generated wastes at the two hospitals in the study area.

TABLE 5.20: Disposal and Management of hospital wastes

Questions	S/A	Agreed	S/Disagreed	Disagreed	No option
(1) Hospital wastes are segregated/sorted from general waste before disposal	12	16	121	48	3
(2) Sharps are sorted before disposal	14	19	64	101	2
(3) Anatomical wastes are disposed openly without sorting and treatment	105	81	11	2	1
(4) Infectious wastes are disposed with general wastes	98	59	23	6	14
(5) Pharmaceutical wastes are disposed with municipal wastes	111	63	14	11	1
(6) Chemical wastes are disposed without treatment	99	72	21	7	1
(7) Pressurized containers are not used in this hospital for disposal of wastes	75	66	30	21	8
(8) Those involved in handling, collecting, sorting and transportation of waste are qualified	12	30	69	86	3
(9) Reports on daily generated wastes are carried out regularly in this hospitals	88	61	33	17	1
(10) Color codes are used in waste identification	37	27	77	58	1

Source: Authors computation (2017)

In order to investigate the method of management of the wastes generated from these hospitals, the information on Table 5.20 was used. From Table 5.20, the respondents confirmed that hospital wastes are sometimes sorted before disposal while majority of the respondent (169%) strongly disagreed that hospital wastes are sorted before disposal to the final site. In further findings, anatomical wastes, chemical wastes,, pasteurized wastes, infectious wastes and pharmaceutical wastes are disposed openly without sorting and treatment, this is mostly found in NOHE where these wastes are dumped openly in the environment as can be seen in the plates 5.1 to 5.5 in appendix C. Moreover, those involved in handling, collecting, sorting and transportation of the generated wastes from these hospitals are not qualified and sometimes are not monitored to ensure the use of personal protective wears as can also be seen in the plates (5.1-5.5) in the appendix C.

Plate 5.1 showing waste handler without protective wear while disposing waste at NOHE.

Plate 5.2 showing lack of segregation of waste

Plate 5.3: Transportation of waste using open van.

Plate 5.4 lack of use of colour code to differentiate hazardous and non-hazardous waste.

Plate 5.5: Illegal dumping of waste on environment.

Table 5.20 further showed that colour codes are not used in waste identification in this hospitals as to help scavengers and wastes handling in knowing the type of wastes and its danger. This color code according to World Health Organization is very essential for identification of content of wastes especially in hospitals but the researcher found out that the studied hospitals do not observe this code coding as at point of this study.

Plates 5.1 to 5.5 shows basically how generated waste from the hospitals are been collected, sorted, segregated and disposed. The figures showed that waste from the two hospitals are not sorted, treated and no colour code used in separating the waste which will serve as an indicator that the waste contains toxicants that can harm human being.

In line with the above, the health implications of improper disposal of hospitals waste on the respondents were examined using questionnaire which was distributed and interpreted using SSPS version 13. The result was presented and interpreted as shown in Table 5.21.

TABLE 5.21: Health/Environmental Implications of improper disposal and management of hospital wastes

Questions indiscriminate dumping of hospital wastes led to pollution of groundwater resources	**S/A**	**Agreed**	**S/Disagreed**	**Disagreed**	**No option**
(1) reduction of aesthetic values	63	50	37	49	1
(2) breeding of pest	61	58	26	45	10
(3) increase the incidences of Hepatitis A,B and C and also AID/HIV infection	91	64	29	14	2
(4) it causes accumulation of toxic chemicals on the environment	75	73	31	19	2
(5) burning of hospital wastes with incinerator releases heavy metals such as dioxin into the air	98	72	21	8	1
(6) burying of biomedical waste causes pollution of water sources	84	61	30	24	1
(7) open dumping invites flies, rodents and other harmful animals	67	58	49	19	7
(8) there has been increase in crop yield in this area due to indiscriminate dumping of hospital wastes	68	57	45	26	4

Source: Authors computation (2017)

From Table 5.21, it was observed that indiscriminate dumping of hospital wastes led to pollution of water resources as was attested to by the populace with more than half of the population 95% strongly agreed with the statement and the laboratory analysis of water samples from the study area. Table 5.21 also showed that implications of improper disposal and management of hospitals wastes could lead to reduction of aesthetic values with more than 98% of the population. Moreover, the table showed that improper disposal of hospital waste on the environment could also increase pest manifestation on the environment thereby increasing in health related diseases such as laser fever, hepatitis A,B and C, accumulation of toxic chemicals on the environment, releases heavy metals such as dioxin into the air, pollution of water bodies, invites flies, rodent and other harmful animals, reduced with low yield as a result of indiscriminate dumping of biomedical wastes in this area and decreased in crop yield in this area due to indiscriminate dumping of hospital wastes on farm land in this area. The above was in line with the study carried out by Shao (2003) who found out that 7550 needle stick and sharp injuries reported by 8645 HCWs, 66.7% was as a result of contaminated hollow-bore needle.

In the same study, 1805 blood samples from the HCWs were tested and 16.7% were sero positive for hepatitis B surface antigen, 12.7% were positive for anti-HCV and 0.8% was positive for anti-HIV. Based on the above observations, the present study therefore strongly showed that improper disposal and management of hospital wastes is dangerous to human health and should be avoided.

In addition to the above findings, the waste management legislation and policies of the study hospitals were examined in order to find out if the existing legislation and policies is active or non-active. This was shown in Table 5.22. Table 5.22 is the results from hospital waste management legislation and policies in place from the study hospitals.

Furthermore, weighted mean was calculated in order to rank the responses based on the order of highest degree of responses. This was shown in table 5.22.

TABLE 5.22: Weighted mean for Health/Environmental Implications of improper disposal and management of hospital wastes

S/N	Weighted Mean
1	3.625
2	3.575
3	4.14
4	4
5	4.29
6	4.015
7	3.795
8	3.795

Ranking

S/N	Weighted Mean
5	4.29
3	4.14
6	4.015
4	4
7	3.795
8	3.795
1	3.625
2	3.575

From the ranking, it was observed that the highest responses on the health implications of improper hospital waste disposal and management was item five (5) which states that burning of hospital wastes with incinerator releases heavy metals such as dioxin into the air which in turn creates health problems to the hospital workers and the inhabitants of the study area. This was followed by item three (3) which states that the high rate of increase in the incidences of

Hepatitis A,B and C and also AID/HIV infection is as a result of improper hospital waste disposal in the study area. Moreover, item six (6) which states that burying of biomedical waste causes pollution of water sources of the study area. Sequel to the above, item 4 causes accumulation of toxic chemicals on the environment due to improper disposal of hospital waste in the environment of the study area. The study went further to confirm that open dumping invites flies, rodents and other harmful animals in the study area. This was shown in item 8, while item stated that indiscriminate dumping of hospital wastes led to pollution of groundwater resources, reduces the aesthetic values of the study area and also increased the breeding of pest that could transmit infectious diseases.

TABLE 5.23: Existing hospital waste management legislation and policies

Questions	S/A	Agreed	S/Disagreed	Disagreed	No option
Is there any current legislation, policy and regulation guiding medical waste in this hospital	63	50	37	49	1
Has there ever been a time a rule was brought out on how to manage and dispose waste in this hospital	61	58	26	45	10
Do you think that enacting a policy on hospital waste management and disposal will improve the waste management method used in this hospital	91	64	29	14	2

Source: Authors computation (2017).

The current legislation, policy and regulation guiding medical waste in the selected hospitals were ascertain using Table 5.23. Table 5.23, 87% of the respondents strongly agreed that there is legislation, policy and regulation guiding medical wastes in Enugu state. It also showed that rules and regulation has been stipulated to help in the management and disposal of wastes in the selected hospitals. Has there ever been a time a rule was brought out on how to manage and dispose waste in this hospital. Table5.23 finally showed that enacting a policy on hospital waste management and disposal will improve the waste management method used in this hospital with more that 95% respondents. The researcher moved further to investigate the wastes constituents fig. 5.2 and segregation of the wastes, fig. 5.5 in order to note how the wastes are collected with the observed health effects in the study area. This was shown in Table 5.24.

TABLE 5.24: Medical waste constituents and segregation

Constituents	S/A	Agreed	S/Disagreed	Disagreed	No option
Paper, card board, boxes	14	19	64	101	2
Radioactive materials	105	81	11	2	1
Dressing cotton, plaster	98	59	23	6	14
Pharmaceutical	111	63	14	11	1
Pathological materials	99	72	21	7	1
Body parts and fluids	75	66	30	21	8
Kitchen wastes	12	30	69	86	3
Pressurized containers	67	93	22	15	3

Source: Author's computation (2017)

From Table 5.24, most of the wastes generated from the hospitals includes radioactive materials, dressing cotton, plaster, pharmaceutical, pathological materials and these wastes from findings goes to the dumpsite without treatment especially wastes from NOHE. These wastes are seen dumped on the environment and very close to water channel and farm lands. Other wastes such as the body parts and fluids, kitchen wastes and pressurized containers are also seen dumped together at the dumpsite. Indiscriminate dumping of these wastes untreated has been reported by several authors to cause human health problems to the public and especially to wastes handlers and scavengers who finds their daily means of survival through waste scavenging.

The above findings further led to the determination of efficient management of hospital wastes from the studied hospitals. From Table 5.24, it was observed that majority of the respondents strongly agreed that hospital wastes could be managed efficiently through seminar/workshop training, general maintenance of the hospital surrounding, provision of adequate and personal protective wears to waste handlers, practicing of sorting/segregations of wastes onsite before disposal, regular disposal of wastes on daily basis, use of color codes for each type of wastes, and provision of adequate machineries for wastes disposal so as to dispose the wastes as and at when due.

TABLE 5.25: Efficient Management of Hospital Wastes

Hospital wastes could be efficiently managed through	**S/A**	**Agreed**	**S/Disagreed**	**Disagreed**	**No option**	**Remark**
seminar/workshop training	76	59	35	24	6	3.875 (Agree)
general maintenance of the hospital surrounding	63	50	37	49	1	3.625(Agree)
provision of adequate and personal protective wears to waste handlers	61	58	26	45	10	3.575(Agree)
practicing of sorting/segregation of wastes onsite	91	64	29	14	2	4.14(Agree)
regular disposal of hospital waste by trained personnel	75	73	31	19	2	4(Agree)
use of separate color code for each type of hospital wastes	98	72	21	8	1	4.29(Agree)
provision of adequate machineries for waste disposal	84	61	30	24	1	4.015(Agree)

Source: Authors computation (2017)

Responses from the respondents in the study area on efficient management of hospital wastes were ascertained. From the responses, more than 90% of the total population strongly agreed that through seminars and workshops training, that hospital waste management could be improved and efficient. According to them, regular workshop and seminar/training of staff could lead to improved waste handling and reduces the effects on the environment. In agreement, majority of the respondents strongly believed that efficient management of hospital wastes could be achieved by general maintenance of hospital wastes evacuation equipment and constant cleaning of the entire hospital vicinity.

Furthermore, the respondents agreed that efficient management of hospital wastes could be achieved by regular provision of adequate and well trained personnel and provision of adequate personal protective wears to the waste handlers in order to reduce the risk of infection. From plates 5.6

Plate 5.6: Disposal of hospital waste without protective device and without observing the WHO colour codes for hazardous waste

waste handlers are not supply with adequate personal protective wears that will guide and protect them during handling of waste and this could lead risk of infection.

Subsequently, the result shows the level of response on the efficient management of hospital waste through practicing of sorting of wastes beginning from point source to the final deposition. The sorting should be done by the use of colour code provided by the World Health Organization as a standard for the hospital wastes management crew. But from Table 5.25 and plate 5.2, waste are not sorted using colour which could also lead to risk of infection to waste handlers and the general healthcare workers. Table 5.25 further explain that there is need for adequate provision of machineries to assist in regular waste evacuation which can go a long way in reducing health related diseases from hospital due to indiscriminate wastes dump. To show the level of toxicity of improper disposed wastes on living organism, rat kidney and liver were used.

5. 12 Chromosomal Aberrations Analysis of the Rats from UNTH and NOHE

Environmental pollutants are released into the air, soil and surface water as a result of unguided dumping, deliberate application and accidental discharge of industrial and agricultural effluents (Ogbuagu *et al.,* 2005). Industrial and urban activities generate metal wastes which pollute soils, leading to the accumulation of toxic metals in the soils and water, transferred to plants and consequently into animals (Nwude, Okoye and Babayemi, 2011.) Some toxicological studies on effect of some hospital wastes dump containing heavy metals in rats from the study area was examined using kidney and liver. The samples showed some degenerative change in the hepatocytes. The portal areas showed sever congestion in the portal vein as well as dilatation in the bile ducts (plate.5.6).

From the plate 5.6, the kidney showed focal inflammatory cells infiltration which was observed in the tissues of the tested rats. At the corticomedullary portion, there was also some degenerative change (plate 5.6). Moreover, liver of second group showed inflammatory changes in the cells of the rats (plate 5.7). While kidney showed degeneration in the lining of the epithelium cells (plate 5.8). Liver of third group showed congestion in the portal vein with serious degeneration in the heopatocytes (plate 5.9). While the kidney of same plate showed mild congestion in the glomerular tufts (plate 5.10). Liver of forth group showed no histopathological alterations/damage (plate 5.11). While at the kidney, it showed mild congestion which was noticed at the glomerular tufts (plate 5.12).

Furthermore, the rate of accumulation of pollutants by the rat organs varies showing that the rate of pollution load from the hospital wastes on environment varies. The implications of the above result is that since rats are potential transmitter of diseases to man, hospitals wastes should be properly treated and disposed as to eliminate the risk to human health. In order to further authentically say that the damages/alterations in the kidney and liver of the studied rats were as a result of the accumulation of effluent and waste from the two hospitals, chromosomal aberration test was conducted and the results shown in plates 5.13 to 5.16. The chromosomal aberrations test for ring chromosomes, stickiness and chromosome breaks was observed as a support to the above findings. The biological risk factor portrays the extent the effects of accumulation of these metals on human health when consumed.

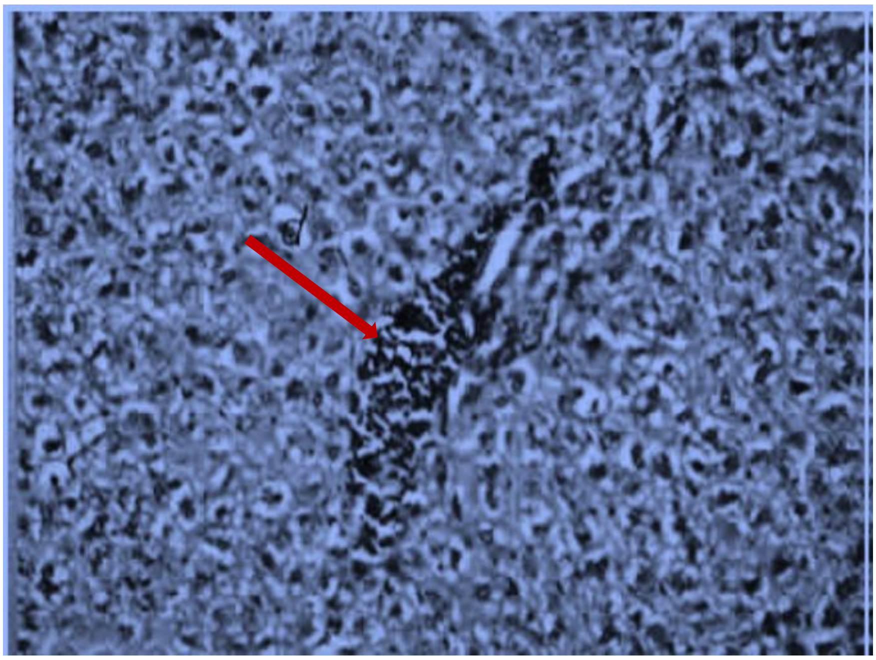


Plate 5.7: Liver of rat A showing degenerative changes in the hepatocytes with high inflammatory cells alterations.

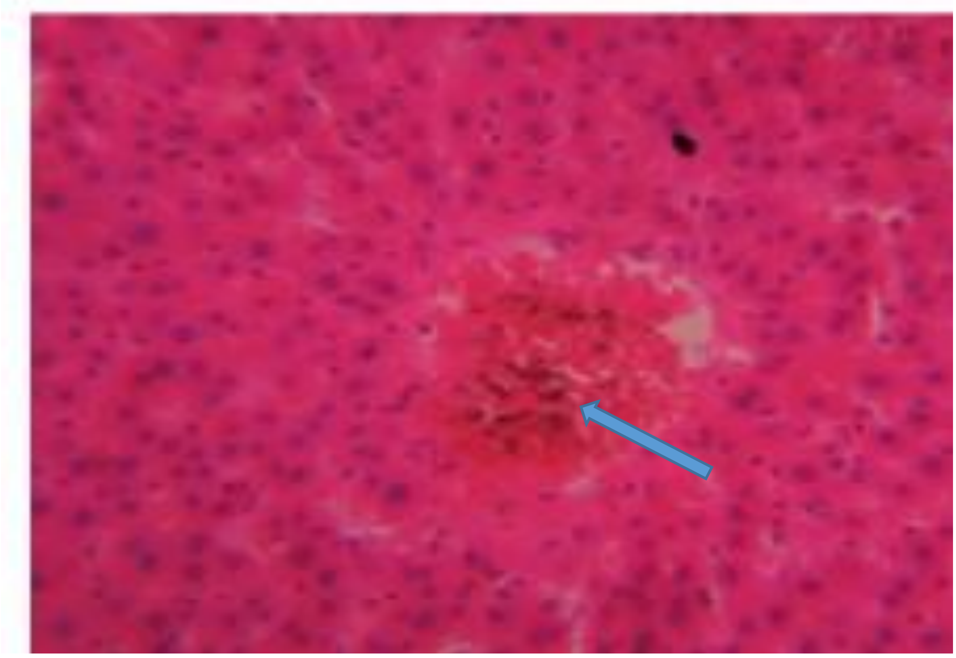


Plate 5.8 liver of Rat B showing dilation in portal vein with inflammatory cells and degeneration in hepatocytes cells.

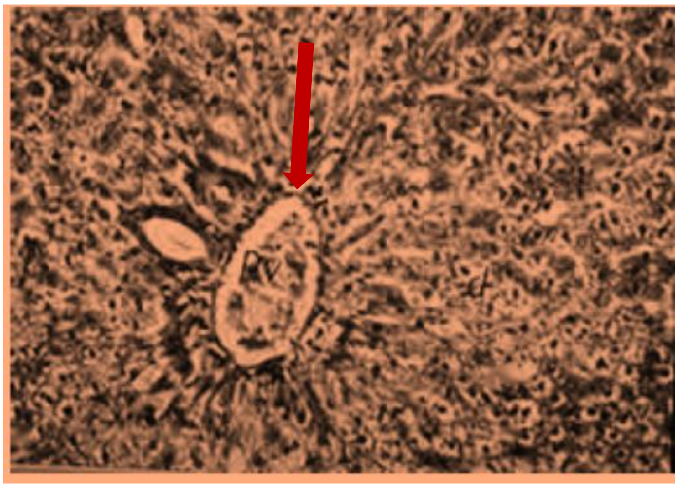


Plate 5.9. Liver of rat C showing heavy congestion and degeneration in the hepatocytes cells.

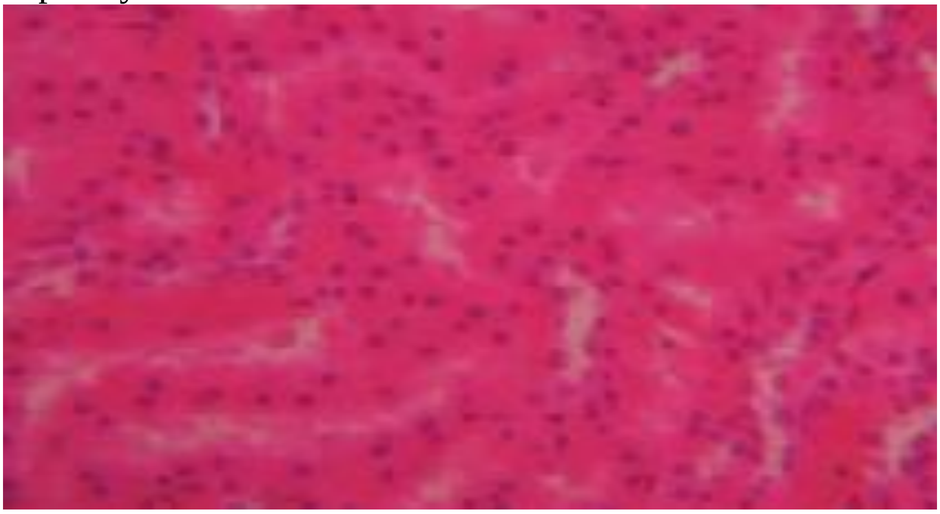


Plate 5.10. Liver of rat D showing normal histological structure.

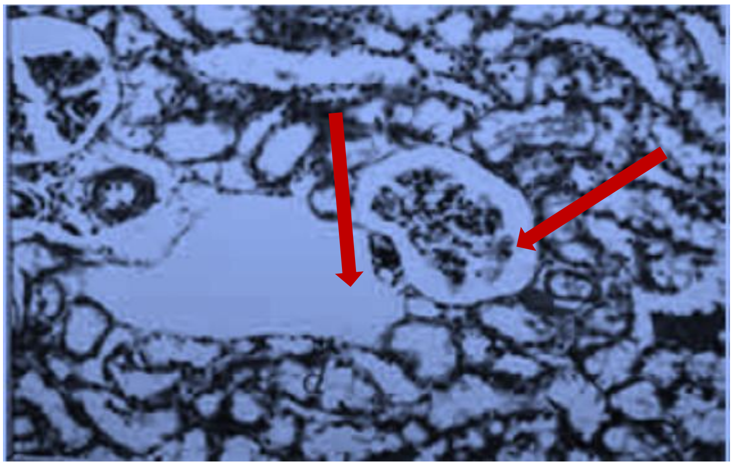


Plate 5.11 kidney of rat A showing serious degeneration in the lining of the epithelium cells.

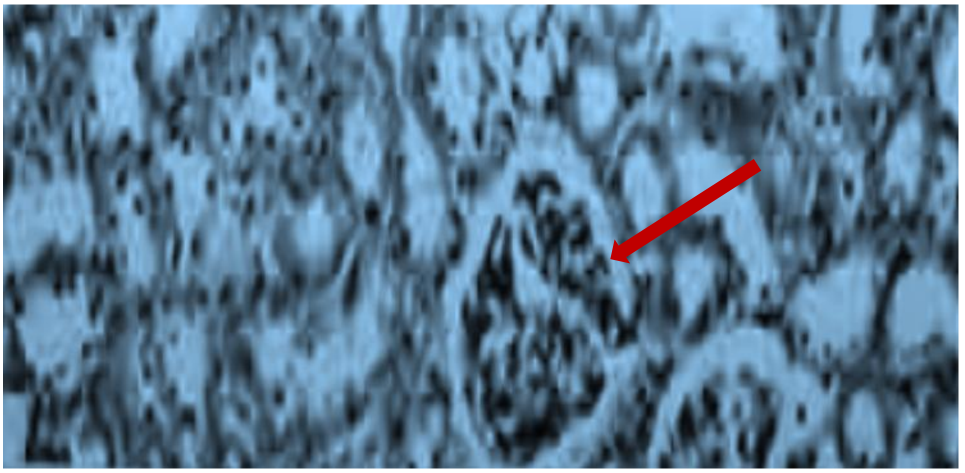


Plate 5.12: Kidney of rat B showing mild congestion the rat organs.

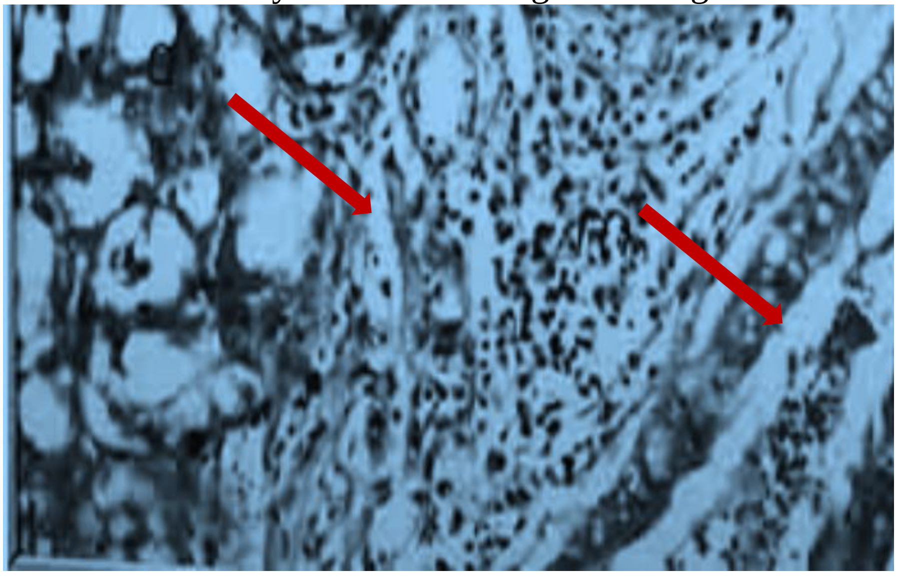


Plate 5.13: Kidney of Rat C showing serious inflammatory cells with congestions in the cells organs.

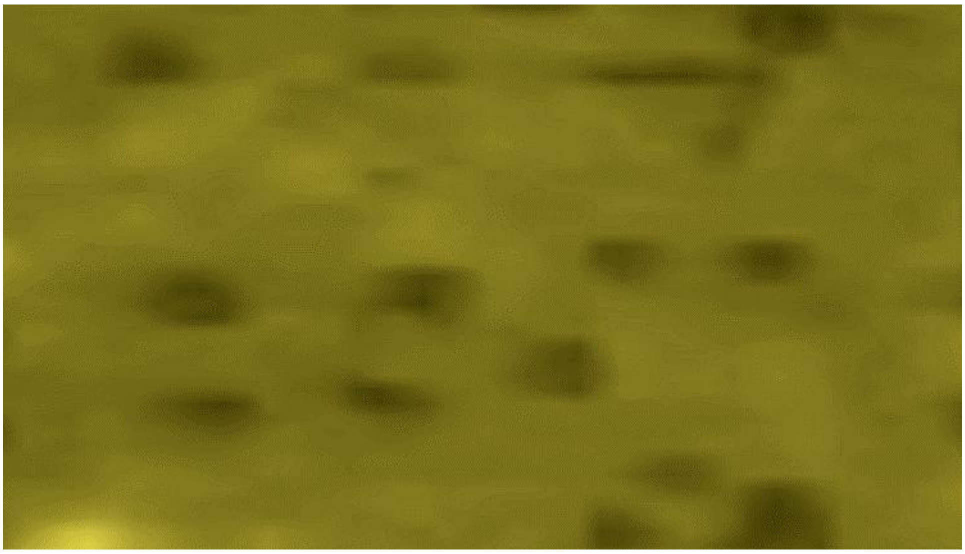


Plate 5.13: Kidney of rat D showing normal histological structure of the rat cells which serves as the control.

The above plates showed different mutagenicity effect of hospital waste on the tested rats kidney and liver which were analyzed for the presence of heavy metals. From the plates, it was observed that serious gene mutation takes place when the rats were fed with water and wastes from the study areas located very close to the dump site. The above findings were in line with several findings of some scholars like Onwuemesi, *et al*, (2013), Obiakor, (2011) and Oje, (2008).

A similar result was obtained by Abudule *et al.*, (2006) with higher concentration of Pd and Co in busy road compared to non-busy roads. Idrees (2009) observed a similar result of high concentration of Zn and Pd in busy roads. Vidhya (2007) obtained high concentration of Pd in busy road. A study by Ogunsola *et al.* (1994) from Nigeria has shown that traffic wardens have a higher blood lead levels than controls and they also have reduced spirometric measurements than controls. Sofoluwe (1968), working in Lagos, Nigeria visited the homes of 98 children suffering from bronchiolitis and pneumonia and found that these patients had been exposed to high concentrations of carbon monoxide, nitrogen dioxide, sulphur dioxide and benzene from burning of hospital waste. Heavy metal concentrations were observed in the control rats to be normal. A similar result was obtained by Babalola *et al.* (2005). The distribution of heavy metals in the organs from the blood is probable that some quantity of this metal was present in the food given to the animals. The calcium supplement in the feed contains traces of lead hence animals that graze on the contaminated feed will contain substantial amount of lead.

In order to show the mitotic metaphase, the microscopic chromosomal picture of rat kidney and liver were shown in figure 5.14a, b, c, d and e respectively.

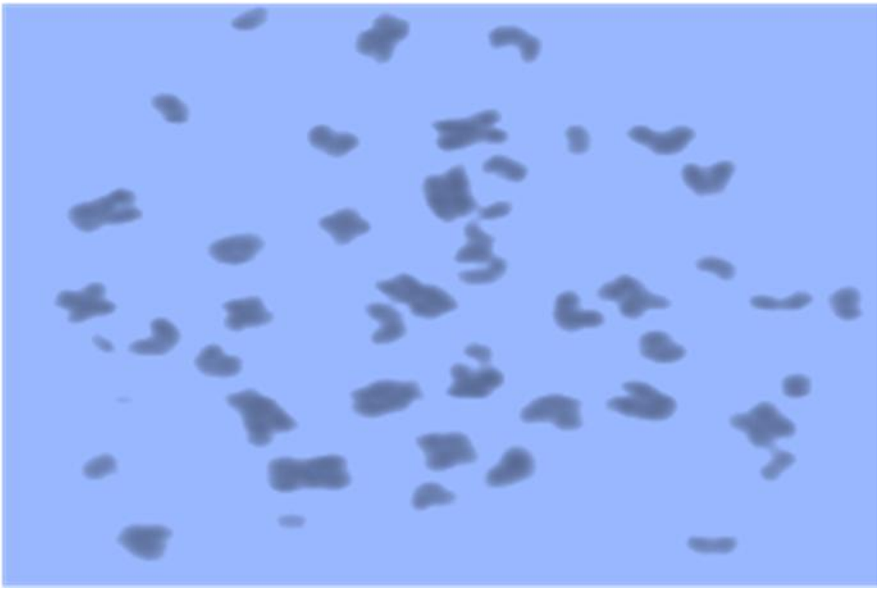
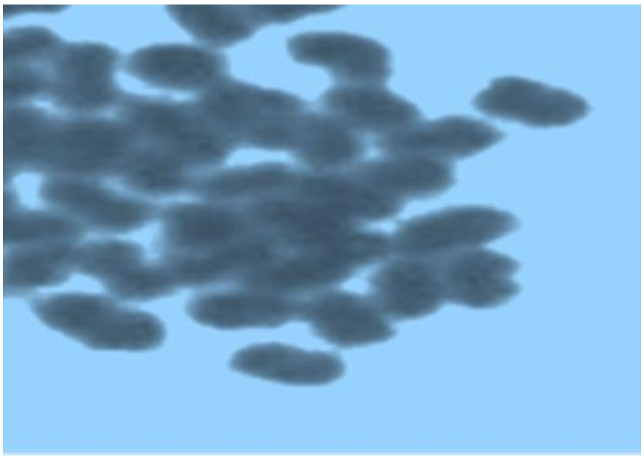
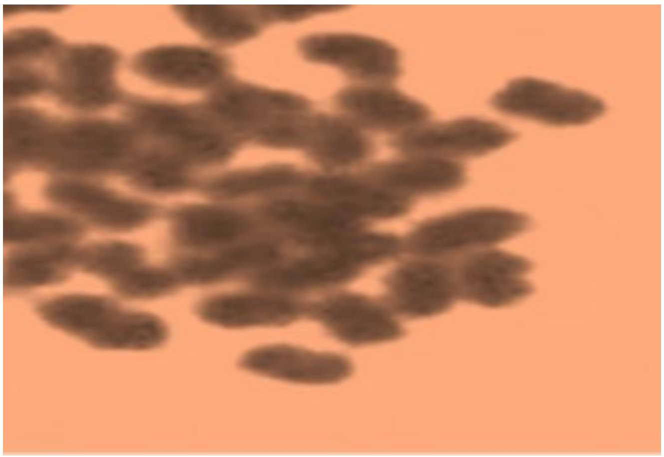


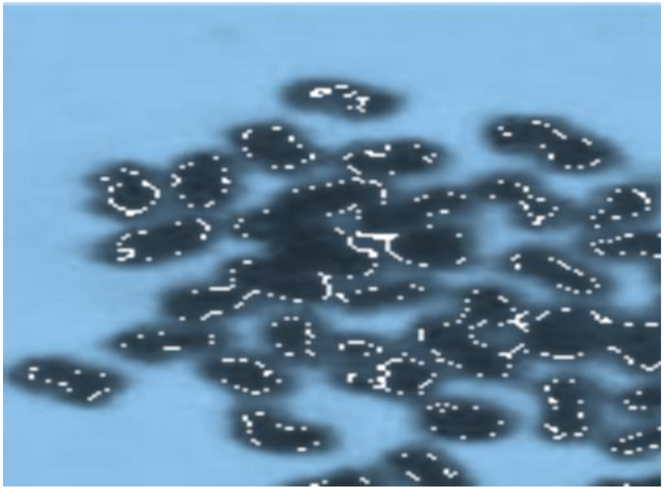
Plate 5.14(a): Photomicrograph Showing Normal Mitotic Metaphase of rat kidney.



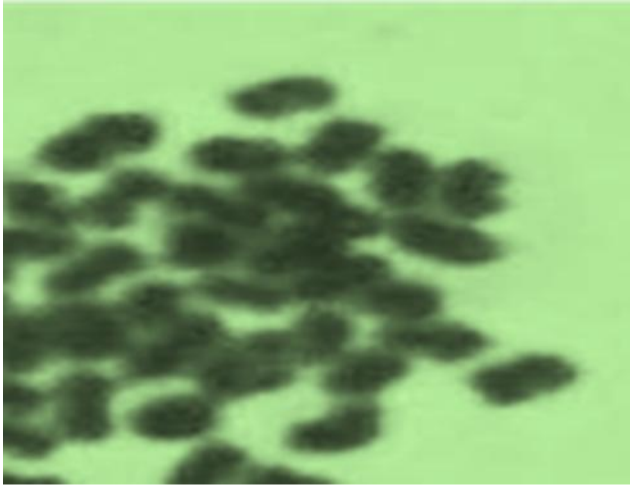
Rat B



Rat C



Rat D



Rat E

Plate 5.14(a) to 5.14 (E) showed a mitotic metaphase microscopic chromosomal picture of rat kidney and liver. From the pictures, there is an alteration in the cell of the rats in Rat B to E. The plates showed that the rat has accumulated the selected heavy metals in their system. Based on the accumulation of these metals, there was mutation in the genetic mechanism of the rats both in the kidney and liver turning the cells to ring-like form. The implication of such changes/alteration is that when human come in contact with such rat either by infesting/invading the food, man become liable and prone to the diseases. When man also drink the water from the study area, it will increase the level of contamination of heavy metal in their system which could lead to health challenges.

The above findings was in agreement with findings of Zahra, Amin and Reza, (2010) who showed that the concentrations of nickel (Ni) and vanadium (V) in liver of rats were higher in *P*. *erumei* than E. *orientalis* in both sampling regions. According to him, histopathology of the liver from their study shows some cellular alterations including degeneration, necrosis and tissue disruption, and histopathological effects were severe in *P. erumei* than *E. orientalis*. Results showed that Bandar Abbass region was more polluted than Bandar Lengeh and because Ni and V were oil pollution indicators and two flat fishes were benthic, they can receive considerable amount of oil pollution through their biological activities like feeding. Also, higher amounts of heavy metal concentrations and major histopathological effects in *E. orientalis* showed strong relationship between benthic habitat of the fish and amounts of received pollutants from water and sediments since *E. orientalis* is more related to the bottom than *P. erumei*.

In a similar findings, Kavita *et al.* (2010) reported a similar result when rats were exposed to diesel exhaust. He observed marked lymphocytes aggregation, oedematous changes in alveolar septa and bronchioles. Also, thickening of alveolar walls and small blood vessels were observed. The long-term exposure period induce the development of lung tumours (Ma and Ma, 2002).

Moreover, Ajayi, *et al.*, (2011) found out that histopathological examination of internal organs (heart, lung, kidney and liver) of rats at busy roads revealed histopathological damage as compared to the control. The results of their findings indicated that vehicular exhaust fumes may have adverse physiological effects on the rats and hence humans living in close proximity to busy roads will be predisposed to automobile pollution.

In the determination of the levels of some heavy metals in urban run-off sediments in Ilorin and Lagos, Nigeria, by Adekola *et al.* (2002), very high concentrations of Zn, Fe and Cd were found in the urban sediment from these cities. Miranda *et al.* (2005) studied the effects of moderate pollution on toxic and trace metal levels in calves from a polluted area of northern Spain; Cd and Pb contents in the liver were moderately and significantly higher in calves from industrialized area. In the findings of Atayese *et al.* (2008) for Lagos environment, Amaranthus grown along major highways accumulated Pb and Cd at concentrations above the normal limit for plants, suggesting pollution by aerial deposition. Asonye *et al*. (2007) reported the concentrations of Pb, Cr, Cd, Fe, Zn, Mn and Cu in water samples of rivers, streams and waterways in southern Nigeria, exceeding the guidelines of WHO. Kpee *et al.* (2009) evaluated seasonal variation of Cd, Ni, Cu and Pb pollution in catfish, sediment and water samples from Ipo stream in Ikwere district of Rivers state, Nigeria. In this study, we made attempt to evaluate metal pollution by studying the levels in the liver of cattle at different seasons.

The above finding also support the present study, that bioaccumulation of heavy metals in liver and kidney of rat could cause a health risk to human and contamination of water, soil and vegetable could also increase the pollution load of pollutant in an environment. the finding showed that waste especially hospital wastes should be treated as toxic wastes and hence proper care and attention should be given to such wastes through collaboration efforts of the wastes management, government and non-governmental organization to ensure greeny environment.

The pictures in the plates above help to portray the amount of damages done by heavy metals in rats samples from the study area. The plates show the type of damages it will do to human being if the metals are being bioaccumulated in the body system of man through constant consumption of contaminated water and vegetable grown close to the dumpsite. From the plates, human genetic mechanism could be altered as a result of constant bioaccumulation of the pollutant from hospital waste disposal via food, soil and water and therefore calls for World Health Organization, Food and Agricultural Organization, Environmental Managers immediate attention with stricter laws and regulation guiding non-compliance with the accepted standard for waste management.

5.7 TESTING OF HYPOTHESES

The hypotheses for this study were tested using suitable statistical tools and method. The results of the hypotheses were discussed below.

Hypothesis 1: There is no significant difference among the leachate, soil, plants and water of the study area.

In order to test for the hypotheses the null hypothesis was used which states that **“**There is no interaction between the leachate and soil, plants and water of the study area”. ($\mu_1 = \mu_2 = ... = \mu_n$)

There is no interaction between the leachate and soil, plants and water of the study area. ($\mu_1 \neq \mu_2 \neq ... \neq \mu_n$)

Test Statistic: the most appropriate test statistic for the hypothesis is One-Way Analysis of Variance since the number of factors is more than two and the hypothesis of interest is to detect significance variation among factors (samples).

Basic Assumptions: One-Way ANOVA has 3 basic assumptions which must not be violated for the suitability of the test statistic. These include normality, independence and constant variance. If any of the three assumptions is violated, the appropriate test statistic becomes Kruskal-Wallis test.

Factors of Interest: 5 factors are to be used for the hypothesis which include sample A, B, C, D and Control, based on that a confirmation of conformity of One-Way ANOVA (Test of basic assumptions) conducted.

Confirmation of conformity of One-Way ANOVA (Test of Basic Assumptions)

Table 5.26: Normality Test

Factors	**P-value**	**Remark**
Sample A	0.005	Not normally distributed
Sample B	0.003	Not normally distributed
Sample C	0.005	Not normally distributed
Sample D	0.005	Not normally distributed
Control	0.003	Not normally distributed

Conclusion

The P-values are less than 0.05 which implies the observations for all the factors of interest are not normally distributed. This violated the first assumption of One-Way ANOVA and the appropriate test Statistic is Kruskal-Wallis Test.

Test of Hypothesis using Kruskal-Wallis test at 5%.

Kruskal-Wallis Test: Observations versus Factors

Kruskal-Wallis Test on Observations

Factors	N	Median	Ave Rank	Z
1	15	6.500	43.2	1.03
2	15	3.900	40.3	0.46
3	15	2.500	36.7	-0.26
4	15	2.300	34.0	-0.79
5	15	2.760	35.8	-0.44
Overall	75		38.0	

H = 1.74 DF = 4 P = 0.003

H = 1.74 DF = 4 P = 0.003 (adjusted for ties)

Conclusion

The P-value of the test is less than 0.05 which is an indication of existence of enough evidence to reject the null hypothesis and conclude that there is significant difference among the leachate, soil, plants and water of the study area.

$(\mu_1 \neq \mu_2 \neq \ldots \neq \mu_n)$.

Further Test for Possible Classification of factors was done which is the Cluster Analysis.

Cluster Analysis of Variables: A, B, C, D, and CONTROL

Correlation Coefficient Distance, Average Linkage

Amalgamation Steps

Step	Number of clusters	Similarity level	Distance level	Clusters joined		New cluster	Number of obs. in new cluster
1	4	99.9947	0.000107	1	2	1	2
2	3	99.9904	0.000193	3	4	3	2
3	2	99.7702	0.004597	3	5	3	3
4	1	87.8972	0.242055	1	3	1	5

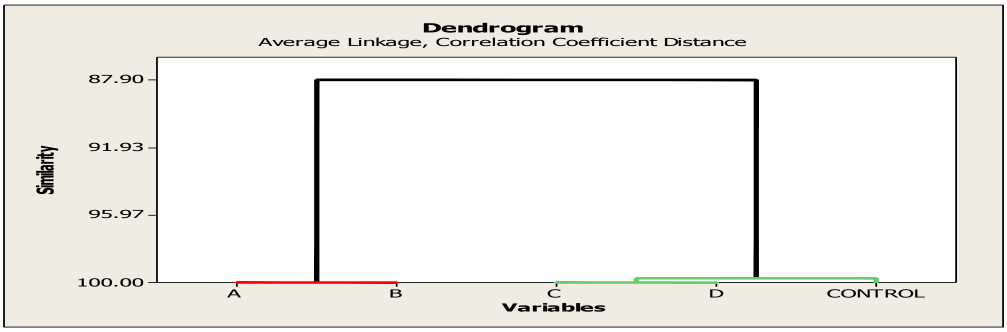
Final Partition

Cluster 1

A B

Cluster 2

C D CONTROL



From the output of cluster analysis, two groups were formed; Sample A and Sample B while the second group is Sample C, Sample D and the Control. This can be interested as no significant difference between samples A and B but samples C, D and Control are significantly different from A, B.

Testing of Hypothesis 2

Null hypothesis: The hydrodynamic solute dispersion trend of the heavy metals in soil and water in the study area do not significantly differ.

Alternative hypothesis: The hydrodynamic solute dispersion trend of the heavy metals in soil and water samples in the study area differ significantly.

Test Statistic: Student T-Test was used since we have two variable which is soil and water.

Table 5.27: Test of significant difference of Lead

t-Test: Two-Sample Assuming Unequal Variances		
	In Soil	***In water***
Mean	2.064833333	0.040333333
Variance	0.002974167	0.001728267
Observations	6	6
Hypothesized Mean Difference	0	
Df	9	
t Stat	72.31561479	
P(T<=t) one-tail	4.67409E-14	
t Critical one-tail	1.833112923	
P(T<=t) two-tail	9.34818E-14	
t Critical two-tail	2.262157158	

Discussion

In terms of Lead, the presence of the chemical in soil is significantly different from that of water with that of soil being higher than that of water, comparing the mean values. The P-value of the test is less than 0.05 which is an indication of the existence of enough evidence to reject the null hypothesis.

Using the calculated value and the table value, the calculated value is 72.32 and the table value is 2.62. Since the calculated value is greater than the table value, the null hypothesis is rejected which implies that the different between presence of lead in soil and water vary significantly.

TABLE 5.28 Test of significant difference of Chromium

	In Soil	*In water*
Mean	0.4455	0.244
Variance	0.7032167	0.051474
Observations	6	6
Hypothesized Mean Difference	0	
Df	6	
t Stat	1.696003553	
P(T<=t) one-tail	0.070407178	
t Critical one-tail	1.943180274	
P(T<=t) two-tail	0.140814356	
t Critical two-tail	2.446911846	

Discussion

In terms of Lead, the presence of the chemical in soil is not significantly different from that of water since the P-value of the test is greater than 0.05 which is an indication of the existence of enough evidence to accept the null hypothesis.

Using the calculated value and the table value, the calculated value is 0.0704 and the table value is 2.45. Since the calculated value is less than the table value, the null hypothesis is accepted which implies the different between presence of chromium in soil and water does not vary significantly.

Testing of Hypothesis 3

The parasitological and bacteriological parameters of heavy metals on vegetable grown around the hospital waste dump do not vary significantly.

Test of significant difference among three selected plant (garden egg leave, water melon and cucumber);

Null hypothesis: the parasitological and bacteriological parameters of heavy metals on vegetable grown around the hospital waste dump do not differ significantly.

Using Student T-Test Statistic,

Table 5.29: Parasitological and bacteriological parameters of heavy metals on vegetable grown around UNTH waste dump

Parasitological Parameters	Bacteriological Parameter
1.6	85.1
1.86	30.09
1.26	67.32
2.18	101
1.79	32.51
1.22	56.97
1.37	61.1
1.76	27.18
1.17	33.48

Using T-test

t-Test: Two-Sample Assuming Unequal Variances

	Parasitological Parameters	*Bacteriological Parameter*
Mean	1.578888889	54.97222222
Variance	0.119936111	697.2809194
Observations	9	9
Hypothesized Mean Difference	0	
df	8	
t Stat	-6.065506206	
P(T<=t) one-tail	0.000150354	
t Critical one-tail	1.859548033	
P(T<=t) two-tail	0.000300708	
t Critical two-tail	2.306004133	

The P-value of the test is 0.00015 which is less than 0.05. There exists enough evidence to reject the null hypothesis and conclude that there is significant variation in the presence of the parameters in UNTH.

Parasitological and bacteriological parameters of heavy metals on vegetable grown around NOHE waste dump

t-Test: Two-Sample Assuming Unequal Variances

	Parasitological Parameters	***Bacteriological Parameter***
Mean	64.58444444	2.238888889
Variance	480.2367028	1.058511111
Observations	9	9
Hypothesized Mean Difference	0	
Df	8	
t Stat	8.52552206	
P(T<=t) one-tail	1.37728E-05	
t Critical one-tail	1.859548033	
P(T<=t) two-tail	2.75456E-05	
t Critical two-tail	2.306004133	

The P-value of the test is 0.0000138 which is less than 0.05. There exists enough evidence to reject the null hypothesis and conclude that there is significant variation in the presence of the parameters in NOHE.

Testing of Hypothesis four (4)

Hypothesis: the toxic waste has no significant negative effects on rats sampled within the hospital vicinity.

Statistical analyses were performed using SPSS 2013. Shapiro-Wilk's (S-W) tests was used to determine the normality of data and was considered statistically significant if p value was less than 0.05. Statistical analyses were carried out after data were log transformed (normalized). Student's T-test was used to compare distribution of metals between livers and kidneys, and differences were considered statistically significant with p value < 0.05. ANOVA analysis were based on log transformed data done to determine the distribution pattern and possible route of heavy metals exposure to rats, using SPSS statistical software 2013. The results were shown below.

Table 5.30. Mean concentrations (± SD) and ranges of heavy metals in the livers and kidneys of rats from NOHE and UNTH.

Sample (ppm)		No	As	Cd	Co	Cr	Cu	Mn	Ni	Pb	Fe	Al
Liver	Mean	8	46	2.59[a]	0.198[a]	0.198[a]	0.147[a]	18.9[a]	5.50[a]	0.869[a]	1.05[a]	263[a]
	SD		2.81	0.321	0.207	0.0908	14.0	2.86	0.522	2.23	95.2	2.81
	Maximum		0.0699	0.0213	0.0784	0.0166	7.59	2.54	0.219	0.0532	112	0.0699
	Maximum		12.6	1.45	1.21	0.406	71.8	19.1	2.11	10.7	524	12.6
Kidney	Mean	8	1.91[a]	1.41[b]	0.382[b]	0.375[b]	14.3[a]	4.09[b]	2.02[b]	3.97[b]	117[b]	1.91[a]
	SD		2.33	3.57	0.333	0.327	4.57	2.79	1.85	8.15	41.7	2.33
	Maximum		0.102	0.0039	0.0741	0.0773	9.17	1.53	0.172	0.044	64.3	0.102
	Maximum		14.0	21.1	1.62	1.72	39.5	16.8	7.85	41.6	284	14.0

n: number of samples; SD: standard deviation; different letters (a and b) between groups indicates significant difference (Student's T-Test; $p < 0.05$).

Source: Statistical result from SPPS, 2013.

From the Table 5.30, the mean concentrations of heavy metals in livers of the selected rats in UNTH and NOHE shows statistically difference in the level of contamination of the metals. All metals measured were detected in 100% of liver and kidney samples. Tests for normality showed a significant variation ($p < 0.001$) in metal distribution in livers and kidneys of the selected rats in the two hospitals. Distribution of Cr, Pb, Cd, Fe, Mn, Ni, Co, Al, Cobalt and Calcium between livers and kidneys differed significantly (Student's T-test; $p < 0.05$) (Table 5.30).

In order to portray the health implications of these metals to human, the results were further discussed. As, Pb, Mn, Cr, Co and Cd which were classified as the most hazardous substances by Agency for Toxic Substances and Disease Registry (ATSDR), 2013) were found to have a mean concentration of As to be higher in the rats liver (2.59 ± 2.81ppm) than kidney with 1.91 ± 2.33 ppm (Table 5.30). The liver is a major target organ of As carcinogenesis according to Onwuemesi, (2013) and could be the reason for the higher As levels. As is toxic and most hazardous substance Onwuemesi, (2013) and due to its non-biodegradable nature, it could accumulate in soil, food and water, through which rats could be exposed since they pick food and water mainly from the ground. Levels of As in soils, drinking water and organs of free-range rat raised health risk concerns for both humans and animals with food and water picking being the dominant sources in most living organisms (rat) Onwuemesi, (2012). The high levels were attributed to incineration/burning of hospital wastes, and this could result in the production of arsenic trioxide gas which is distributed throughout the study area via air.

As shown in Table 5.30, the mean levels of Cd in the kidney of the exposed rats from the hospitals (1.42 ± 3.57) was seven times higher ($p < 0.05$) compared to the liver (0.198 ± 0.321) of the selected rats from the hospitals. It has been observed that animals exposed to Cd usually accumulate pollutant in their kidney because of the presence of free protein-thiol groups which leads to a strong fixation of the metal (Pompe-Gotal and Crnic, 2002). Cd concentrations in blood, urine and kidney have been recognized as good indicators of exposure by Brzoska *et al*., (2004). Cd could increase excretion of calcium and reduce the generation of active vitamin D in kidney.

The high level of Cd in the kidney of the exposed rat from the study showed that human are at risk especially in the areas where rats serves as source of protein. It could also lead to reduction in the free protein-thiol groups which could lead to production of active vitamin D in the kidney that could anemia especially to young children and pregnant mothers. Consequently, Cd uptake and absorption in gastrointestinal gut were observed to damage the kidney, Chen *et al*., (2013). Supporting the above findings, bone lesions, apart from kidney damage, are the main health consequences of chronic exposure to Cd. Osteopenia, osteomalacia and osteoporosis with pathological fractures have been reported in Cd-exposed humans by Jarup, (2002); Alfven *et al*., (2000) and Honda et al., (2003).

Furthermore, the levels of Pb in the rats were higher ($p < 0.05$) in kidney (3.97 ± 8.15ppm) than liver (1.05 ± 2.23 ppm) (Table 5.30). In some studies by different scholars, high levels of Pb was found in *Manihot esculenta* (cassava), soils and chickens from some communities around mining areas in Nigeria, which cause health risk to residents and especially children (Akanwa, 2016 and Onwuemesi, 2012). Bortey-Sam *et al*., (2015d) confirmed that the levels of Pb in organs of free-range chickens tested in Tarkwa, Nigeria emanated from contamination of soil, feeds and/or water sources, and these could be the same route through which animal were exposed. The above was in line with the present study, which shows higher concentration of Pb in the liver of eight selected rats from NOHE and UNTH when exposed to experimental analysis. This confirmed the test, that accumulation of Pb in the liver of rat could be a source of human exposure since rat can invade human house and infect the food, water and soil leading to increase in health related diseases. Moreover, some communities in Nigeria uses rats as source of protein, when hospitals were sited without putting into consideration method of waste disposal and management, it could lead to serious health challenges to such community. Based on the above findings, hospitals should consider location, method of wastes disposal and management before siting their hospitals and government should also make sure that hospitals were sited under due process and closely monitored to ensure sustainability.

Moreover, high level of Mn concentrations were also observed in the kidney of the selected rats. Liver (5.50 ± 2.86) accumulated higher ($p < 0.05$) levels of Mn than kidney (4.09 ± 2.79) (Table 5.30). This is because, the liver is key for maintaining Mn homeostasis according to Finley, (1998). It was also confirmed by Dorman, *et al* (2006) that liver produces toxin that when exposed to heavy metals could lead to homeostasis. He further stated that liver produces two of the main plasma transport proteins of Mn-albumin and transferrin which could cause excess neurotoxicity. The excess Mn causes neurotoxicity, production of reactive oxygen species and disturbance of mitochondrial dynamics according to Barhoumi *et al.*, (2004) and Martinez-Finley *et al.*, (2013). From the table, it confirmed that the mean concentrations of Mn were above the WHO/FAO (2006) maximum levels (0.5ppm) and the increase or high concentrations were attributed to proximity of the hospital waste dump to water resources and also due to percolation of water to the soil during rainy season results to the pollution of the vegetables and soil.

CHAPTER SIX

SUMMARY, CONCLSUION AND RECOMMENDATIONS

6.1 Summary of Findings

Over the years, the world has witnessed the rapid population growth in different patterns which results in extraordinary waste generation. In studied hospitals, collection, transportation, treatment and disposal of waste are the major challenges for government, organizations and other institutions. Hospital waste or clinical waste is classified as one of the most dangerous wastes by World Health Organization. Hospital waste refers to any waste that is generated during medical activities such as diagnosis, monitoring, and minimization or treatment of human beings or animals. It includes viruses and bacteria that potentially cause diseases which are produced by hospitals, clinics, doctor's offices and other types of healthcare institutions.

This study revealed that there were bacterial, parasitic and heavy metal contamination of water, soil, rat and leafy vegetables (cucumber, water melon and garden egg leave) grown around the hospital waste dump in the selected hospitals.

The present study showed that waste from hospital when ingested by man, rat or absorbed by the soil increase bacterial loads in such produce. The bacterial load from this study revealed an increase above the recommended limit by FAO/WHO (2001) with a range of $4.8x10^4$ to $1.5x10^8 CFUg^{-1}$ as against the standard of 10^3 to 10^5 coliform $100g^{-1}$ wet weight of vegetable usually eaten raw. The level of waste minimization at health facilities in Enugu is extremely poor as was identified in the present study. Even though the HCFs adopt minimal recycling, reuse or reduction, this is not done on a very regular basis. Furthermore, this cannot be done effectively as the level of sorting/segregation of waste is very poor. Wastes are hardly sorted, are not properly handled by assigning proper color codes and the use of separate bins for sharps and non-sharps for final wastes disposal and the disposals from the hospitals to landfills are not frequently performed.

In addition, the water samples from the study area showed traces of heavy metal concentration which support the above findings that contamination of pollutant especially from hospital waste could lead to health related diseases to man. Supporting the findings, soil samples from the study also showed that the quality of the soil for agricultural purposes has been altered due to disposal of hospital waste on the environment. Furthermore, it was also observed that rat which is used as an indicator to show the sublether and toxicological impact of hospital waste on human were contaminated. This show that hospital wastes if not proper disposed could posse risk to human health. It was further discovered that there is not enough information on medical waste management technologies and impacts in the study area. Practice of proper medical waste disposal and management is also inadequate from the result of the present study. However, from the hydrodynamic dispersion trend analysis, the results showed that the studied hospitals were located at cracked zone which allows easily pollutants to the environment thereby polluting water, soil and vegetable grown in the study area. The chromosomal aberration analysis also support the finding that waste from the studied hospitals have impacted on the environment of the study area. This was confirmed from the result of toxicological analysis on the kidney and liver of rats fed with waste and water from the study area.

6.2 Conclusions

Enugu State has numerous healthcare service deliveries in which National Orthopaedic Hospital and University of Nigeria Teaching Hospital are among them. These hospitals generate waste that poses health challenges to healthcare workers and the communities in general. The types of waste generated in these hospitals are special wastes, including sharps, chemicals, genotoxic, pasteurized, pressurized, pathogenic and infectious wastes.

Owing to the fact that these wastes are carelessly disposed in the environment around the hospitals without pre-treatment creating health challenges to the populace of the study area and the general public. The haphazard disposal and management of hospital wastes, generated by the large number of healthcare facilities in Enugu State especially in the study area calls for urgent attention.

6.3 Recommendations

The following recommendations can be drawn from the results of this study:

1. Public awareness and proper health education is essential particularly for the scavengers and waste handlers involved in the recycling processes. As the scavengers have direct contribution towards the savings of costs of waste collection and management system, the authorities responsible for hospital wastes management is to be given the task to educate and educate them on the need for them to use protective clothing to downplay health hazards of poor scavengers.
2. Due to the potential microbiological risks of vegetable, it should be treated directly with certain disinfectant (salt) before consumption and to develop highly effective treatments for removing pathogens from a wide range of raw produce.
3. Government should impose strict measures to control or at least minimize the risk of microbial contamination by implementing the Hazard Analysis and Critical Control Point (HACCP) at every hospital.
4. Open dumping should be discouraged completely.
5. Proper disposal of hospital waste using incineration is needed in the studied hospitals.
6. Integrating waste management with the development of any healthcare facility from the onset will help sanitized the system. Such sustainable environmental management plan will prevent a technological paradox of increasing healthcare facilities with attendant promotion of environmental degradation and communicable diseases.

7. Pollution monitoring using Triple Product Vector Model is highly recommended to ensure effective monitoring of the dispersion level of solute (heavy metals) from hospitals periodically.
8. Regular check by waste management committee is very vital to ensure the adequate supply and use of personal protective wear is practiced by waste handlers to help reduce the health risk.
9. Mandatory check by government personnel's (Environmental Health Department) on the use of color code is highly recommended to ensure that hospital waste generator do not expose the public and healthcare wastes handlers to the danger of infection.
10. Awareness should be created by Environmental Health Officers to educate the public on the need not to plant their crops very close to hospital waste dumpsite.
11. There is need for specified development guidelines for storage, transportation and disposal of hospital wastes. The issues in this regard should be that: a bag should not be loaded beyond its weight or volume capacity; the bagged wastes should be stored for a minimum amount of time so as to ensure containment and to prevent penetration by rodents and vermin; access to the storage area be limited; the wastes should be transported to place of disposal in leak-proof trucks, washed and disinfected regularly.

12. Environmental Health Officers should adopt training and retraining of relevant personnel especially the waste handlers and other adhoc staff of the hospitals should be mandatory.

6.4 Contribution to Knowledge

This dissertation has contributed immensely to the following;

1. Ingestion of heavy metals by rats lead to the disruption of DNA structure in rats. This implies same in man, as man continuous consumed the metals via food, water and vegetable.
2. Triple Vector Product Model was developed for monitoring of horizontal and vertical dispersion of metals in soil and water in this dissertation which serves as a tool for monitoring of pollution level of dispersion anywhere.
3. A mathematical model usable to predict heavy metal dispersion was also developed in this dissertation.

6.5 Recommendations for further studies

Further research should be carried out on the following areas;

1. There is need to carry out a further research using bigger sampling size covering wider geographic regions.
2. Further study should include hospitals wastewater treatment and its impacts on the environment in order to investigate the human and environmental effects of improper hospital waste disposal.

3. Further study should also include other organs of animal such as blood, urine, serum and sperm to further show toxicity of heavy metals on human.

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APPENDIXES 1

QUESTIONNAIRE

INSTRUCTION: Please kindly answer the question(s) provided in all sincerity by appropriately ticking the right answer that best suit the option(s).

Section A: Personal Data

1. what is your sex? (a) male [ ] (b) female [ ]
2. to which of the age bracket does your age fall (a)5-10 [ ] (b) 15-24 [ ] (c) 25-35 [ ] (d) 36-46 [ ] (e) 47-57 [ ] (f) 58 and above [ ]
3. what is your educational attainment (a) FSLC [ ] (b) SSCE [ ] (c) NCE/OND/HND [ ] (d) B.Sc and above [ ]
4. what is your profession? (a) medical doctor [ ] (b) Nurse [ ] (c) medical laboratory scientist [ ] (d) pharmacist [ ] (e) waste manager/handler [ ] (f) others specified

Section B: Medical waste management legislation and policies

4 Is there any current legislation, policy and regulation guiding medical waste in this hospital (a) yes (b) no (c) no idea

5 Has there ever been a time a rule was brought out on how to manage and dispose waste in this hospital? (a) yes (b) no (c) no idea

6 Do you think that enacting a policy on hospital waste management and disposal will improve the waste management method used in this hospital? (a) yes (b) no (c) not quite sure

Section C: Medical waste constituents and segregation

Where SA means Strongly Agreed

A means Agree

U means Undecided

D means Disagreed

SD means Strongly Disagreed

7 Which of these do you consider to be constituents of medical waste?

Constituents	SA	A	U	D	SD
Paper, card board, boxes					
Radioactive materials					
Dressing cotton, plaster					
Pharmaceutical					
Pathological materials					
Body parts and fluids					
Kitchen wastes					
Pressurized containers					

Section D: Health/Environmental Implications of improper disposal and management of hospital wastes

1. Do you know that improper disposal of hospital wastes has health and environmental implications? (a) yes (b) No (c) not quite sure
2. Indiscriminate disposal and management of hospital wastes in this hospital has led to? (a) contamination of ground water (b) reduction of aesthetic value (c) site for pest breeding (d) increase in hepatitis A,B,C and HIV/AIDs (e) accumulation of heavy metals in the environment

Section E: Disposal Techniques and best management strategies

1. Which method of hospital waste disposal is practiced in this hospital? (a) autoclaving (b) Incineration (c) chemical disinfection (d)open dumping (e) landfill
2. Which method of waste disposal is used in disposing other wastes that is not hospital waste in this hospital? (a) autoclaving (b) Incineration (c) chemical disinfection (d)open dumping (e) landfill
3. Which method of waste disposal treatment do you think is suitable for hospital waste in this hospital? (a) on site treatment (b) off site treatment (c) autoclaving (d) incineration (e) sanitary landfill (f) microwave treatment
4. What is your level of satisfaction with the current medical wastes management system in this hospital (a) highly satisfied (b) satisfied (c) not satisfied (d) undecided
5. Have you attended any seminar or training program on hospital waste management? (a) Yes (b) No (c) not quite sure

6. How regular do you attend the training or seminar program on hospital wastes management? (a) weekly (b) monthly (c) yearly (d) once in a while (e) Never
7. In this hospital, waste could be managed efficiently through? (a) seminar/workshop training (b) general maintenance of the hospital surrounding (c) provision of adequate and personal protective wears to waste handlers (d) practicing of sorting/segregation of wastes onsite (e) regular disposal of hospital waste by trained personnel (f) use of separate color code for each type of hospital wastes (g) provision of adequate machineries for waste disposal

DESCRIPTION OF THE HOSPITAL

8. Name and location of the hospital: (a) National Orthopedic Hospital at Enugu State (b) University of Nigeria Teaching Hospital at Ituku/Ozalla in Enugu State
9. Number of patients daily: (a) 50 (b) 60 (c) 70 (d) 80 (e) 90 (f) Above
10. Number of out-patients: (a) 20 (b) 30 (c) 40 (d) 50 (e) 50 (f) Above

DISPOSAL AND MANAGEMENT OF BIOMEDICAL WASTES

11. Biomedical waste, Plant waste, kitchen waste are sorted before disposal? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

12 Sharps are sorted before disposal? a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

13 Anatomical waste is disposed openly without sorting? a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

14 Infectious waste is disposed with general wastes? a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

15 Pharmaceutical waste is also disposed with general waste? a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

16 Chemical waste is disposed with general waste? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

17 Pressurized containers are not used in the hospital? a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

18 Is someone responsible for waste? (a) Yes (b) No

19. Who are the persons involved in handling, collecting, storing and transporting waste? (a) trained personnel (b) untrained personnel

20. Are there any national legislative provisions on waste management? If so, what are they?____

21. Is there any national waste management plan in Enugu State? (a) Yes (b) No

22. Is there any waste management plan in the health facility in this hospital? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

23. Is any budget allocated to biomedical waste management in Enugu State? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

24. Is the budget allocated effectively utilized for its purposes in this hospitals? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

25. Is the waste treated on-site? (a) Yes (b) No. If so, how? _________

26. Is the waste treated off-site? (a) Yes (b) No. If so, by whom __________________________and how ______________________?

27. Is there any waste treatment facility at the hospital where you work? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

28 Is there a landfill in the vicinity of this hospital where wastes are dumped? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

29. Waste management training has been set up for the hospital staff? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

30. Do the people who handle waste have PPE at their disposal? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

31. If so, what equipment is available to them? (a) Hand gloves (b) nose mask (c) apron (d) eye protector (e) boot (f) over all (g) none of the above

32. Is it appropriate? (a) Yes (b) N0

33. Is it worn regularly? (a) Yes (b) No

34. Are personal hygiene facilities available (wash basins, showers)? (a) Yes (b) No

35. Do they work? (a) Effective (b) not effective (c) undecided

36. Have all of the staff been vaccinated against hepatitis A and B and tetanus? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

37. Is the working group for waste management operational? (a) effective (b) not effective (c) undecided

38. Are there definitions of the duties of each group member working with waste? (i.e picking, sorting, treating and disposal) (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

39. Is the reporting on waste quantities carried out at regular interval and correctly? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

40. Has there been a significant increase in the quantity of waste generated? If so, why? ______________________________________

41. Are the resources provided sufficient for implementing the waste management plan in this hospital? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

42. Care is being taken to implement the waste minimization policy in this hospital - i.e. to reduce the quantity of waste generated at source (less packaging, returning containers to the supplier, reusable equipment)? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion.

43. Each type of waste generated daily in the hospitals is clearly identified by a color code and symbol as indicated by WHO? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion.

44. Containers and bags are located everywhere where waste is generated? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion.

45. Sorting are carried out effectively throughout the chain (from waste production to storage)? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion.

46. Checks are carried out regularly? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion.

47. Are there adequate stocks of bags and containers? (a) Yes (b) No

48. Is the waste collected at regularly bases? (a) Yes (b) No

49. Is the storage time for category biomedical waste limited to 48h as indicated by WHO? (a) Yes (b) No

50 Does the storage facility meet the WHO requirements (closed, covered, cleaned regularly, protected from animals, well aired and well lit)? (a) Yes (b) No

51. Method of waste disposal in this hospital is by burning? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

52. Wastes are treated by incineration? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion

Impact of biomedical waste on environment

53. Sources of water in this place is? (a) stream (b) hand dug well (c) spring (d) dam (e) borehole
54. At what depth is the water table? (a) 30m (b) 35m (c) 40m (d) 45m
55. Water quality is poor? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion.
56. Soil quality is reduced with low yield? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion.
57. low crop production is associated with biomedical waste dump in the environment? (a) agree (b) strongly agree (d) disagree (c) strongly disagree (d) no opinion.

APPENDIX 2 A

(a) Statistical Data Analysis for Lead concentration (C) in soil at National Orthopaedic Hospital Enugu.

Univariate Statistics

Count:	33	33	33
1%-tile:	15	15	0.020685
5%-tile:	15	15	0.02283
10%-tile:	15	15	0.02712
25%-tile:	30	45	0.079215
50%-tile:	45	60	0.114915
75%-tile:	60	90	0.173445
90%-tile:	60	105	0.20271
95%-tile:	60	120	0.227685
99%-tile:	60	120	0.22983
Minimum:	15	15	0.020685
Maximum:	60	120	0.231975
Mean:	38.1818181818	66.9696969697	0.125197878788
Median:	45	60	0.114915
Geometric Mean:	33.8012036683	56.2575715821	0.102597706324
Harmonic Mean:	29.2610837438	44.3094629156	0.0768320000513
Root Mean Square:	41.7786374294	75.0958982861	0.141708007996
Trim Mean (10%):	37.5	65.1666666667	0.121634666667
Interquartile Mean:	38.8235294118	66.4705882353	0.124132352941
Midrange:	37.5	67.5	0.12633
Winsorized Mean:	38.1818181818	65.1515151515	0.122430606061
TriMean:	45	63.75	0.1206225
Variance:	296.590909091	1190.53030303	0.00454435851098
Standard Deviation:	17.2218149186	34.5040621236	0.0674118573471
Interquartile Range:	30	45	0.09423
Range:	45	105	0.21129
Mean Difference:	19.5454545455	40.1515151515	0.0787093560606
Median Abs. Deviation:	15	30	0.05853
Average Abs. Deviation:	15	29.3939393939	0.0575425757576
Quartile Dispersion:	0.333333333333	0.333333333333	0.372951792923
Relative Mean Diff.:	0.511904761905	0.599547511312	0.62867962958
Standard Error:	2.99793317233	6.00638625543	0.0117348981106
Coef. of Variation:	0.451047533583	0.515219027185	0.538442488002
Skewness:	-0.0476573842737	0.0407607293076	0.0437020936675
Kurtosis:	1.51675658324	1.68511810693	1.68401810564
Sum:	1260	2210	4.13153
Sum Absolute:	1260	2210	4.13153
Sum Squares:	57600	186100	0.6626782645
Mean Square:	1745.45454545	5639.39393939	0.0200811595303

Inter-Variable Covariance

	X	Y	C (solute concentration)
X:	296.59091	-11.931818	-0.065691477
Y:	-11.931818	1190.5303	2.3244309
Z:	-0.065691477	2.3244309	0.0045443585

Inter-Variable Correlation

	X	Y	C (solute concentration)
X:	1.000	-0.020	-0.057
Y:	-0.020	1.000	0.999
Z:	-0.057	0.999	1.000

Inter-Variable Rank Correlation

	X	Y	C (solute concentration)
X:	1.000	-0.017	-0.130
Y:	-0.017	1.000	0.993
Z:	-0.130	0.993	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	0.999910955408	0.999910955408	0.000142999726381
Y:	0.0133441963636	0.0133441963636	-0.00195099626692
Z:	-0.000116952739518	-0.000116952739518	-0.00195099626692
Lambda:	1190.69407441	296.431682071	4.96771619904e-018

Planar Regression: C = AX+BY+D

Fitted Parameters

	A	B	D
Parameter Value:	-0.000143	0.001951	2.77555756156e-017
Standard Error:	2.20817331661e-011	1.10215290103e-011	1.19198494704e-009

APPENDIX B

(d) Statistical Data Analysis for Lead Concentration (C) in water at University of Nigeria Teaching Hospital Ituku Ozalla

Univariate Statistics

X

Count:	27	27	27
1%-tile:	0	20	0
5%-tile:	0	20	0
10%-tile:	0	40	0
25%-tile:	20	60	0.146
50%-tile:	40	80	0.292
75%-tile:	60	100	0.438
90%-tile:	80	120	0.584
95%-tile:	100	120	0.73
99%-tile:	100	120	0.73
Minimum:	0	20	0
Maximum:	120	120	0.876
Mean:	41.4814814815	82.962962963	0.302814814815
Median:	40	80	0.292
Geometric Mean:	N/A	74.7695176016	N/A
Harmonic Mean:	N/A	63.9053254438	N/A
Root Mean Square:	53.8860251244	88.7777082464	0.393367983408
Trim Mean (10%):	37.5	82.5	0.27375
Interquartile Mean:	35.7142857143	84.2857142857	0.260714285714
Midrange:	60	70	0.438
Winsorized Mean:	38.5185185185	84.4444444444	0.281185185185
TriMean:	40	80	0.292
Variance:	1228.49002849	1037.03703704	0.0654662336182
Standard Deviation	35.0498220893	32.203059436	0.255863701252
Interquartile Range:	40	40	0.292
Range:	120	100	0.876
Mean Difference:	39.886039886	36.6951566952	0.291168091168
Median Abs. Deviation:	20	20	0.146
Average Abs. Deviation:	28.1481481481	26.6666666667	0.205481481481
Quartile Dispersion:	N/A	0.25	N/A
Relative Mean Diff.:	0.961538461538	0.442307692308	0.961538461538
Standard Error:	6.7453414061	6.19748167803	0.0492409922645
Coef. of Variation:	0.844951068224	0.38816187713	0.844951068224
Skewness:	0.510894381158	-0.444027369789	0.510894381158
Kurtosis:	2.1492926933	1.9438212816	2.1492926933
Sum:	1120	2240	8.176
Sum Absolute	1120	2240	8.176
Sum Squares:	78400	212800	4.177936
Mean Square:	2903.7037037	7881.48148148	0.15473837037

Inter-Variable Covariance

	X	Y	C (solute concentration)
X:	1228.49	518.51852	-5.182792
Y:	518.51852	1037.037	3.7851852
Z:	-5.182792	3.7851852	0.065466234

Inter-Variable Correlation

	X	Y	C (solute concentration)
X:	1.000	0.459	-0.578
Y:	0.459	1.000	0.459
Z:	-0.578	0.459	1.000

Inter-Variable Rank Correlation

	X	Y	C (solute concentration)
X:	1.000	0.426	-0.573
Y:	0.426	1.000	0.426
Z:	-0.573	0.426	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	-0.639662439424	-0.639662439424	0.00729961101409
Y:	0.768587197798	0.768587197798	-0.00729961101409
Z:	0.0102802223517	0.0102802223517	-0.00729961101409
Lambda:	1660.04577826	605.546753505	-1.92256156457e-018

Planar Regression: C = AX+BY+D
Fitted Parameters

	A	B	D (curvature)
Parameter Value:	-0.0073	0.0073	0
Standard Error:	2.70974996482e-011	2.94929288822e-011	2.32567814581e-009

(b) Statistical Data Analysis for Lead concentration (C) in water at National Orthopaedic Hospital Enugu.

Univariate Statistics

	X	Y	C (solute concentration)
Count:	22	22	22
1%-tile:	15	15	0.1617
5%-tile:	15	15	0.27405
10%-tile:	30	30	0.3234
25%-tile:	30	30	0.66045
50%-tile:	60	45	1.0962
75%-tile:	75	60	1.7073
90%-tile:	105	60	2.2554
95%-tile:	105	60	2.36775
99%-tile:	120	60	2.6418
Minimum:	15	15	0.1617
Maximum:	120	60	2.75415
Mean:	62.2727272727	44.3181818182	1.27220227273
Median:	60	45	1.152375
Geometric Mean:	53.3007817511	41.2334222486	1.00225917793
Harmonic Mean:	43.8885370488	37.358490566	0.721840391663
Root Mean Square:	69.8537433109	46.6734302458	1.4867429932
Trim Mean (10%):	58.6842105263	44.2105263158	1.18056842105
Interquartile Mean:	56.3636363636	45	1.12509090909
Midrange:	67.5	37.5	1.457925
Winsorized Mean:	62.2727272727	45.6818181818	1.23645454545
TriMean:	56.25	45	1.1400375
Variance:	1049.35064935	224.512987013	0.620092110114
Standard Deviation:	32.3936822444	14.9837574397	0.78745927521
Interquartile Range:	45	30	1.04685
Range:	105	45	2.59245
Mean Difference:	37.6623376623	16.6883116883	0.918971212121

Median Abs. Deviation:	30	15	0.5796
Average Abs. Deviation:	26.3636363636	11.5909090909	0.653593181818
Quartile Dispersion:	0.428571428571	0.333333333333	0.442128603104
Relative Mean Diff.:	0.604796663191	0.376556776557	0.72234677757
Standard Error:	6.9063562599	3.19454781985	0.167886881576
Coef. of Variation:	0.520190517793	0.338095039666	0.618973328448
Skewness:	0.302867510074	-0.462432220927	0.370203359722
Kurtosis:	1.84741656072	1.95830526772	1.83985747174
Sum:	1370	975	27.98845
Sum Absolute:	1370	975	27.98845
Sum Squares:	107350	47925	48.6289040125
Mean Square:	4879.54545455	2178.40909091	2.21040472784

Inter-Variable Covariance

	X	Y	C (solute concentration)
X:	1049.3506	230.19481	25.307114
Y:	230.19481	224.51299	4.2482159
Z:	25.307114	4.2482159	0.62009211

Inter-Variable Correlation

	X	Y	C
X:	1.000	0.474	0.992
Y:	0.474	1.000	0.360
Z:	0.992	0.360	1.000

Inter-Variable Rank Correlation

	X	Y	C
X:	1.000	0.454	0.990
Y:	0.454	1.000	0.338
Z:	0.990	0.338	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	-0.25141941893	-0.25141941893	-0.0257507355515
Y:	0.967780911923	0.967780911923	0.00748730626089
Z:	-0.0137252432619	-0.0137252432619	0.00748730626089
Lambda:	1109.83320749	164.650520988	-3.26312083681e-016

Planar Regression: C = AX+BY+D

Fitted Parameters

	A	B	D
Parameter Value:	0.02576	-0.00749	2.77555756156e-016
Standard Error:	N/A	N/A	N/A

(C) Statistical Data Analysis for chromium concentration (C) in soil at National Orthopaedic Hospital Enugu.

Univariate Statistics

	X	Y	C (solute concentration)
Count:	31	31	31
1%-tile:	15	15	0.0315
5%-tile:	15	15	0.063
10%-tile:	30	15	0.399
25%-tile:	45	15	1.071
50%-tile:	75	30	2.478
75%-tile:	90	45	3.5805

90%-tile:	120	60	4.5885
95%-tile:	120	60	4.62
99%-tile:	120	60	4.956
Minimum:	15	15	0.0315
Maximum:	120	60	5.292
Mean:	70.3225806452	37.2580645161	2.4635483871
Median:	75	30	2.478
Geometric Mean:	61.2659296738	32.8763652771	1.65644764368
Harmonic Mean:	50.7009345794	28.4693877551	0.467818250321
Root Mean Square:	77.3867538886	40.9464638672	2.90301154254
Trim Mean (10%):	68.75	36.4285714286	2.360375
Interquartile Mean:	67.8125	35.625	2.32575
Midrange:	67.5	37.5	2.66175
Winsorized Mean:	71.2903225806	37.2580645161	2.45169354839
TriMean:	71.25	30	2.401875
Variance:	1078.22580645	298.064516129	2.43701887258
Standard Deviation:	32.8363488599	17.26454506	1.5610954079
Interquartile Range:	45	30	2.5095
Range:	105	45	5.2605
Mean Difference:	38.2150537634	19.6129032258	1.82763225806
Median Abs. Deviation:	30	15	1.407
Average Abs. Deviation:	27.9032258065	15	1.32932258065
Quartile Dispersion:	0.333333333333	0.5	0.539503386005
Relative Mean Diff.:	0.543425076453	0.526406926407	0.74186984418
Standard Error:	5.89758235445	3.10080382986	0.280381012229
Coef. of Variation:	0.466938905806	0.463377399879	0.633677591267
Skewness:	0.00860606520061	0.0380423220437	0.0989175986703
Kurtosis:	1.71800459535	1.50713266017	1.71152804037
Sum:	2180	1155	76.37
Sum Absolute:	2180	1155	76.37
Sum Squares:	185650	51975	261.2517565
Mean Square:	5988.70967742	1676.61290323	8.42747601613

Inter-Variable Covariance

	X	Y	C (solute concentration)
X:	1078.2258	40.080645	49.670984
Y:	40.080645	298.06452	-4.7968629
Z:	49.670984	-4.7968629	2.4370189

Inter-Variable Correlation

	X	Y	C(solute concentration)
X:	1.000	0.071	0.969
Y:	0.071	1.000	-0.178
Z:	0.969	-0.178	1.000

Inter-Variable Rank Correlation

	X	Y	C (solute concentration)
X:	1.000	0.069	0.976
Y:	0.069	1.000	-0.140
Z:	0.976	-0.140	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	-0.0496047403249	-0.0496047403249	-0.0468367809283
Y:	0.99846365607	0.99846365607	0.0223698058165
Z:	-0.0246920482172	-0.0246920482172	0.0223698058165
Lambda:	1082.53544794	296.191893511	-1.05368869459e-015

Planar Regression: C = AX+BY+D
Fitted Parameters

	A	B	D
Parameter Value:	0.0469	-0.0224	2.22044604925e-016
Standard Error:	N/A	N/A	N/A

(d) Statistical Data Analysis for chromium concentration (C) in water at National Orthopaedic Hospital Enugu.

Univariate Statistics

	X	Y	C (solute in concentration)
Count:	22	22	22
1%-tile:	15	15	0.024
5%-tile:	15	15	0.0375
10%-tile:	30	30	0.051
25%-tile:	30	30	0.1155
50%-tile:	60	45	0.231
75%-tile:	75	60	0.3465
90%-tile:	105	60	0.462
95%-tile:	105	60	0.505
99%-tile:	120	60	0.5265
Minimum:	15	15	0.024
Maximum:	120	60	0.591
Mean:	62.2727272727	44.3181818182	0.264045454545
Median:	60	45	0.24975
Geometric Mean:	53.3007817511	41.2334222486	0.199166151842
Harmonic Mean:	43.8885370488	37.358490566	0.126946279396
Root Mean Square:	69.8537433109	46.6734302458	0.310523128988
Trim Mean (10%):	58.6842105263	44.2105263158	0.245657894737
Interquartile Mean:	56.3636363636	45	0.237545454545

Midrange:	67.5	37.5	0.3075
Winsorized Mean:	62.2727272727	45.6818181818	0.255136363636
TriMean:	56.25	45	0.231
Variance:	1049.35064935	224.512987013	0.0279762597403
Standard Deviation:	32.3936822444	14.9837574397	0.16726105267
Interquartile Range:	45	30	0.231
Range:	105	45	0.567
Mean Difference:	37.6623376623	16.6883116883	0.195813852814
Median Abs. Deviation:	30	15	0.141
Average Abs. Deviation:	26.3636363636	11.5909090909	0.137636363636
Quartile Dispersion:	0.428571428571	0.333333333333	0.5
Relative Mean Diff.:	0.604796663191	0.376556776557	0.741591454967
Standard Error:	6.9063562599	3.19454781985	0.0356601762476
Coef. of Variation:	0.520190517793	0.338095039666	0.633455527412
Skewness:	0.302867510074	-0.462432220927	0.296566871568
Kurtosis:	1.84741656072	1.95830526772	1.87783930761
Sum: 1370	975	5.809	
Sum Absolute:	1370	975	5.809
Sum Squares:	107350	47925	2.1213415
Mean Square:	4879.54545455	2178.40909091	0.0964246136364

Inter-Variable Covariance

	X	Y	C (solute in concentration)
X:	1049.3506	230.19481	-1.7498701
Y:	230.19481	224.51299	1.7043182
Z:	-1.7498701	1.7043182	0.02797626

Inter-Variable Correlation

	X	Y	C (solute in concentration)
X:	1.000	0.474	-0.323
Y:	0.474	1.000	0.680
Z:	-0.323	0.680	1.000

Inter-Variable Rank Correlation

	X	Y	C (solute in concentration)
X:	1.000	0.454	-0.325
Y:	0.454	1.000	0.664
Z:	-0.325	0.664	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	-0.251765866273	-0.251765866273	0.00429965068907
Y:	0.967704905553	0.967704905553	-0.0119990251788
Z:	0.0126950520916	0.0126950520916	-0.0119990251788
Lambda:	1109.24559311	164.64601951	1.29039626552e-017

Planar Regression: C = AX+BY+D (plane curvature)

Fitted Parameters

	A	B	D
Parameter Value:	-0.0043	0.012	-1.11022302463e-016
Standard Error:	N/A	N/A	N/A

APPENDIX B

(F) Statistical Data Analysis for Lead Concentration (C) in water at University of Nigeria Teaching Hospital Ituku Ozalla

Univariate Statistics

X

Count:	48	48	48
1%-tile:	0	20	-0.02698
5%-tile:	0	20	-0.0023
10%-tile:	0	20	0.02238
25%-tile:	20	40	0.06944
50%-tile:	60	60	0.16356
75%-tile:	100	100	0.24764
90%-tile:	140	120	0.297
95%-tile:	140	120	0.31938
99%-tile:	140	120	0.34406
Minimum:	0	20	-0.02698
Maximum:	140	120	0.3564
Mean:	70	70	0.16471
Median:	70	70	0.16471
Geometric Mean:	N/A	59.8759033105	N/A
Harmonic Mean:	N/A	48.9795918367	N/A
Root Mean Square:	83.6660026534	77.888809637	0.195499056264
Trim Mean (10%):	68.3720930233	68.8372093023	0.160826046512
Interquartile Mean:	68	68.8	0.1608992
Midrange:	70	70	0.16471
Winsorized Mean:	70	70	0.163664166667

TriMean:	60	65	0.16105
Variance:	2144.68085106	1191.4893617	0.0113264649191
Standard Deviation:	46.3106990993	34.5179570905	0.106425865837
Interquartile Range:	80	60	0.1782
Range:	140	100	0.38338
Mean Difference:	53.6170212766	39.7163120567	0.124030992908
Median Abs. Deviation:	40	30	0.0891
Average Abs. Deviation:	40	30	0.09032
Quartile Dispersion:	N/A	0.428571428571	N/A
Relative Mean Diff.:	0.765957446809	0.567375886525	N/A
Standard Error:	6.68437364783	4.98223795452	0.0153612505724
Coef. of Variation:	0.661581415704	0.493113672722	N/A
Skewness:	0	0	2.53340224511e-015
Kurtosis:	1.6892567791	1.66003720238	1.82289574033
Sum:	3360	3360	7.90608
Sum Absolute:	3360	3360	7.99392
Sum Squares:	336000	291200	1.834554288
Mean Square:	7000	6066.66666667	0.038219881

Inter-Variable Covariance

	X	Y	C (solute concentration)
X:	2144.6809	0	-1.3232681
Y:	0	1191.4894	3.5387234
Z:	-1.3232681	3.5387234	0.011326465

Inter-Variable Correlation

	X	Y	C (solute concentration)
X:	1.000	0.000	-0.268
Y:	0.000	1.000	0.963
Z:	-0.268	0.963	1.000

Inter-Variable Rank Correlation

	X	Y	C (solute concentration)
X:	1.000	0.000	-0.277
Y:	0.000	1.000	0.960
Z:	-0.277	0.960	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	4.12312624578e-006	4.12312624578e-006	0.000616997161329
Y:	0.999995589578	0.999995589578	-0.00296998633573
Z:	0.00296998435708	0.00296998435708	-0.00296998633573
Lambda:	2144.68166753	1191.4998717	-3.00603222059e-018

Planar Regression: C = AX+BY+D

Fitted Parameters

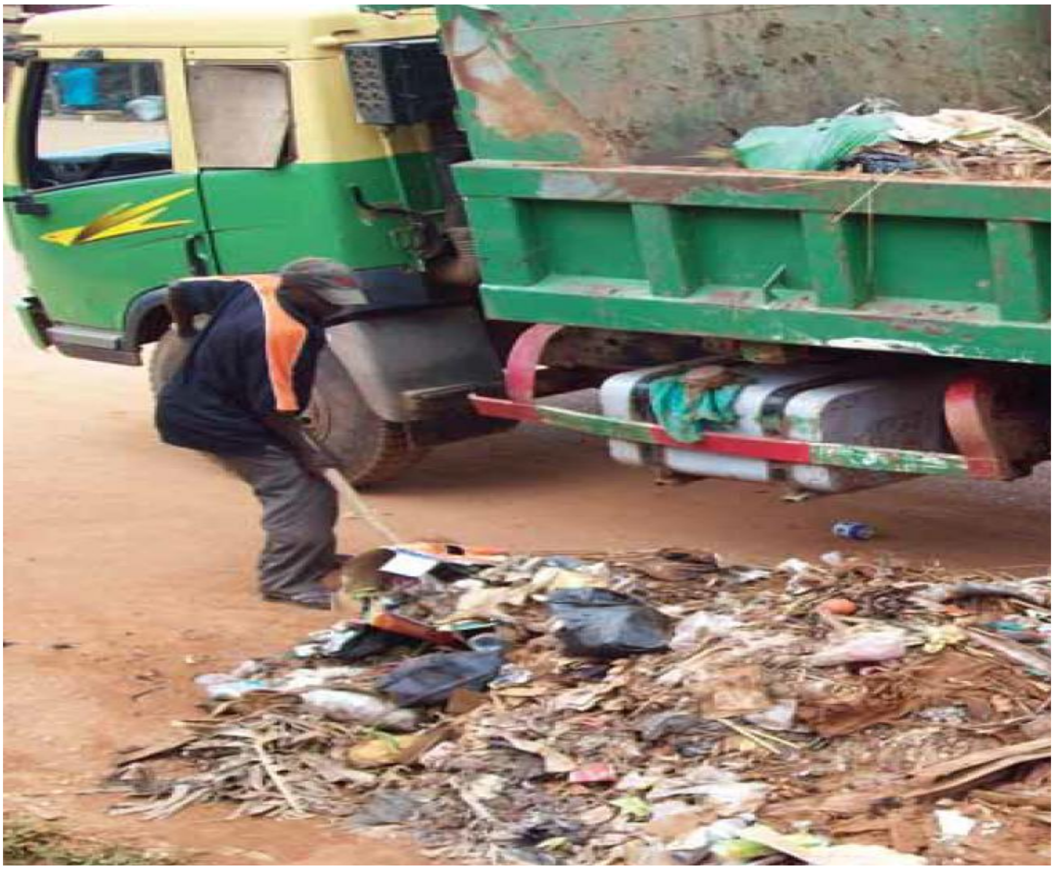
	A	B	D (plane curvature)
Parameter Value:	-0.000617	0.00297	-2.77555756156e-017
Standard Error:	N/A	N/A	N/A

FILD WORK PICTURES

Agricultural setting found adjacent to waste dump at UNTH

Indiscriminate disposal of hospital waste near farmland at NOHE

Burning of hospital waste at UNTH



Illegal disposal of hospital waste with municipal wastes along the street

Improper storage of both general waste and infectious waste at one of the hospitals surveyed

Burning of wastes in an open place at National Orthopaedic Hospital.

Mixing of hospital waste with municipal wastes at Abakaliki Enugu where both NOHE waste are disposed with municipal waste by Enugu State Waste Management Board.

Visit by the researcher to NOHE permanent waste dump located at Emene/Abakaliki road behind the NOHE Enugu, site designated by Enugu State Waste Management Board for municipal waste dump.

APPENDIX 3

Waste dump

COLLECTION OF WATER SAMPLES FOR THE STUDY

Ufam River located at UNTH Ituku/Ozalla (front view)

Ufam river located at UNTH Ituku Ozalla and the river was petitioned from which the Ituku Ozalla draws their water.

COLLECTION OF WATER SAMPLES FROM UFAM RIVER

WATER SAMPLING FROM THE Uvuna stream at NOHE Enugu

Incineration seen at UNTH although is not functional at the time of the study

Waste handler disposing wastes at NOHE without protective wears

Truck carrying daily generated wastes at UNTH

Illegal disposal of used syringes and placenta at UNTH

Open dumping of waste at NOHE

Open disposal of wastes at NOHE

Illegal disposal of used syringes and contaminated wastes at UNTH

Illegal disposal of wastes at UNTH

Illegal disposal of used tolicate, syringes and blood bank at UNTH

Fresh disposed wastes at UNTH

Used cotton wool and syringes dumped at UNTH

Illegal dumping of waste at NOHE

Illegal dumping of wastes at NOHE