SPATIAL ANALYSIS OF SITE SUITABILITY FOR WASTEWATER TREATMENT PLANT IN KANO METROPOLIS, NIGERIA

BY

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DECLARATION

I declare that this dissertation entitled "Spatial Analysis of Site Suitability for Wastewater Treatment Plant in Kano metropolis, Nigeria" has been carried out by me in the Department of Geography and Environmental Management. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

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CERTIFICATION

This dissertation entitled "SPATIAL ANALYSIS OF SITE SUITABILITY FOR WASTEWATER TREATMENT PLANT IN KANO METROPOLIS; NIGERIA" by AHMAD HAMZA ABDULLAHI meets the regulations governing the award of the degree of Master of Science in Remote Sensing and Geographical Information System of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to my beloved mother Hajiya Fatima Abubakar Janare and my father late Alhaji Abdullahi Na Namu for their uncountable efforts toward dragging me to school and providing all necessary assistance for my study and well being. May all their good work be rewarded and their short coming forgiven amen!

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ABSTRACT

Discharge of wastewater especially from industries and residential areas of Kano metropolis is a real threat to the public health and the environment. The study focused on the spatial analysis of site suitability for wastewater treatment plant in the study area. Field survey, landsat satellites, administrative map, public responses through questionnaire administration and interview as well as the use of Descriptive statistics and GIS - based Multi-Criteria Decision Analysis (MCDA) were the materials and methods used for the study. The results of the study shows that Pit latrine (38%) and soak away (55%) are the major means of discharging black water in the study area, while canal serves as the major method of discharging grey water with 76.3%. The environmental impacts of wastewater disposal have been found to be breeding of disease-causing organisms and bad odour with 61.2% and 22.7% respectively. The result also shows that the health implications from the public response were malaria that accounted for 47.9% and typhoid with 35.8%. The study further showed that, residential, commercial, agricultural and industrial activities serve as the major sources of wastewater discharge in the study area. The results show 10 best sites for offsite wastewater treatment plants in the study area with the size of 41 acres, 28 acres, 16.9 acres, 17.8 acres, 77 acres, 61.6 acres, 20.3 acres, 31.2 acres, 51.8 acres, and 45.4 acres. In conclusion, farmers utilize wastewater for irrigation activities and the source of water to Challawa and Tamburawa conventional water treatment plants mixes with untreated wastewater, hence, public and ecosystem health were at risk. It is therefore recommended that, wastewater should be given a special treatment through construction of offsite wastewater treatment plant in a suitable location, so as to minimize the impact of wastewater to the public and ecosystem.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Locally available fresh water which is colourless, tasteless and odourless liquid, that is a compound of hydrogen and oxygen (WHO, 2006) can easily be contaminated when mixed with wastewater, this call for proper management of wastewater before discharge. Wastewater management system is one of the most important means of protecting public health and environment, due to the fact that, unmanaged wastewater can widely impact negatively on the environment and public health. A wastewater is water which carries waste in suspension or solution usually originates from industrial, municipal, agricultural and commercial areas and drains mainly through drainage system.

Effluents entering water bodies carries pathogenic organisms that transmit diseases such as typhoid, cholera and skin infections to human beings and other animals which consequently lead to untold suffering and loss of life. Side effects of wastewater does not end at causing diseases to human and animals, but it affects the phenology and vigour of farm products and other plants. The use of wastewater for irrigation purpose is a common practice in many developing countries such as India, Pakistan, Egypt, Sudan as well as Nigeria. Chen, Wang, and Huang (2004) observed that crops produced with wastewater especially from coal industry are highly affected by aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCPs). They further argued that, the levels of persisted organic pollutants (POPs) in the water and a soil of irrigated land in India for example, is influenced by sewage sludge. In Kano metropolis, the practice of using wastewater has been on the increase especially in irrigation activities.

The term ‘treatment’ of wastewater implies the use of chemical, physical or biological agents to remove pollutants and organic matter from wastewater; while wastewater treatment plant comprises the site, physical infrastructure and the process involved (FSC, 2003).

There are various techniques used to treat wastewater depending on the nature and extent of contamination; either the wastewater is grey water, black water, industrial or agricultural wastewater. These techniques may be categorized into decentralized and centralized techniques of treating wastewater. The decentralized or primary techniques are the on – site wastewater treatment system whereby the wastewater is partially treated close to where it was produced, such methods include the use of green plants, septic tanks, chemical toilet, compositing toilet, cesspool and so forth. According to USEPA (2015), the use of non - toxic and low sodium soap and personal care products is recommended to protect vegetation when reusing grey water for irrigation purposes. But of all various kinds of on - site treatment systems, septic tank is highly applicable in both developed and developing countries. USEPA (2008) observed that, about 20% of homes in United States use septic tanks and other on-site sewage facilities. Yet, septic tank is not applicable when the wastewater came from industrial centre or densely populated areas, because, the system is often suitable option for small – scale residential areas with sufficient land for an adequate drainage field (Environmental Alliance, 2006).

The centralized techniques of treating wastewater is otherwise known as off–site wastewater treatment system whereby package or passive wastewater treatment plants (WWTP) are used, wastewater that does not undergo any treatment or passes through primary treatment such as septic tank is sent to the centralized treatment plant through a watercourse or drainage field for further treatment. In package treatment plant for

instance, wastewater undergoes more than one process before discharge. When selecting best site for centralized treatment system factors such as slope, geology, and distance from settlement, road and water bodies should be put into consideration. Of the two treatment techniques, the decentralized system is more practicable in both developed and developing countries due to the influence of factors such as financial and site suitability.

The need for identifying a suitable site for construction of centralized (offsite) wastewater treatment plant has become necessary considering the population and the amount of wastewater being generated daily in the study area. Proper method of collection and nuisance free disposal of the liquid waste of a community are legally recognized as a necessity in an urbanized, industrialized society (Mc Graw-Hill, 2011).

Previous studies particularly on site selection have been hampered due to paucity nature of data. However, with the introduction of modern technology such as remote sensing and Geographical Information System (GIS), data on site selection and or suitability assessment is now available for effective study. Remote sensing is an extensive tool and technique that is used to capture the characteristics of the physical environment without onsite observation, while Geographical Information System (GIS) is a computer based information system that enables one to capture, store, retrieve, analyse and display geographically referenced data (ESRI, 1990).

1.2 Statement of the Research Problem

Untreated and partially treated wastewater in the study area and elsewhere in the world are being discharged into the environment and nearby water bodies which consequently result to various environmental and public health implications. Wastewater is highly responsible for the spread of various kinds of diseases. According to Young (1985),

lack of adequate water and wastewater treatment plants resulted in catastrophic epidemics of waterborne diseases during 1840s and 50s. Consequently, this brought about the struggle to find a way of treating wastewater in United State and Europe towards the end of the 19th and early 20th century through the construction of wastewater treatment plant, but these developments were not successful in developing countries and hence the wastewater treatment coverage remained low. According to UNEP (2000), only 2% of the cities in Sub – Sahara Africa had wastewater treatment plant and only 30% of these were operating satisfactorily.

Site selection through analysis of variables, such as, distance from surface water and built-up areas becomes necessary, because, environmental and public health problems' resulting from the disposal of wastewater does not end with the construction of WWTP. IRC (2017) observes that, during super storm sandy in 2012, several WWTPs in New York and New Jersey were inundated with storm surge, causing hundred million gallons of untreated sewage to spill into neighboring water ways. This is because, many of these plants were constructed at the bottom of watersheds and riverine areas, but since the plants have developed resilience plans and increased infrastructure fortification against floods and storm surge, these problems were not destructive (IRC, 2017).

Negative implications of wastewater to public health and environment especially nearby water bodies in the study area has been studied by many researchers such as, Dawaki, Dikko, Noma and Aliyu (2013); Bernerd and Ogunle (2015); Koki and Jimoh (2015), others include, Mukhtar, Indabawa and Imam (2010), also evaluated the suitability of ponds within Kano metropolis for the discharge of sewage. Data were gathered, through visits to the existence sewage ponds. The result of the study showed

high concentration of disease vectors, such as mosquito, offensive odour, toxic chemicals and pathogenic bacteria in the ponds, which are threat to public health.

Adedokun and Agunwamba (2014) analyzed the influence of industrial effluents on the pollution of River Challawa in Kano metropolis. The study discovered high levels of pH values, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Sediment (TSS), Total Dissolved Solids (TDS) and Total Solids (TS) in the River beyond National Environmental Standards and Regulations Enforcement Agency (NESREA) standard. Plate 1 shows how wastewater from industrial area drains into River Challawa due to the absence of offsite wastewater treatment plant which consequently resulted in the contamination of the water body that serves as a major source of water supply to the conventional domestic water treatment plants situated at Tamburawa and Challawa.

In an attempt to reduce these problems, two WWTPs were constructed by the Kano state government at Nomansland and Tukuntawa in Kano metropolis around 1980s, but none of them is still functioning due to the fact that, the sewers that convey wastewater from source to the plants were blocked up, likewise, buildings and other structures have presently reached the plants, which render it dangerous to public health and environment. These problems were attributed to the fact that, traditional methods were used during the design path. Since then, no further attempt has been made for WWTP site selection in the study area, even though, UNIDO (2003) and Mukhtar, Indabawa and Imam (2010) called for the construction of offsite WWTPs at suitable locations in the study area. This study therefore, tried to find answers to the following issues of site suitability for wastewater treatment plants in Kano metropolis.

1. what are the major sources of wastewater generation in the study area?

2. what are the environmental and health implications of wastewater in the study area?
3. where are the best sites for wastewater treatment Plant in the study area?

Plate I: Challawa Industrial Wastewater Drains into River Challawa
Source: Preliminary Survey, 2016

1.3 AIM AND OBJECTIVES

The aim of this study is to analyse suitable sites for wastewater treatment plants in the study area. The aim was achieved through the following objectives, to: -

i. identify the major sources of wastewater generation in the study area.
ii. examine the environmental and health implications of wastewater in the study area.
iii. identify and map out best sites for wastewater treatment Plants in the study area.

1.4 JUSTIFICATION FOR THE STUDY

It is quite significant to reason out how best to tackle the problem of wastewater in our environment, for if no significant effort is done, there will be continues spread of diseases and consequent loss of lives. The lag of matter which is centered to this research is to evaluate the possibility of having a site that is suitable for the location of offsite wastewater treatment plant in Kano metropolis due to the high concentration of harmful substances, such as, pathogens, metals, organic compounds, metalloids and endocrine descriptor compound contained in wastewater. Any of these compounds especially in excess can cause harm to man and his environment (UNEP, 2010).

The growing amount of wastewater is an issue of great concern worldwide particularly in Kano metropolis as a result of the rate at which the population is fast expanding. Despite the efforts being made by government and other agencies to safe guard the life and properties of the public through various environmental programs, still wastewater poses a serious threat to the health of not only people in the study area but the crops they produce as well as the animals. Therefore, the provision of treatment plants at suitable locations in the study area will go a long way to reducing the potential risk of

wastewater as well as enables the Kano state government to meet all laws and regulations governing water pollution and wastewater disposal.

1.5 SCOPE OF THE STUDY

The study covers eight Local Government Areas which form Kano metropolis, namely: Kano Municipal, Gwale, Nassarawa, Dala, Tarauni, Fagge, Kumbotso and Ungogo. Geographically, the area is located between Latitude $11^{o}\,52^{'}2^{''}$N and $12^{o}\,7^{'}41^{''}$ North of Equator and between longitude $8^{o}\,25^{'}3^{''}$ E and $8^{o}\,39^{'}57^{''}$ East of Prime meridian. The study examines major sources of wastewater generation in the study area and their environmental and public health implications. It also identifies and map out best sites for the siting of offsite wastewater treatment plant using land sat of 6 March, 2015 and Digital Elevation Models (DEMs) of 2006.

1.6 ORGANIZATION OF THE WORK

The entire study is organized and presented in five chapters; the first chapter focuses on the introduction which comprises the background to the study, statement of the research problem, research question, aim and objectives, justification and scope. Chapter two of the study covers review of related literature. Chapter three looks into the study area, materials and methods of the study. Chapter four deals with results and discussion while chapter five deals with summary, recommendation and conclusion as per the findings of the study.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

This chapter reviewed relevant literature related to the topic of study. Wastewater discharge, major source of wastewater discharge, implication of wastewater to man and his environment, wastewater management, wastewater reuse, processes of wastewater treatment, wastewater treatment site suitability criteria and application of geographical information system in wastewater site selection.

2.2 Conceptual Framework

Waste which brings about land, air and water pollutions must be generated as long as human activities exist; it is generated in form of municipal, agricultural, and industrial wastes. Olorunfemi (2009) defines wastes as any substances which constitute scrap materials or effluents or other unwanted surplus substances arising from the application of process. Waste may be categorized as solid waste, liquid waste and gaseous waste; it is a leftover, used product whether liquid or solid having no economic value or demand to the user and which must be disposed (Oluwande, 2002). According to Sharma (2010) waste may be defined as valuable raw materials located at a wrong pace.

For the purpose of this study, waste may be referred to as liquid substances in form of wastewater (sewage) which has been disposed by the original user and become dangerous to environment and public health when left untreated. Due to the nature of waste, it must be managed; therefore, waste management is the act of maintaining acceptable environment, which supports the life and property of public towards a better living. Jaya and Kaberi (2015) define waste management as an act of reducing or

eliminating adverse impacts of waste on the environment and human health and supports economic development and improved quality of life.

The history of wastewater discharge and its consequences on man and his environment could be traced back from the origin of man, this is because, the production of urine and excreta as one form of wastewater is a natural part of human life but increase in population and economic development has risen the problems associated with the large accumulation of wastewater (Eckart et al, 2011). In China one of the rapidly urbanized countries of the world, rising of population and economic developments has brought about the risen volume of domestic wastewater discharge. Li, Qin and Qin (2012) stated that, in 2001, the volume of domestic wastewater discharge in China had reached 22 billion tons, which is about 53% of the total wastewater discharge; of course this is as a result of development of the country which started in 1992. This risen volume of wastewater discharge in the world has generally been considered to be an increase in the level of resource with negative impacts on man and his surrounding environment, through the contamination of both surface and ground water, and also generation of bad odour in general, wastewater discharge result to environmental and public health risk which need to be tackled.

The searches, for the best method for the management of wastewater in the world, have been in many forms, but the most important factor that attracted the attention to the need of proper collection and treatment of wastewater before discharge was the global outbreaks of Cholera in the 19^{th} century. It has been observed that, the first outbreak of Asiatic cholera in Britain during the autumn of 1831 claimed over 52,000 lives by the time it had run its course (Haley, 1978). The disease that led to the outbreaks was gradually traced back to well-water supplies that were contaminated with human waste from cesspools and privy vaults, hence, this led to a wider focus on wastewater disposal

practices (Britannica, 2012) and therefore the development of centralized wastewater treatment systems during the late 19th and early 20th century in United State and United Kingdom.

Treatment of wastewater before discharge is an excellent environmental protection work, but, handling of one problem may lead to the introduction of another one, this brought about the issue of best site selection for wastewater treatment. Remote Sensing (RS) and Geographical Information System (GIS) have been widely used in a broad range of geo-location related studies for data collection and management (Zhao, 2015). These two techniques are very important toward data collection and analysis for wastewater treatment site selection. RS as described by Lillesen and Kiefer (2000) is the science of obtaining information about an object, area or phenomenon under investigation. While Abuga and Ndegwe (2015) define GIS as the scientific and technological tool that enables the integration of data from different sources into a centralized database from which the data is modeled and analyzed based on its spatial component. The main reason behind using RS and GIS techniques in wastewater treatment site selection is that technical, economic and environmental concerns in the designed paths are not considered in traditional methods (Abuga and Ndegwe, 2015).

Application of RS and GIS software and data enable the researchers, scientists and governments to find optimal location for siting wastewater facilities by taking into account natural and manmade obstructions such as vegetation, land use, slope, road network, water bodies and settlements. Many researchers applied geographical information system in suitable site selection for wastewater treatment, notably among them is Zhao (2015), who used GIS – based multi criteria analysis for optimal site selection for sewage treatment plant in China. Others who utilized the same approach

include Asante and Barimah (2012); Msangi and Liwa (2014) and Manjubashini, Rinsitha and Singh (2014).

2.3 Review of other Relevant Literatures

2.3.1 Wastewater Discharge

The term "wastewater" is usually used to describe all forms of waste which are in liquid form, that is, liquid substance whose colour, taste or odour change and discharge after use. A wastewater is a combination of one or more of domestic effluent (blackwater and greywater), water from commercial establishment and institution (e.g. hospital), agricultural dissolved or suspended matter, industrial effluent, storm water and other urban run-off (Corcoran et al, 2010).

Wastewater is a problematic substance to man and his environment if not properly controlled and treated; it contaminates the environment including surface and underground water. Josiah et al (2014) observed that the pathogenic, organic and indicator organisms present in the drinking water supply in Okada town, Edo state render the water unfit for human consumption. According to Pushpendra and Kanjan (2015) wastewater discharges from municipal and industries to the natural water bodies are the major components of pollution, contributed to oxygen demand nutrient loading of the water bodies as well as destabilized aquatic ecosystem and public health. The findings of researchers such as Momani (2013); Mustapha and Aris (2012a) indicated how wastewater from municipal, industrial, agricultural, ground leaching and run off contaminated freshwater.

The volume of wastewater in the metropolis of Kano state is increasing day in day out due to the rise of population and expansion in the economic activities, such as

commercialization and industrialization. It has been estimated by United Nations Industrial Development Organization (UNIDO) (2003) that about 325m^3volume of wastewater is discharged to River Challawa hourly, this amount most have been raised up with the increased in the level of industrial development in the area. On a similar vein, the population of Kano metropolis is also rising annually from the rate of 2.5% per annum in the 1960s to about 2.9% in 2008 (Nabegu, 2008) and 3.55% as at 2016. The rising of population, unplanned settlements and socio-economic activities of any region has influence on the volume of wastewater generated in the environment (Nyenje et al, 2012). So it is also the case in Kano metropolis.

2.3.1.1 Sources of Wastewater Discharge

Discharge of raw or partially treated wastewater is one of the major concerns of public and researchers now a days, hence, determination of the source of these ugly material to the people and ecosystem is also very important; growth of population, rapid industrial development and new way of life serve as the sources of high volume of wastewater discharge in both developed and developing nations. One of the major global issues now a day has to do with declining water quality due to human population increase, as well as the expansion of industrial and agricultural activities (WHO, 2012). Industrial, domestic and commercial activities serve as the major sources of wastewater in urban centers, domestic and agricultural activities are the sources in rural areas while natural source affects both urban and rural areas.

i. Agricultural Wastewater: Agricultural activities are the major core to life sustenance. They are sources of raw materials to the industries and domestic activities, agricultural activities acts as cause and victim of wastewater. This is because, pollutants and sediments are discharge to the surface water through agricultural activities, the

pollutants through application of fertilizer, pesticides, and herbicides are transported to the above ground or underground receiving water system which consequently drains into major water bodies. According to Carpenter et al (1998) pollutants from agricultural activities such as ranching and farming may include nutrients, sediments, pesticides, pathogens, metals and salts in excess. In a similar research, Kaown et al (2012) reported that agricultural activities have been shown to produce high concentration of nutrients such as phosphate and nitrate in many sites of the world. As well this include the metropolitan Kano state because vast agricultural activities which include farming and rearing of animals,' are taking place in many parts of Kumbotso and Ungogo local governments areas of Kano metropolis.

ii. Domestic Wastewater: Domestic or Municipal wastewater refers to the liquid waste discharged from residential areas, institution such as Market; washing water, food preparation waste, laundry waste and other liquid waste products of normal living; these types of wastewater is basically categorized into Blackwater and Greywater. According to Environmental Health Project (2014) domestic wastewater is a wastewater that came from toilet, washing, food preparation and other water used domestic activities. Kagu, Badawi and Abba (2013) identified bathing, washing of cloths, washing of utensils and flushing of toilet as the sources of domestic wastewater discharge from residences, commercial areas, institutional and similar facilities in Maiduguri metropolis.

The term "blackwater" is used to describe water that comes from toilet while "greywater" refers to as water discharge from other domestic activities. Blackwater is water that contains faeces, urine and flush water from flush toilets along with anal cleansing water but greywater is that which has been generated from washing of clothes, food utensils; as well as from bathing (Tilley, 2012). The concentrations of

organic micro pollutants such as benzene in greywater have been found to be few (Etchepare and VanderHoek, 2015) hence, it is less dangerous when compare with the blackwater.

The level and quantity of municipal wastewater in the metropolis of Kano state is increasing due to the risen of population. The increase in the volume of municipal wastewater in areas such as Jakara and Salanta attracted farmers to cultivate vegetables using the wastewater which resulted to the contamination of the vegetables cultivated in the area. Table 2.1 shows the values of physicochemical parameters of River Jakara in 2008 due to contamination.

Table 2.1: Physicochemical Parameters in River Jakara

Parameters	Values
PH	10.34+-1.43
Temperature (O^oC)	36.34+-2.94
Turbidity (NTU)	42.22+-3.10
COD (mg/l)	698.11+-6.45
BOD (mg/l)	341.11+-4.34
DO (mg/l)	8.43+-0.56
TDS (mg/l)	2655.43+-16.33
TSS (mg/l)	2673.22+-17.32
Conductivity (micros cm^{-3})	1534.21+-12.43
Sulphate (mg/l)	252.21+-1.32
Nitrate (mg/l)	284.33+-1.74
Phosphate (mg/l)	164.22+-0.56

Source: Akan, Abdulrahman, Dimari and Ogugbuaja (2008)

iii. Industrial Wastewater: Belay (2010) observed that, wastewater from industries such as metal cleaning, cement factory; dyeing processing and leather tanning are the major sources of chromium into the environment; which consequently make industries to be a potential pollution sector. Before industrial revolution, there was low contamination of water bodies but when industrial activities began to rise in the mid of 18^{th} century, the quantity of polluted water bodies started to rise, hence, industrial wastewater can be considered as one of the major sources of water pollution more especially in the developing countries. Application of polluted water to the soil especially through irrigation activities resulted to the decrease in the quality of soil. It has been reported that high level of copper and nickel concentration in soil leads to the decreases in plant growth (Kataeva et al, 2012). Industrial wastewater is basically divided into organic and inorganic industrial wastewater.

Organic industrial wastewater is produced from industries that make use of organic substances from chemical reaction that includes tanneries, textile factories, oil refining industries, brewery and fermentation factories, pharmaceuticals, cosmetics and other organic dye stuffs; wastewater produced by these types of industries is more harmful and difficult to treat (Hanchang, 2010). But inorganic industrial wastewater is less severe and requires less treatment when compared with organic, these are mainly produced in the coal and steel industry, non metallic minerals industries as well as industries for surface processing of metals. The principal pollutants in industrial wastewater are shown in Table 2.2. Egila, Dauda, Iyaka and Jimoh (2011) asserted high concentration of Cr, Cu, Pb and Zn in the water of River Chllawa of Kano state from the industrial effluents discharge to the river. The water pollution due to the industrial effluents is also studied by researchers such as Hin, Qiao, Zhou and Li (2012); Bhuiyan et al (2011) and Silvaalves et al (2012).

Table 2.2: Principal Pollutants in Industrial Wastewater

Industries	Principal pollutants
Dairy, Milk processing	Carbohydrates, fats, protein
Meat processing	Suspended solids, protein
Poultry processing	Suspended solids, protein
Bacon processing	Suspended solids, protein
Sugar refining	Suspended solids, Carbohydrates
Breweries	Carbohydrates, protein
Canning fruit	Suspended solids, Carbohydrates
Tanning	Suspended solids, protein, sulphide
Electroplating	Heavy metals
Laundry	Suspended solids, Carbohydrates, soaps, oils
Chemical plant	Suspended solids, acidity, alkalinity

Source: Kiely (1996)

The history of industrialization in the metropolis of Kano state could be traced back to 1900 when the region was incorporated into the world capitalist economy; It has been observed by Nabegu (2008) that, most of the industrial activities in Kano metropolis have to do with the plastic products, textile goods, metal, paper, cosmetics and toiletry, and leather goods. Industrial growth and various associated environmental problems in the study area were observed and analyzed by several researchers such as Bichi (2000), who showed that Kano as one of the major industrial cities in Nigeria, having over 350 industries release wastewater into rivers leading to the deterioration of the water in the rivers. In fact, the implications of wastewater to man and environment in the study area and elsewhere in the world were studied by researchers such as Akan, Abdulrahman,

Dimari and Ogugbuaja (2008); Mukhtar, Indabawa and Imam (2010) and Dawaki, Dikko, Noma and Aliyu (2013).

2.3.2 Implications of Wastewater on Man and Environment

Wastewater as one form of human resource is generally considered as resource with negative impact to public and ecosystem health, due to its characteristics of bad view and odour as well as the type and quantity of substances contain. Health risk associated with untreated wastewater has to do with pathogenic contamination while the overloading of physical and chemical components resulted to environmental problems. For instance, when nitrogen and phosphorous are over loaded into natural water bodies, the growth of algae will extensively rise; and since large amount of oxygen is required for algae decomposition, the available oxygen for aquatic life will be inadequate. Awomesu, Taiwo, Gbadebo and Adenowo (2010) observed that there is zero presence of oxygen at the points closest to the point of textile effluent discharge in Lagos.

High amount of potential contaminants within wastewater renders it unfit for consumption and therefore water bodies where wastewater is discharged into are very dangerous to public, animals and other organism; public and scientists concern over the discharge of effluents into water bodies has been increasing considering their extreme toxicity to human health and biological ecosystem. Gouzalez-mendez et al (2015) observed that application of wastewater to irrigated soil adds up to 2.5 times more water than the soil can retain, therefore the use of wastewater in irrigation increases the level of Nitrogen entering agro ecosystem which consequently leads to the emission of N_2O and CO_2 into the atmosphere.

Moreover; wastewater from industries and municipal treated or untreated is highly being utilized for irrigation agriculture in both developed and developing countries,

when untreated has been used, both, farmers and consumers of the product are negatively affected due to the characteristics of the water. Keraita, Drechsel and Konradsen (2008) reported diarrhea disease and worm infections as the main health hazards caused by excreta-related pathogens to the consumers of vegetables irrigated with wastewater. It is also reported that farmers and people having contact with untreated wastewater in Combodia and Vietnam are infected with skin diseases such as dermatitis (Trang et al., 2007). Therefore, release of pollutants from industries make environment to be hostile to the surrounding people as well as real threat to the health and welfare of the public.

The effluents generated through human activities such as agricultural, industrial, commercial and residential constitute the major sources of wastewater which consequently leads to negative environmental and health risk to the inhabitants (Nda, Aliyu and Dalil, 2013). Several studies conducted across the universe revealed that a significant relationship exist between wastewater discharge and heavy metals contaminations with consequences resulted to human and environmental problems such as underground and surface water pollution, environmental degradation, offensive environment, breeding ground for diseases-causing vectors as well as spread of bad odour. Some of the literatures related to those consequences include:

Dawaki, Dikko, Noma and Aliyu (2013) challenged the use of untreated wastewater in agriculture due to the higher concentration of metals and toxic industrial chemicals. According to these researchers wastewater has to be treated before reuse especially in agricultural activities due to its negative implication on human health resulting from the level of both chemical and physical parameters, such as Copper (Cu), Nickel (Ni), Chromium (Cr) and Zinc (Zn). In a similar study, Bos, Carr and Keraita (2010) assessed the wastewater related health risk among low income countries and revealed

that consumption of irrigated crops produced by wastewater exposed urban customers to health related problems but these negative implication of wastewater do not end on crops produced in agriculture activities rather they affect the lives of aquatic and terrestrial animals. Oyeniyi and Latunji (2012) found that, industrial wastewater discharge from Agbara industrial estate, Ogun state contained chemicals that are potential germ cell mutagens to animals such as Mouse.

Akan, Abdulrahman, Dimari and Ogugbuaja (2008) observed that, pH, electrical conductivity, temperature, nitrate, sulphate, phosphate, TSS, TDS, DO, BOD and COD in Jakara River of Kano state were higher than the maximum permissible limits set by FEPA, Nigeria and concluded that vegetables cultivated with the water of the river is unfit for consumption. The researchers failed to suggest the most appropriate way to tackle the problem. Therefore, since these problems are associated with the discharge of untreated wastewater to the river, construction of wastewater treatment plant in a suitable location will help to control the problem.

Sheykhi, and Moore (2012) studied geochemical characterization of Kor river water quality in Fars province of southwestern Iran and found that discharge of metals from industries along with indiscriminate use of heavy metals containing fertilizer and pesticides in agricultural practices are among the sources of polluting the river. The increase of wastewater production contributes to the reduction in the quantity and quality of aquatic animals as observed by Adeogun and Chukwuka (2010) the scholars worked on the differential sensitivity of Saggital Otolith growth and Somatic growth in *Oreochromis Niloticus* exposed to effluents discharge by textile industries. The result of their work indicates that the weight of exposed fish decreases when compared with that of controlled fish.

Massod and Malik (2013) studied the Cytotoxic and Genotoxic potential of tannery waste contaminated soil and found that the soil irrigated with tannery effluents has been highly contaminated. Their investigation brought out how industrial wastewaters contaminate soil. Wastewater discharge to the environment resulted to the changing in the colour of soil, as well as physical, biological and chemical parameters.

Jimenez et al (2010) studied the environmental and health implication of wastewater, sludge and excreta in developing countries and observed that, wastewater discharge in most cities of the countries exceeded the assimilation capacity of the environment due to the poor level of wastewater treatment. The study brought out how the volume of wastewater discharges in developing countries out weight the level of treatment process. In a similar researched, Dan'azumi and Bichi (2010) studied the implication of industrial pollution on the source of water supply for the inhabitant of Kano, Nigeria and discovered the level of lead, chromium, manganese, iron and TSS in the raw water sent to the treatment plant exceeded the recommendation of FEPA and WHO which may subsequently pollute even the treated water. One thing to understand from this study is that the lives of people in metropolitan Kano is at risk due to continued discharge of industrial wastewater to the water bodies.

Mukhtar, Indabawa and Imam (2010) examined how the presence of wastewater ponds in Kano metropolis, converts the city into ugly and dirty environment with chasing odour; and how the sites served as breeding ground for many disease vectors such as mosquitoes and many other epidemic explosions. There are numerous ponds in Kano metropolis which serve as sites for the discharge of wastewater especially domestic, some houses don't have toilet for excreta, and they discharge their black water directly into the ponds which of course become dangerous to lives.

Bloch (2012) conducted a research toward water management in sub-Sahara Africa and found that, about 80% of the Dakar in Senegal ground water was contaminated by nitrates; the research also related the contamination of the Lagos of Nigeria, Accra of Ghana and Cotonou of Benin republic ground water with the effluents discharge by industries.

Yahaya, Adegbe and Emuroto (2012) found heavy metals concentration such as Cd, Pb, Ni, in the surface water of Oke-Afa Canal Isolo, Lagos of Nigeria. Concentration of heavy metals in water reduce the quality of the water for drinking and other domestic purposed and of course this is one of the major health problem that affect the world now days. In another research, Al-Amin (2013) studied the quality of water in River Kaduna, Nigeria and attributed the high concentration of metals such as mercury, lead, cadmium, rabidity, high acidity, conductivity, BOD, DO, COD and DS to the discharge of industrial and domestic wastes to the river. High level of these elements does not end in causing problem to water bodies but it destroys even the quality of soil for agricultural activities.

Nda, Aliyu and Dalil (2013) observed that, the discharge of wastewater into the environment of a city like Minna of Niger state, Nigeria, converts the sites to a breeding ground for houseflies, mosquitoes, rodents and other vectors of communicable diseases such as diarrhea and dysentery. In a similar research, Tamunobereton-ari, Uko and Horsfall (2013) correlated sewage disposal method with the incidence rate of typhoid and cholera in Port-Harcourt metropolis, Nigeria and concluded that, polluted water sites serve as pathway for the spread of various infectious diseases. Similarly, Kagu, Badawi and Abba (2013) observed how poor wastewater disposal system in Maiduguri metropolis, Nigeria produce serious environmental and public health problems such as breeding of disease-causing organisms and bad odour in the area.

Thus, these studies have shown that improper discharge of wastewater is dangerous to human health. Adedokun and Agunwanba (2014) identified high concentration of DO, BOD_5 and COD at "yandanko and Tamburawa outlet of River Challawa, Kano, which therefore makes the water threat to public and environmental health. In a similar study, Koki and Jimoh (2015) related the contamination of River Challawa to increasing level of toxic metals such as chromium and iron which drain into the river. Of course, this is attributed to the drains of untreated industrial effluent to the river which could only be controlled with construction of offsite wastewater treatment plant.

The relevance of wastewater to the quality of water supply and public health has been studied by many researchers; Mustapha and Aris (2012b) observed that in most of the developing countries, raw wastewater has been discharged into water bodies which consequently resulted to the contamination of fresh water. Therefore, the quality of water bodies in developing countries such as Nigeria cannot be guaranteed for public use due to constant disposal of untreated industrial effluents (Ado et al, 2015). Even though many studies have shown how raw wastewater discharged to the environment has negatively affected the biophysical environment and socio-economic status of public due to the level of physical, biological and chemical parameters, however, some researchers concern has to do with how wastewater produced can be of benefit to man and his environment. According to Jimenez et al (2010) if wastewater can be treated before discharge, the environment and public health is protected through fresh water conservation and irrigation system. Because, the presences of sufficient level of nitrogen, phosphorous and potassium in raw wastewater are highly essential for vegetable and other crops growth which subsequently provides higher return than the use of fresh water (Roy, Bannu, Mamun and Farukh, 2013).

2.3.3 Wastewater Management

Wastewater management is a system that focuses on finding a means of disposing liquid waste in a manner that is safe to Man and his environment (Environmental Health Project, 2014). The world is actually facing a global water quality crisis; the world's hospitals beds are occupied by sick people most of who were linked with contaminated water. It was estimated by World Health Organization in 1964 that one in every four hospital beds in the world is occupied by a patient with a disease caused by polluted water (Gadd, 1973). WHO/UNICEF (2010) observed that almost 900 million people in the world lack access to safe drinking water, and an estimated 2.6 billion people lack access to basic sanitation. Urban areas are basically both the consumers and producers of large amount of wastewater; hence, management of wastewater could only be done when urban context is put into consideration due to the fact that, the rate of urbanization and industrialization is growing rapidly which put the life and economic well being of urban settlers in danger. Sheikh (2008) observed that the average low – income family of five in the slums of Delhi spends 37 % of their income on communal toilet facilities.

Wastewater management should not be done any how rather different approaches are required depending on factors such as size and density of people, level of economic development, and technical capacity. Wastewater management system should reflect the community and ecological needs of each downstream ecosystems and user (Corcoran et al., 2010), while selection of best technology lies upon receiving environment (Laugesen, Fryd, Kaottatep and Brix, 2010).

Generally speaking, wastewater management could only be done through wastewater treatment system, the onsite and offsite systems; either of the policy being taken must

be harmonized. Kvarnstrom et al. (2011) stated that when regulations and policies on wastewater are not coherent a lot of problems would arise.

2.3.3.1 Wastewater Management in Developing Countries

The problem of the contamination of water bodies through the discharge of wastewater is a long history; these problems were increasing which brought about thinking on the way wastewater would be treated. At early stage wastewater is treated at a local level but with the increasing quantity of pollutants more especially in densely populated and industrial area, the solution to this problem could only be achieved through the process of wastewater treatment plants. Towards the end of 19^{th} and early 20^{th} centuries, United State and United Kingdom devised a more modern method of offsite wastewater treatment. According to Britannica (2012), through the 20^{th} century, there was an increasing public concern for environmental issues, leading to a wider focus on wastewater disposal practices.

The first WWTP in New York of United State was constructed at Brooklyn in late 1890s and the second early 1900s in Queens, while as at early 2017 the nation's WWTP reaches 14,748 treating about 76% of the nation's wastewater (IRC, 2017) but with all these developments, the trend is still low in developing countries. Studies revealed that, about 80% of sewage produced in developing countries do not pass through preliminary treatment before discharge (Water Wiki, 2011), only 2% of the cities in Sub – Sahara Africa had wastewater treatment plants and only 30% of these were operating satisfactorily (UNEP, 2000). Hence, only 30% of the populations in Sub – Saharan Africa have access to improved sanitation (WHO/UNICEF, 2012). It is also observed that outside South Africa, few cities in African continent have functioning wastewater treatment plants (World Bank, 2012). The study further revealed that out of

eleven cities assessed only half had WWTPs and they are not functioning significantly. This generally indicated that there is very poor wastewater treatment system in developing countries.

2.3.3.2 Wastewater Management in Nigeria

The disposal of wastewater especially in urban areas of both developed and developing countries is a problem that continues to grow with development of nations and growth of population. Discharge of wastewater in the urban and industrial cities of Nigeria due to the rising population and industrial activities is one of the major environmental problems that need to be checked up. It has been observed that, most African cities including Nigeria suffered from mining related pollution of surface and ground water even after the activities have ceased (Bloch, 2012). According to Federal government of Nigeria (FRN), there is generally lack of comprehensive sanitation strategy for the disposal of excreta; wastewater and solid waste in the country (FRN, 2000).

Many researchers have been conducted so as to find the level of water contamination in the Nigeria; Yahaya, Adegbe and Emurotn (2012) found high level of metals that leads to the contamination of Oke – Afa Canal in Lagos. In another study Nda, Aliyu and Dalil (2013) reported that, out of 36,494m^3 wastewater discharge daily in Minna of Niger state about 65% flows freely without even primary treatment. However, Ayobahan et al (2014) reported how anthropogenic activities such as industrial and other human activities contaminated the quality of water in river Benin of Nigeria.

Over the years some Nigerians utilized more of the decentralized wastewater treatment system for domestic wastewater disposal than the centralized system, due to some constraints but even the most frequently used decentralized system (septic tank) is not properly utilized in the country. Burubai. Akor, Lilly and Ayawar (2007) found that the

quality of effluents from the septic tank which should determine the design of the soak away device is not considered in the construction. While Anderson, Siegrist and Otis (1989) stated that, the factors affecting the performance of different decentralized systems in Nigeria include: effluents absorption rates, and percolation rate of between 20 and 90 minutes per inch is considered to be the acceptable range for good septic system. However, Some interest have been put towards the upsurge of centralized system in some part of Nigeria such as Abuja the capital city of the country, the new plant was constructed at Gudu district, these drew the attention of some researchers towards the assessment of the performance of such wastewater treatment plant in the country. Doughaw, Dodo and Mbuha (2007) accessed the performance of Gudu Sewage Treatment Plant and its impact on Gudus Stream, the study observed that, the wastewater treatment plant leads to the contamination of the stream, which pose dangers to the health of the users of the water, hence they concluded that, the water is not fit for domestic purpose due to the poor management and sanitary of the plant.

The problems associated with wastewater discharge and poor treatment system in Nigeria were also observed by many researchers among others; Olusegun, Fidelia and Peter (2010) have a view that, lack of centralized wastewater treatment facilities in most of the industrial centers of the country (Nigeria) has to do with inadequate laws enforcement. In another view; Ekiye and Luv (2010) stated that, very little if at all anything, has been done in an integrated level concerning industrial pollution abasement in Nigerian waters.

2.3.3.3 Wastewater Management in Kano State

One of the main factors that increase poor health and environmental pollution is the poor way of discharging wastewater. The main sources of water for Kano metropolis

have been dug wells, borehole, hand pump and pipe water. Bello and Abdullahi (2013) observed three sources of pipe water to Kano metropolis namely: Watari, Tamburawa and Challawa conventional water treatment plants, whereby River Challawa serves as the source of water to these treatment plants which therefore determine the quality of water supply to the people in the area. However, River Challawa serves as the major recipient of the untreated and partially treated wastewater (UNIDO, 2003).

A research conducted by Dan'azumi and Bichi (2010) revealed the contamination of Challawa River due to the discharge of untreated wastewater from Challawa and Sharada industrial estates. In a similar study, Koki and Jimoh (2015) showed high concentration of metals such as chromium, and iron in River Challawa due to the effluents discharge by tanneries to the river.

The situation of wastewater treatment facility in the metropolis of Kano state is highly inadequate due to the fact that, even the two decentralized domestic wastewater treatment plants owned by government situated at Tukuntawa and Nomansland were not functioning for years, while most of the primary wastewater treatment option situated within the industries of Kano state have not been properly designed and/ or not properly operated (UNIDO, 2003). There is no any centralized (secondary or tertiary) wastewater treatment plants in the metropolis, therefore construction of off-site wastewater treatment plants is the best solution to the problems associated with wastewater discharge in Kano metropolis and elsewhere in the country, and will brought more sources of economic development through wastewater reused. Otherwise the problems observed by the United Nations Industrial Development Organization and other researchers will continue to exist.

2.3.3.4 Wastewater Reuse

Wastewater reuse for agricultural irrigation could be traced back as far as 5,000 years ago (Angelakis and Apyridakis, 1996), but the implication of untreated wastewater to the public and ecosystem health has changed the dimension of using wastewater towards the end of 19^{th} and early 20^{th} centuries. The inadequate water supply and catastrophic epidemics of waterborne diseases during the 1840s and 50s (Young, 1985) brought about the development of new technologies for treating and reuse of wastewater, so that treated wastewater can be reused in various aspect of human life, and its adverse effect on man and environment shall be minimized (Asano and Levia, 2004).

Wastewater could be treated and reused not only at centralized level or standard decentralized system but even within household for easy access. Hence, rainwater could be invested while grey water is recycled at household level and at community level (Batchelor, Foneseca and Smits, 2011), natural systems could also be used to recycle wastewater within neighborhood (Bieker, Cornel and Wagner, 2010). In an effort to categorize various areas where wastewater could be utilized Asano and Levia, (2004) came up with seven categories of wastewater reuse.

- Groundwater recharge; this help to raise the volume of available groundwater through spreading basins or direct injection to groundwater aquifers.
- Agricultural irrigation; this is the largest area where wastewater reuse program takes place both in developed and developing countries, either peri – urban irrigation system or irrigation agriculture in rural areas.
- Landscape irrigation; in this project there are usually two distribution system, one for reclaimed water and other for potable water supply, landscape system

involved supply for landscaped areas around residences, commercial and industries, the playgrounds, irrigation of parks, freeway medians as well as golf courses.

- Industrial reuse; industrial uses of water vary greatly, hence providing adequate water to industries has becomes one of the major concern of water supply agencies, in this case, wastewater reuse system could help in providing water for cooling of towers and ponds and also the needs for other process.
- Non-potable urban uses; this category of reuse is accidental and depends on proximity to the wastewater treatment plant or channel, in this category treated wastewater are used for fire fighting, construction, toilet flushing, flushing of sanitary sewers and air conditioning.
- Environmental and recreational uses; treated wastewater can be discharged for habitat creation, restoration, provision for additional treatment before discharge to receiving water, development of recreational lakes, marsh enhancement, stream flow argumentation and other non-potable uses related to land – based water features.
- Indirect or direct potable reuse; wastewater reuse system in this category is very limited compared to other system but it acts as an input to the water distribution system when highly treated at tertiary stage.

Treated wastewater could be reused in several aspects of human life and it can also serve as a way of protecting environment against pollution. Therefore, the reuse of wastewater can provide the possibility of addressing the sanitation problems among African cities (Howe et al, 2011) and hence, it is highly essential to manage wastewater through onsite and offsite treatment process before it is reused.

2.3.4 Processes of Wastewater Treatment

It is necessary to treat raw wastewater before reuse so as to meet specific needs and public safety. Advance in science and technology came up with various options for the treatment of wastewater from simple technology to more complex ones; the simple one includes soil aquifer treatment (Essandoh et al, 2011). While the more complex one is categorized into decentralized and centralized wastewater treatment options (BORDA, 2012).

2.3.4.1 Decentralized Wastewater Treatment System (DEWATs)

Decentralized wastewater treatment systems are the on-site or primary methods of wastewater management that includes conventional septic systems, privies, private decentralized cluster systems, experimental and other alternative on-site systems (GDPH, 2014). The main reason behind development of DEWATs is to protect ecosystem and public health against the negative impacts associated with discharge of wastewater, therefore, a system has been designed to remove organic compounds by adsorption to sediment or uptake by plants and animals, to dilute waste concentrations and break down solid waste and recycle nutrients (GDPH, 2014).

According to Nnaji, Ekechukwu, Onyia and Afangideh (2013) the used of DEWATs for wastewater management help to eliminate the high need of capital for wastewater transportation as well as operation and maintenance of other infrastructural facilities. Hence, the system is considered to be the most appropriate solution to the problem of wastewater management in developing countries such as Nigeria. However, of all categories of DEWATs, septic tank is more practicable in both developed and developing countries, but, application of the system does not completely solve the problems induce by wastewater to the environment and public health. A study

conducted by Oliver, Redeliff, Hableselassive and Clerk (2013) in Georgia indicated a correlation between stream base flow, nitrogen level and septic tank density, in other word, the study found that, high density of septic tank is a significant predictor to explain the increased level of nitrogen and base flow.

It has been observed from a study conducted in Aledo of Texas by Napier, Rahn and Kramer (2015) that, elevated concentrations of nitrogen and phosphorous and the fecal coli forms in the downstream water samples from septic tank indicated the presence of untreated human and animal wastes. Therefore, total dependence of DEWATs in Nigeria and the other world means further spread of disease related to the discharge of wastewater, this is because, on-site sanitation is often inappropriate in denser settlements and slum areas (Water and Sanitation Program, 2013). This therefore, call for the integration of DEWATs with centralized (secondary and tertiary) system as the best option toward protecting environment against wastewater related problems.

2.3.4.2 Centralized Wastewater Treatment System (CEWATs)

Centralized wastewater treatment system handles large volume of wastewater and cover large areas, usually owned by government so as to serve part or whole community. It is a technique whereby wastewater that passes or does not pass through primary treatment is sent, in order to remove other effluents that were not removed, such as fecal coli forms and nitrogen. Gondhalker (2013) stated that the pressure on existing water resources and risk of water pollution by sewage disposal through soak pits and septic tanks will continue to exist in the absence of CEWATs. Even though, IWA Water wiki (2012) reported waste stabilization ponds and constructed wetlands which are also forms of DEWATs used in Cambodia remove about 97% of coli forms; in this case, it

is not possible to completely accept or reject one of them but a prior and needs to proceed on a case by case basis (Libralato, Ghirardini and Avezzu, 2012).

Centralized wastewater treatment system is basically divided into secondary and tertiary treatment. The secondary system is where microorganisms are dissolved through oxidation and particulate biodegradable matter into smaller units and tertiary treatment is an advance system that involved different options of wastewater treatment, where nutrients and other contaminants are also completely removed.

Libralato, Ghirardini and Avezzu (2012) observed that CEWATs would surely be favoured by economic scale of any society, except in the case of a site with a range of significant different heights above sea level that would make DEWATs more suitable. Based on this, adoption of appropriate technology through site evaluation became necessary, otherwise failure to take into consideration local conditions of the targeted community results into project failure (Libralato, Ghirardini and Avezzu, 2012).

2.3.5 Wastewater Treatment Plant Site Suitability Criteria

The main purpose of site suitability analysis for wastewater treatment plant is to ensure that wastewater facilities are located at best locations so as to minimize their negative impact to the people and environment. Site suitability analysis for wastewater treatment plant should be based on careful consideration of region's land use and development patterns as well as sufficient area, site alteration, availability of utilities, environmental and mitigation of community impacts (FSC, 2003). A comprehensive list of the criteria to be considered for wastewater treatment plant siting together with the constraint criteria designed by Spokane County is shown in Appendix I.

Chelsea (2011), relied on proximity to an important river, access to the site on an existing road, proximity of wetlands, land acquisition, proximity to residences, traffic and dust pollution, construction of conduits, collectors and outlets, geotechnical stability of the site and existing treatment plants in the city to choose a location along Mill road as the best site for new wastewater treatment plant. In this study, sites close to river were given priority than those some distance apart for easy discharge of the treated wastewater not how the treatment plant may contaminate the existing water bodies.

Benujah and Devi (2013) relied on thickly habituated area, slope, distance from main roads and distance from water bodies as factors to be considered for the evaluation of sewage treatment plant in Nagercoil Municipality of India. In similar study, Subramani, Subramanian, Kathirvei and Bharathadelvi (2014) considered 15% of ground slope, thickly habituated area, distance to road and river (200 meters each) as design constrains criteria toward finding the wastewater treatment plants suitable site in Salem Corporation of India. The factors considered in this and the study of Benujah and Devi above are limited to only four factors which may be attributed to the fact that the study areas are cities and do not include the suburb.

Anagnostopoulos, Gratziou and Vavatsikos (n.d.) developed twelve sub criterion maps to determine and evaluate best site for wastewater treatment. Thus, sloping areas with value of 15%, 500m threshold from nearby settlement, and distance from main registered faults, main rivers, lakes, main road, railway network and Agnatic highway (300m each), areas with lower annual temperature and distance from environmental sensitive areas protected by national and international treaties are also considered as criteria, other factors considered are soil and land use of the study area. Of course, the factors are numerous which may therefore lead to more accurate result.

Msangi and Liwa (2014) considered environmental attributes such as topography, environmentally protected areas, existing land uses and infrastructure to choose a best site so as to reduce the risk of contamination from wastewater in the capital of Tanzania. While, Yadvendra, Singh, Yadav and Singh (2015) considered technical feasibility, environment sustainability and social acceptability of the site such as ground slope, land use, distance from surface water, distances from roads, distance from railway network and proximity to the dwelling places for zoning of wastewater drainage of Allahabad city. In this study almost all most important factors were put into consideration.

All of the works cited put more emphasis on road, water, slope and land use to be considered as criteria for siting wastewater treatment plants with the addition of one factor or another. Therefore, this study is adopting the factors considered by Yadvendra et al (2015) however, with addition of proximity to airport due to the fact that, siting wastewater facilities in airport vicinity is dangerous due to the presence of several kinds of land use, and size criteria because most of the suitable sites are smaller in size and therefore cannot occupy the entire plant facilities. This study is also adapting and modifying the constraint criteria of Benuja and Devi (2013) due to the fact that, metropolitan Kano is densely populated and there are no standard constraint criteria designed by Kano State Ministry of Environment.

2.3.6 Geographical Information System for Site Selection

Geographical Information System (GIS) is an integrating system which links various disciplines together such as surveying, geography, computing, cartography, economics, planning and so forth to yield a better result. GIS is a system that helps to capture, store, analyze, manage and present data that are linked to location(s). It is a system that

integrates cartographic computer aided design systems, statistical analysis tools and data base technology toward better decision making (Mohammedshum et al 2014). GIS enables user to manipulate and analyse geographical databases to produce new result in form of maps, charts and tables, it also facilitates decision supports system and deals with both simple and complex problems.

GIS supports the solution of complex spatial problems through the use of spatial analytical tools which can transform, manipulate and use techniques that can be applied to geographical data to add value to them, support decisions, and reveal patterns and anomalies through inductive, deductive and normative reasoning (Ahmed and Salihu, 2013). GIS is a computer – based system that offers a convenient, powerful and reliable platform for performing suitability analysis especially land allocation. Processing of a large amount of location-based information to find best locations by taking natural and manmade features into consideration is easily achieved using GIS software and data (Abuga and Ndegwe, 2015). In order to measure the potentiality of GIS, Integration of GIS with Multi Criteria Decision Analysis (MCDA) technique in site selection has been highly recognized by many researchers, among others include Kiema, Dangana and Karanja (2014) who integrated GIS with MCDA for rail line route selection and Rathore,Ahmad and Shirazi (2016) in suitability model to identify landfill sites.

2.3.7 Multi-Criteria Decision Analysis (MCDA) Techniques

A decision analysis is a kind of spatial analysis that deals with the complex decision problem in various fields of human endeavour. MCDA is a process that combines and transforms geographical data into decision. It is a formal technique used to support decision in many fields and can be especially valuable in environmental decision

making (Huang, Keisler and Lincov, 2011). The technique can be used to identify a single most preferred option from various objectives.

Therefore, as the sites evaluation for wastewater treatment facility process depends largely on variety of laws, regulations and factors to be considered, a sophisticated technique such as multi criteria decision analysis is required. This is because, multi criteria technique could be particularly useful in situations where there are a large number of alternatives for a development, and large number of potential criteria to be taken into consideration The result of the analysis using MCDA can be directly used for further studies as well as making decisions in subsequent researches (Zhao, 2015). Moreover, the technique (MCDA) is both an approach and group of techniques aiming to aid decision making by laying out the problem, objectives and available options in a clear and transparent way (Ariz and Panos, 2016). Their applications involve assisting decision maker to identify criteria, basic information about each criteria and the relation between them that will lead to better result (Ganesh and Reddy, 2013).

A study conducted by Munjubashini, Rinsitha and Singh (2014) used Analytical Hierarchy process (AHP) for liquid waste dumping site suitability analysis in Chengalpattu Taluk; the rank and weighted calculation are done by pair wise comparism method in which six thematic maps are interpreted and overlaid to get the suitability map. In another development, Subramani et al (2014) used weighted index overly analysis to locate suitable site for sewage treatment plant. Weights are assigned to various classes in the thematic layers; they finally came out with the three different categories of areas as good, moderate and poor.

Asante and Barimah (2012) made use of multi-criteria analysis to come up with 20 km^2 parcel of land north of Accra metropolitan as suitable for centralized wastewater

treatment plant. In another research, Zhao (2015) used a GIS – based multi-criteria analysis to find optimal site for sewage treatment plant in Sichuan province of southern western China, weight to each factor are calculated using AHP and formula method while final site were determined by weighted linear overly.

Yadvendra et al (2015) adopted a methodology of using weighted overlay tool in ArcGIS for zoning of wastewater drainage, thereby identifying suitable sites based on their weights in such a way that the highest weight indicates most suitable area, the researchers made use of the technique due to its easiness in understanding and interpretation.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter presents the description of the study area and various methods employ for this study.

3.2 Study Area

The various aspects of the study area that have relevance to the topic are discussed as follows:

3.2.1 Location and Size

The study area, Kano metropolis, is bounded by Minjibir Local Government Area on the North East, Gezawa Local Government Area to the East, Dawakin Kudu Local Government Area to the South East, Madobi and Tofa Local Government Area to the South West and finally Dawakin Tofa Local Government Area to the North West. The area under investigation is located between Latitude $11^{o}\ 52^{'}2^{"}$N to $12^{o}\ 7^{'}41^{"}$ North of Equator and Longitude $8^{o}\ 25^{'}3^{"}$ E to $8^{o}\ 39^{'}57^{"}$ East of Prime meridian. Kano metropolis has an approximate land mass of about 499 km^{2}, whereby the longest distance north to south is 26.9km and west to east is about 19.5km as shown on Figure 3.1.

3.2.2 Climate

The climatic characteristics of Kano metropolis and Kano state as a whole is predominantly tropical wet and dry, coded as Aw according to Koppen's classification (Olofin, 1987). The area is strongly influenced by the tropical maritime air mass and the tropical continental air mass. A tropical maritime air mass is large bodies of air that

originates from Atlantic Ocean and extends into Nigeria as north – west trade wind, the air mass covers the entire country during Northern Hemisphere's summer, notably from May to September in far north, such as, Kano state bringing rainy season. The tropical continental air mass originates from Sahara desert and crosses Nigeria from north during Northern Hemisphere's winter, meeting tropical maritime air mass at Inter-Tropical Convergence Zone (ITCZ), hence dry conditions prevail.

Temperature of Kano metropolis is generally high throughout the year, but there are some seasonal changes. According to Ibrahim (2011), there is a gradual increase from January to April where maximum value reaches as high as 43^0c. The amount of rainfall receives in the area varies between that of northern and southern part of the state based on the latitudinal and continentality factors.

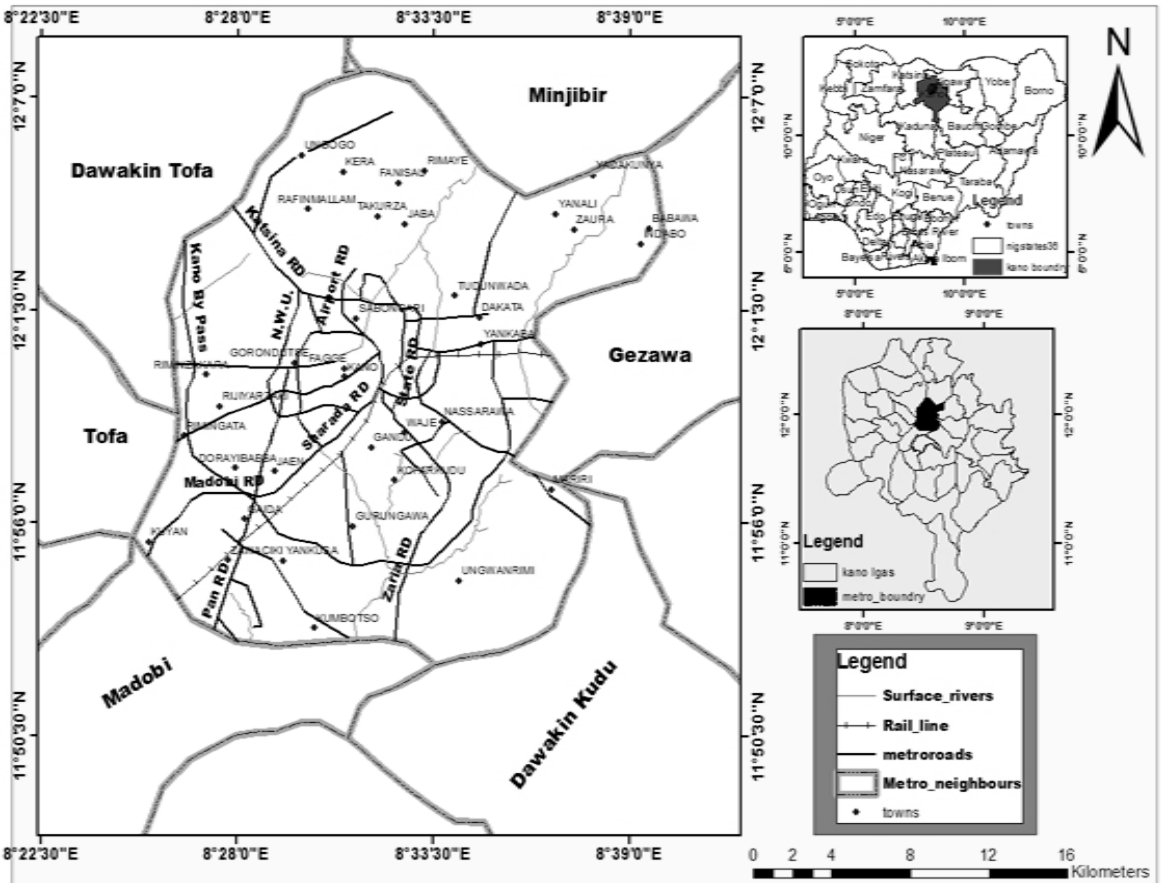

Figure 3.1: Map of Nigeria Depicting the Study Area
Source: Adapted and Modified From Kano State Ministry of Land

3.2.3 Soil

The influence of topography and wind-drift materials from the desert is what shapes the aggregate of the Kano state soil structure. The matured soils are latosoil of ferruginous type; but a number of sub-classes within the major classification can be identified (Olofin, 1987). The soil of Metropolis differs from that of the other parts of the state in term of texture, structure and physicochemical properties, similarly between one area of the metropolitan Kano and another.

The soil around Dala and Goron Dutse are immatured due to the influence of hills while that around Jakara River and Challawa River contain high level of metals. FAO (1992) attributes the presence of high amount of nitrogen, phosphorous and organic carbon in the soil around River Jakara to the presence of domestic wastewater. These variations were also observed by Esu (1991) who reported that, the level of organic carbon contents rank from low in watari area outside Kano metropolis and Challawa along the southern edge of the metropolis to medium along Jakara an area at the centre of the metropolis.

3.2.4 Vegetation

The natural vegetation of Kano state is a transition zones between Northern Guinea Savannah and Sudan Savannah (Olofin, 1987), but its nature and density vary from place to place due to the influence of urbanization and industrial activities. The vegetation of Kano has been subjected to destruction through fuel wood extraction, urban encroachment and population pressure (Dakata and Yelwa, 2012). Therefore, urban encroachment leads to Sudano Sahelian Savannah vegetation in Kano metropolis. The grasses are annual and hardly exceed one meter in terms of height. The common tree species include Acacia *Albidda* (Gawo), *Vitex Doniana* (Dinya), *Acacia*

senegalancies (Dakwara), *Balanites aegyptiaca* (Aduwa), *Hyphene the baica* (Kaba), *Borrasus aethiopum* (Giginya), *Anilotica* (Bagaruwa), *Diospyros mespiliformis* (kanya*), Leiocarpus* (mark), *Khaya Segalensis* (Madaci), and *Ziziphus spina-chrisli* (Kurna), among others (Yalwa, 2014). Discharge of wastewater especially untreated to vegetation cover negatively affects the phenology and vigour of farm products and other plants.

3.2.5 Drainage System

The metropolitan Kano state has been surrounded by several kind of drainage system, such as River Challawa, River Jakara and River Salanta and ponds which include Hauren Wanki, Gadon kaya, Fagge, Kabuga and Gidan Murtala. Mukhtar, Indabawa and Imam (2010) identify River Challawa, Salanta and Getsi as the most prominent rivers in Kano metropolis. River Challawa which is the second largest River in Kano after River Kano located in the southern part of metropolis serves as the source of water to Challawa and Tamburawa conventional water treatment plant, the river meets River Kano at Tamburawa, 20 meters from Kano city; Salanta River to the south-central metropolis through Sharada phase III meets River Tsatsawarki at extreme south where they move south-ward to joint River Challawa. While River Getsi which is located to the north together with Jakara receive most of the domestic wastewater from the metropolis and drain into Minjibir Dam in Minjibir local government area.

The flow of the Rivers in the study area highly depends on the discharge of wastewater, otherwise they are seasonal Rivers. The stream flow in Kano state is characterised by seasonality, River flow is rising and falling in response to rainfall occurrences (Yalwa, 2014). The high flow exceeded 10% of the times are recorded mainly in July and August in response to rainfall events 30mm or more (Ahmed, 2003).

3.2.6 Population and Urbanization

The ancient city of Kano has a long history which can be dated back to over 1000 years. It was one of the seven Hausa kingdoms founded by the descendants of the well known person called Bayajidda. The city of Kano cover an area of about 17.5 Km^2 was surrounded by ancient wall made from mud bricks (Liman and Adamu, 2003).

Metropolitan Kano is the most rapidly populated urban centre in Northern Nigeria, one of the three outstanding colonial agents named Barth estimated the population of Kano city as at March 1851 to be about 60,000 people (Barau, 2006). This population raised continuously as a result of merging with nearby Local Government Areas, from about 1,432,255 in 1991 to about 2,828,861 in 2006 (NPC, 2006). The rate of natural population increase in Kano has risen from an estimated 2.51% per annum in the 1960s to about 6.5% in 1991 to 6.7% in 2006 (NBS, 2012), leading to a projected population of 3,333,326 in 2011 (NBS, 2012). Currently, Kano metropolis is the second largest city in Nigeria after Lagos with population of 3,626,068 in 2015 (TMTN, 2016). This increase of population brought about rising in the level of wastewater generated.

3.2.7 Human Activities

For centuries, Kano has been known as an important trading part for trans-Sahara trade which has led to the growth of prominent Markets such as Kurmi Market among others (Olofin, 1987). Industrialization as one of the major sources of economic development in Kano metropolis and Kano state as a whole could be traced back since from 1945 when people engaged in traditional industrial activities, such as, blacksmithing. The first industrial zone was established at Bompai in 1970s. According to Nabegu (2008) by the end of 1985, there were about five hundred manufacturing industries within Kano metropolitan industrial zones employing over one hundred thousand workers. Of

course, economic activities of this nature have contributed to the increase in the quantity of wastewater in the study area.

Agricultural activities operated by the people of Kano metropolis depends on the physical environment of the area. The major agricultural practices in the Kano region are crop production, animal husbandry, forestry and fishery (Lynch, Binns and Olofin, 2000). Two major system of crop production in the study area are rain-fed during rainy season mostly in Kumbotso and Ungogo Local Government Areas and irrigation farming in areas where wastewater drains, such as, Salanta, Aminu Kano Teaching Hospital, as well as along Jakara River.

3.3 Methodology

3.3.1 Introduction

This section, presents the methodology used to collect data and the techniques of data analysis, namely: statistical and GIS-based MCDA techniques. The methodology flow diagram to achieved objective 3 is shown on Figure 3.2

3.3.2 Reconnaissance Survey

Before deciding on the topic of the research, type of data and methodology for this study, several observations were made, discussion with the colleague and field visit during which the researcher identified various problems associated with the discharge of wastewater ranging from health risk to various environmental consequences. The visit made it possible to identify relevant issues and questions for the design of questionnaire, type of data to be used as well as best technique. After the visit the researcher together with the staffs of Pollution Control Department of the Kano State Ministry of Environment choose spatial analysis for sites suitability of wastewater

treatment in Kano metropolis, public responses through interview and questionnaire administration, satellite imageries of 2015 as well as statistical and GIS-based MCD Analysis, as the sources and type of data and technique of data analysis.

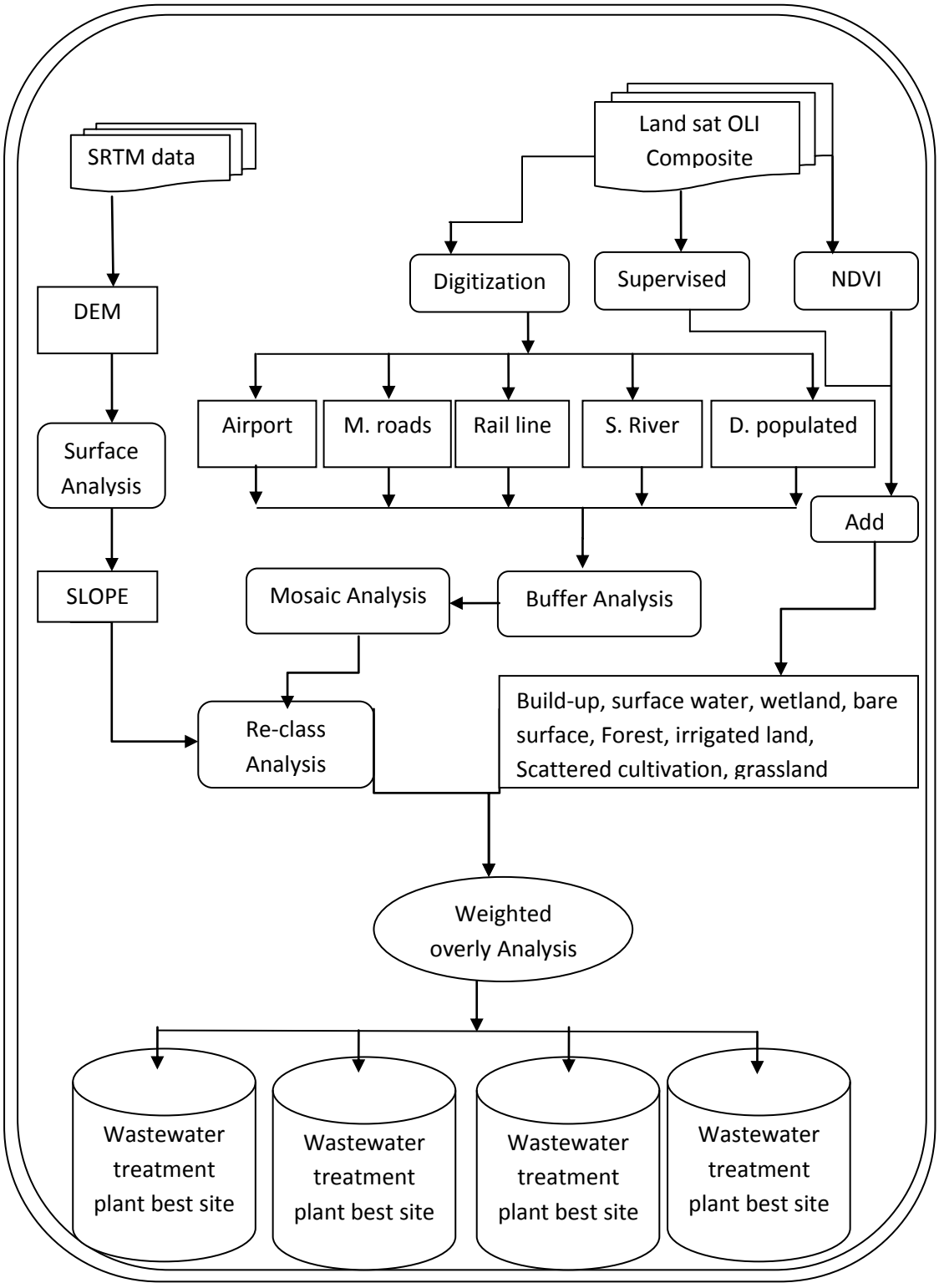

Figure 3.2: Conceptual Flow of Site Selection for WWTPs in the Study Area
Source: Author's Survey, 2016

3.3.3 Types and Sources of Data

To achieve the aim and objectives of this study, the following forms of data were used.

i. Public responses (between 27thSeptember to 11th October, 2016) through questionnaire administration and interview with the staffs of the Kano State Ministry of Environment. This was used to extract information on the major sources of wastewater discharge, their various categories, methods of disposal as well as their environmental and public health implications.

ii. Land sat 8 (OLI) imagery with level 9 imagery quality and Land sat Scene ID of "LC81880522015065LGN00", 0.07% cloud cover, consisting of eleven bands as shown on Table 3.1, were downloaded from United State Geological Survey (USGS) archive. This was used to extract LULC, highly populated area, surface rivers, major roads, rail line and Airport maps of the study area. Land sat OLI was used because it has been of higher quality compared with other land sat data even land sat ETM+ (Zhao, 2015).

iii. The study utilized SRTM (Shuttle Radar Topography Mission) DEMs image of 2006, derived from the original 1 arc second data (SRTM-1) with approximate cell size of 30m at the equator and then generated into 3 arc second data (SRTM-3) by averaging. This data were downloading from United State Geological Survey archive and was used to extract slope map of the study area.

iv. Existing literature from journals, textbooks, seminar papers, thesis, and web references.

Table 3.1: Land sat -8 Operational Land Imager Bands (µm)

Bands	Wavelengths(µm)	Resolution(M)
Band 1 -Visible(coastal, aerosol)	0.43 - 0.49	30
Band 2 –Visible (blue)	0.45 – 0.51	30
Band 3 –Visible (green)	0.53 – 0.59	30
Band 4 – Visible (Red)	0.64 – 0.67	30
Band 5 –Near Infrared (NIR)	0.85 – 0.88	30
Band 6 –SWIR 1 (MIR)	1.57 – 1.65	30
Band 7 -SWIR 2	2.11 – 2.29	30
Band 8 –Panchromatic	0.50 – 0.69	15
Band 9 –Cirrus	1.36 – 1.38	30
Band 10 – TIR – 1	10.60 – 11.19	100
Band 11 – TIR – 2	11.30 – 12.51	100

Source: Xu and Guo (2014)

3.3.4 Data Collection

3.3.4.1 Questionnaire

The questionnaire used in this study is in form of open and closed questions designed to gather information on the respondent personality, major sources and categories of wastewater generation, methods of discharging domestic wastewater as well as its implications on the public health and environment. To achieve this objective a total of four hundred (400) self administered questionnaire were administered for households responses across the eight Local Government Areas of the study area (Appendix: II) out of which 392 were successfully return.

i. Sample Size and Sampling Techniques: Considering the extent and population of the study area which was projected as 3,333,326 as at 2011 (NPC, 2011), more time was required for the administration of questionnaires and field work. Therefore, based on the suggestion of Ader, Mellerbergh and Hard (2008), that sampling size should be small in order to improve the accuracy and quality of research work, 400 sample sizes was arrived at using Yamane (1967) formular giving in equation 1 while 5% margin errors was adopted from Krejcie and Morgan (1970) who stated that in social science and educational researches, the general rule is that, relative acceptance margin error in categorical data is 5% while continuous data is 3%.

$$n = \frac{N}{1+N(e)2} \quad \text{(equation 1)}$$

Where

n = Sample size

N = population size (3,333,326)

e = Margin error (5.0%)

It was based on population differences of 2011 projection among the eight Local Government Areas, formular in equation 2 was used to determine the representative samples and the result is shown on Table 3.2.

$$rs = \frac{nQ}{N} \quad \text{(equation 2)}$$

Where

rs = representative Sample

n = population of the representative (Local Government Areas)

Q = Total sample size (400)

N = population size (3,333,326)

Selection of individual households for questionnaire administration was done using systematic sampling techniques, the first house was picked to determine the starting point of questionnaire administration, and others were then picked at regular intervals predetermined by the researcher (interval of twenty houses) until the numbers required were exhausted, this enabled every relevant household probability of being picked.

Table 3.2: Representative Areas, Projected Population and Sample Size

S/N	Representative Areas	Projected (2011)	Sample Size
1	Dala	493,881	59
2	Fagge	235,991	28
3	Gwale	422,018	51
4	Kano Municipal	437,841	53
5	Kumbotso	347,203	42
6	Nasarawa	703,403	84
7	Tarauni	261,641	31
8	Ungogo	431,348	52
	Total	**3,333,326**	**400**

Source: NPC, 2011

3.3.4.2 Interview

Structural interview was conducted with the staffs of Pollution Control Department of Kano State Ministry of Environment, four personnel where interviewed within the period of three days. Data collected during the interview include; categories of domestic and industrial wastewater as well as number and types of industries that discharge more wastewater see Appendix III.

3.3.4.3 Satellite Imagery

The Land sat OLI imagery after download was uncompressed using 7-zip and imported into Arcgis 10.1 version software environment, it was imported to the software on band by band basis; the study area was then extracted using extract by mask because: (i) the study area is not up to one tenth of the scene; (ii) subset of the study area saves processing time; and (iii) it reduced storage space.

Band 2 to 7 were composed to generate true color composite imagery as shown on Figure 3.3, because, land sat band combinations are also used for the detection of various phenomena such as water, minerals and vegetation (Mullis, 2014). Bands 1, 8, 9, 10 and 11 were excluded because band 1 was deep blue for coastal water and aerosol, band 8 is a panchromatic 15m resolution, band 9 is for cirrus cloud detection while band 10 and 11 are thermal bands with 100m resolution, hence, they were considered as not useful for this study. These methods were adapted and modified from Asante and Barimah (2012); Yadvendra, Singh, Yadav and Singh (2015).

i. Satellite Imagery Processing: One of the great challenges to remote sensing and Geographical Information System (GIS) has been land use/ land cover classification especially in urban areas, because, it comprises numerous features that are difficult to distinguish from satellite data, such as un-tarred roads, open spaces and children's play ground or water bodies covered by algae and grassland areas and different classes having the same cover materials leading to the same or very similar spectral reflectance. Therefore, this kind of problems leads to erroneous classification of pixels (Aplin, 2003).

The satellite imagery used in this study was orthorectified by the USGS centre before download, therefore, it does not required any form of imagery correction even image

enhancement. Land sat OLI has been geo-reference, radiometrically and geometrically corrected by USGS as well as neither have striped nor gap which need to be filled such as that of land sat ETM+ (USGS, 2016).

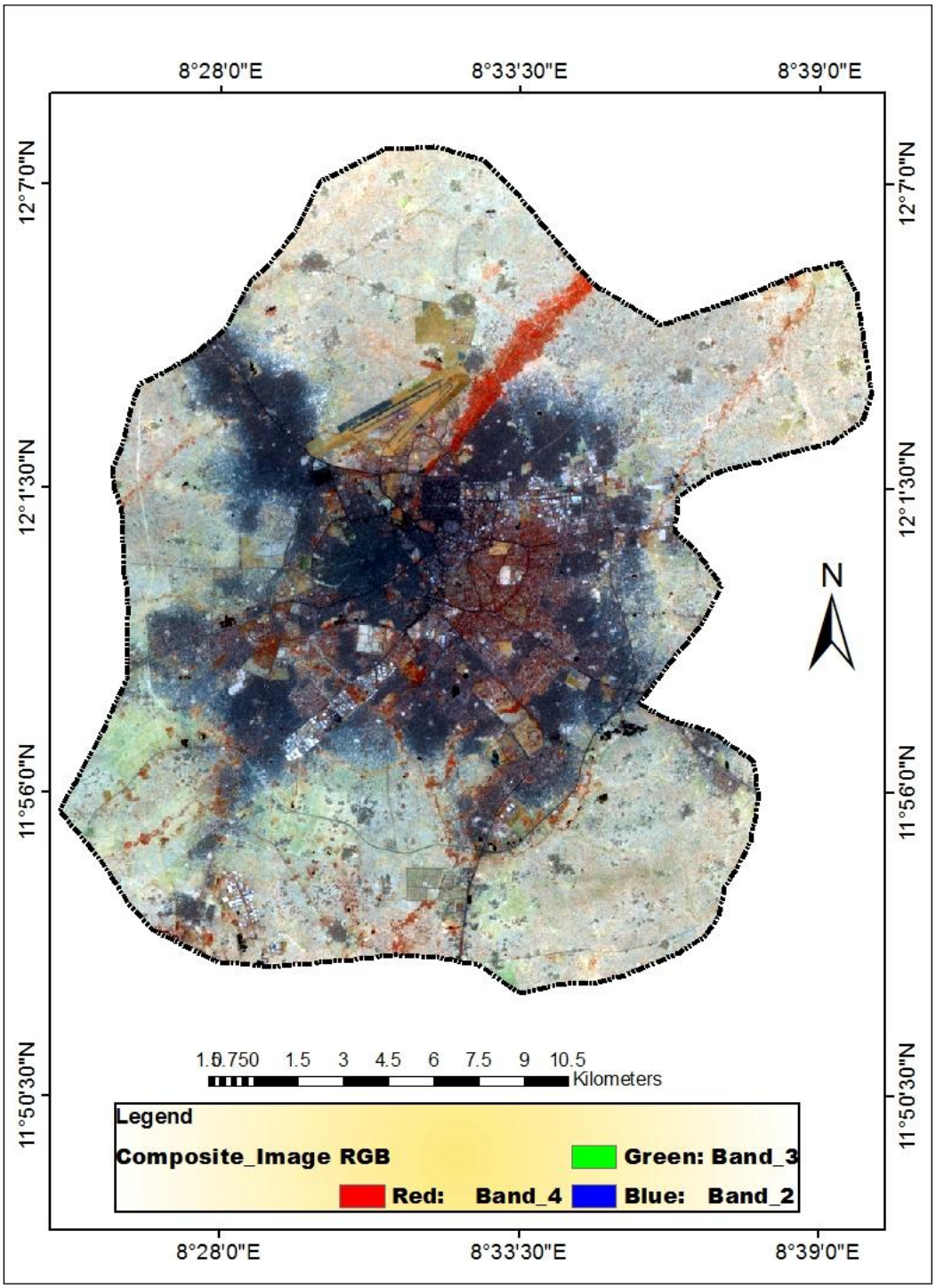

Figure 3.3 True Colour Composite Land Sat Imagery of the Study Area
Source: Author's Data Analysis, 2016

ii. Satellite Imagery Classification: To achieve high classification accuracy in classifying satellite data into various LULC classes in the study area two techniques were used namely; supervised and difference indices.

Maximum Likelihood Classifier (MLC) of supervised techniques was use due to the researcher prior knowledge of the area of study and it yielded better result than minimum distance, neutral network and any other supervised algorithms technique. Training classes were generated based on the actual LULC to categorize the satellite imagery into built-up area, bare surface, surface water, wetland, irrigated land and vegetated area. The selection of the training classes aimed at true representation of the information class through careful observation based on the knowledge of the study area, after delineating of the training areas, the researcher then examined the frequency of all spectral bands using Histogram, Scattered plot, mean and covariance.

Normalized Difference Vegetation Index (NDVI) was used to classify the imagery into forest, grassland, scattered cultivation and non-vegetated area based on Brunseli and Gillies (2003) techniques, due to the fact that, variations in the vegetation cover of the study area is highly important for this study, the NDVI imagery was derived using the formula in equation 3.

$$\text{NDVI} = \frac{Nearinfrared - Red}{Nearinfrared + Red} \qquad \text{equation 3}$$

Band 4 of OLI is the Red band while band 5 is the near infrared (NIR) band; these bands were set in the NDVI option of Image Analysis Tool of Arcgis 10.1. Red and NIR bands were used to generate NDVI, this is because, according to Ozyavuz (2010) detection of vegetation variations are well suited with NIR bands since chlorophyll absorbs red wavelengths and has its highest reflectance in the NIR wavelengths. Holme, Burnside and Mitchell (1987) also reported that, healthy vegetation reflects

large portion of the near-infrared light, sparse vegetation reflects less near-infrared light while bare surface reflects moderate in both near-infrared and red portion of electromagnetic spectrum.

The two imageries derived from supervised classification and NDVI were finally added together using Raster Calculator to come up with eight land use/ land cover classes of the study area based on Anderson, Hardey, Roach and Witmer (1976) level one scheme of Land use/Land cover classification, namely: surface water, wetland, forest, grassland, Irrigated land, Scattered cultivated area, bare surface and built-up area.

iii. Classification Accuracy Assessment: Since accuracy assessment compares classified imagery to an imagery which is assumed to be correct such as, an aerial photo (Parece, Campbell and McGee, 2011). Therefore, the accuracy assessment for this study was done using a set of random points generated in Arcgis 10.1 to obtain error matrix and kappa coefficient, this is because, it has been observed that, sample data are often summarized in an error matrix, and then subjected to various statistical analysis (Congalton, Oderwald and Mead, 1983) one of which has been Kappa (Cohen, 1960). Kappa coefficient has been chosen because it is frequently used to summarize the results of an accuracy assessment used to evaluate land-cover classifications obtained by remote sensing (Stephen, 1996).

Four hundred and ninety six (496) points were randomly generated in Arcgis 10.1 to represent an average of 62 points per category of classified LULC as adopted from (Tammy, James and John, 2013). The points were saved and exported as .kml file into 2015 Google Earth imagery which serves as reference imagery. Reference values were generated by examining the Google Earth imagery after which the reference values were compared with the values of the classified imagery to see those fit the

classification. The reference values and random point's values were then used to compile the error matrix, calculate overall accuracy and estimate Kappa based on Congalton and Green (1999) formular in equation 4 to 6:

$$\text{Overall accuracy} = \frac{\sum_{i=1}^{k} nii}{n} \quad \text{equation 4}$$

Where

$\sum_{i=1}^{k} nii$ = total number of correct classification

n = total number of sample points

$$\text{Estimated Kappa} = \frac{\text{Observed} - \text{expected}}{1 - \text{expected}} \quad \text{equation 5}$$

Where

$Observed$ = overall accuracy

$$Expected = \frac{\text{Product matrix}}{\text{Cumulative sum of product matrix}} \quad \text{equation 6}$$

iv. Digitization of the other Data: Editor Tool in the Arcgis 10.1 environment were used to digitized the following data: highly populated areas map, major roads map, surface rivers map, rail line map and Air port map from Land sat OLI imagery thereby creating shape file for each, and save.

v. Generation of Slope Map: The surface analysis sub-menu of Spatial Analyst Tools in Arcgis 10.1 was used for the determination of the slope map from SRTM DEMs as adopted from Oluwatola, Oluwatoyin, Moshood and Abel (2013) and Yalwa (2014).

3.3.5 Data Analysis

Data analysis for this study was carrying out through the following steps:

3.3.5.1 Statistical analysis

The information gathered from respondents through questionnaire administration and interview were coded and entered into Microsoft excel for descriptive analysis in form of Tables, percentage and chart.

3.3.5.2 GIS – based MCD Analysis

GIS – based MCDA was used to identify and map out best sites for offsite wastewater treatment plants in the study area using Analytical Hierarchical Process (AHP) in Microsoft excel and Weighted Overlay Tool in arcgis 10.1 environment as adopted from Asante and Barimah (2012); Zhao(2015); Manjubashini, Rinsitha and Singh (2014) through the following steps:

i. Factors of Sites Suitability Determination: The software (Arcgis 10.1) was used to determine the suitability of the factors considered through buffering and reclassification using proximity and re-class tools, to protect the lives of human, animals and plants against the negative impacts of wastewater such as offensive odour and other nuisance based on the modification of Benujah and Devi (2013) techniques, Therefore, a suitable site should be:

i. of surface slope less than or equal to 5.32^0
ii. greater than or equals to 200 meters away from highly populated areas
iii. greater than or equals to 200 meters away from surface rivers
iv. greater than or equals to 100 meters away from major roads
v. greater than or equals to 100 meters away from rail line

vi. greater than or equals to 100 meters away from airport station

vii. bare surface or grassland area

ii. Factors Weight Determination: The weight of the factors in this study was determined based on Saaty (1980) analytical hierarchical process (AHP) pair wise comparison matrix through the following steps:

In the first step, the hierarchy of the factors has been structured in such a way that, the objectives to be achieved were distinguished from the factors representing the attributes as shown on Figure 3.4.

In the second step, pair wise comparisons of the factors were constructed in Microsoft excel using AHP excel template, whereby the relative importance of one factor were evaluated against other factor, relative to its important based on Saaty 9 points scale as shown on Figure 3.5.

Thirdly, weight of each factor was calculated using normalized eigenvector of the matrix, in this step based on expert advice LULC, highly populated areas and surface rivers maps were given equal importance and considered to be moderately more important than major roads and slope, strongly more important than Airport and very strongly more important than Rail line, hence assigned the value of 1, 3, 5 and 6 respectively.

In step four, after the calculation of weight in step three the consistency of matrix of the factors was checked using consistency index based on the formula in equation 7 to 8 as developed by Saaty (Saaty, 2013):

$$CI = \frac{\square \max - n}{n-1} \quad \text{equation 7}$$

Where

CI = Consistency Index

λmax = Maximum eigen value

n = number of factors in the decision

$CR = \frac{CI}{RI}$ equation 8

Where

CR = Matrix's consistency ratio

RI = Random consistency Index (Table 3.3)

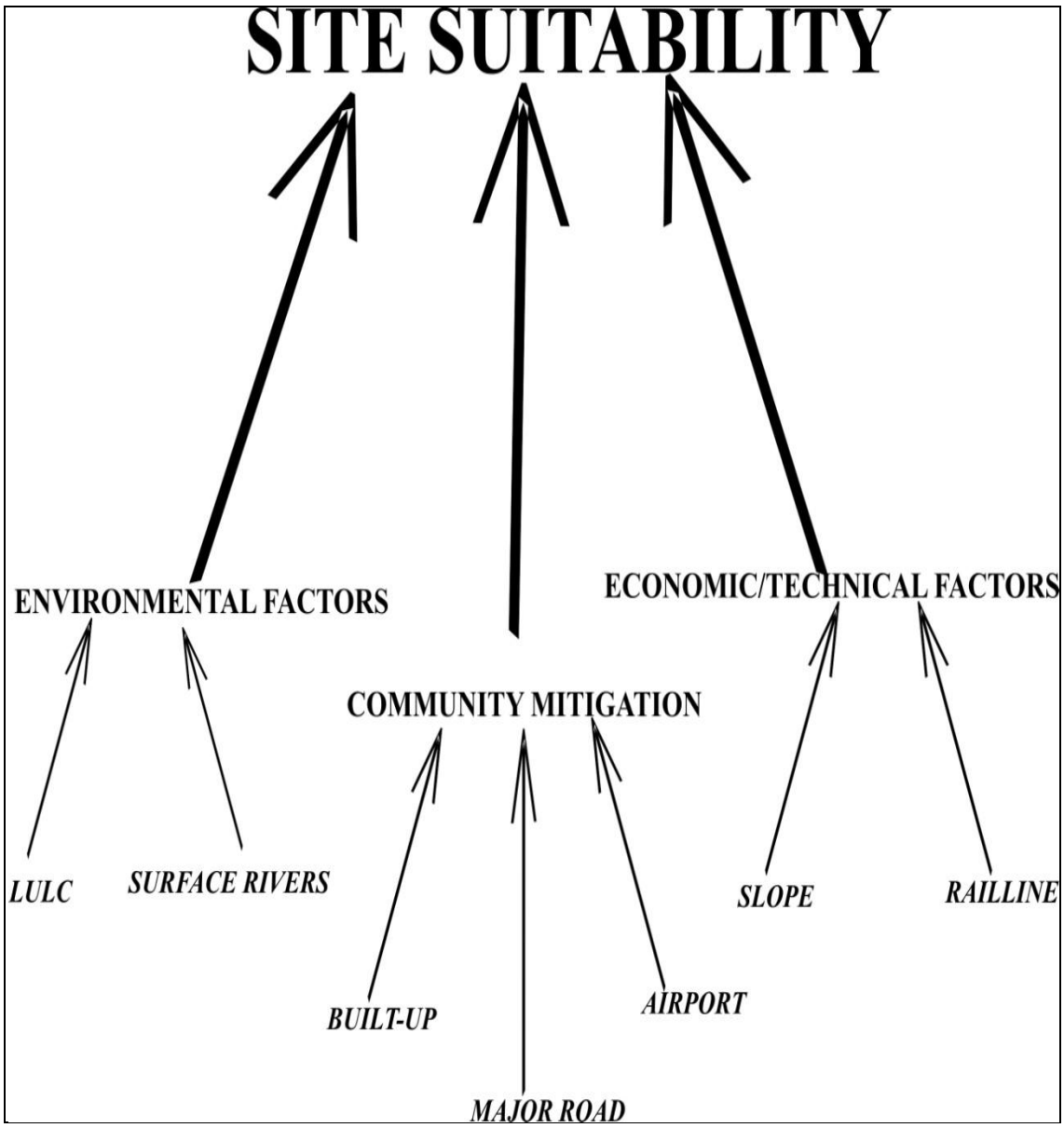

Figure 3.4 Hierarchies of the Factors
Source: Author's Field Observation

Figure 3.5 Comparison Importance's Between Every Two Factors
Source: Saaty (1980)

Table: 3.3 Random Consistency Index

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source; Saaty (1980)

Finally, the final results of the factor's' weight analysis were arrived within an acceptable limit of less than 0.1 (10%).

iii. Overlay Analysis: After weight determination for the various factors using pair wise comparism matrix in Microsoft excel, the weighted overlay tool in the spatial analyst tools of Arcgis 10.1 environment was used to overlay the various factors maps to determine the most suitable sites.

During the overlay analysis, the factor suitability maps of highly populated areas, major roads, surface rivers, rail line, Airport, slope and LULC maps were assigned restricted in the scale value of 0, 1 in the scale value of 1, and 2 in the scale value of 2 as unsuitable, suitable and most suitable respectively. Finally, the suitability map is categorized into unsuitable, suitable and most suitable.

iv. Best Site Determination: Determination of best site for wastewater treatment plants in the study area is highly important, due to the fact that, most areas identified as suitable and most suitable are smaller in size and therefore cannot occupy the entire facilities for offsite wastewater treatment plant. Therefore, best sites were extracted

from most suitable sites using filter tool in the spatial analysis tools of Arcgis 10.1 based on the FSC (2003) criteria for wastewater treatment plant site selection, which is sites with size of greater than or equal to 15 Acres.

v. Field Check for Best Sites: Field checks was carried out at the end of the analysis, so as to determine the accuracy of the sites identified as the best, Google Earth Imagery of the study area was captured and overlaid into the result for easy identification of features that serves as guide during field visit. Centroid geographical coordinate of the best sites were derived in Arcgis10.1 while Garmin 72H Model of Global Positioning System (GPS) was used to identify the actual locations of the best sites on the ground.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter is concerned with the presentation and discussion of results of the analysis. Variables considered in the analysis include: major sources of wastewater discharge in the study area, environmental and health implications of wastewater discharge, methods of wastewater discharge, suitable sites for WWTPs as well as best sites for wastewater treatment plant in the study area.

4.2 Socio-Demographic Characteristics of the Respondents

Table 4.1 Socio-Demographic Characteristics of Respondents

Variables		**Frequency**	**Percentage %**
Gender	Male	309	78.8
	Female	83	21.2
	Total	**392**	**100**
Age	18-25	50	12.8
	26-35	68	17.3
	36-45	231	58.9
	46->	43	11.0
	Total	**392**	**100**
Occupation	Civil servant	76	19.4
	Trading/Business	296	75.5
	Farming	20	5.1
	Total	**392**	**100**
Education	Qur'anic studies	164	41.8
	Primary	75	19.1
	Secondary	50	12.8
	Tertiary	103	26.3
	Total	**392**	**100**

Source: Author's Field Survey, 2016

The results presented on Table 4.1 shows that, majority of the respondents in the study area are males with 78.8% while females constituted only 21.2%. The ratio of males is

greater due to the fact that, males are the custodian of the activities that are associated with the use of wastewater, such as; farming, laundry and industrial work as well as concern with the environmental protection. The results further showed the age structure of the respondents in the study area which revealed four age group intervals. The analysis revealed that most of the respondents fall within the age group of 36 – 45 which constituted 58.9%, this was followed by age group of 26 – 35 with 17.3%, 18 – 25 with 12.8 while 46 and above constituted the lowest percentage of 11%. This clearly shows the age structure of the developing countries including Nigeria and it implies the continuous rising of population in Kano metropolis since people at the age of child bearing given birth are higher hence, increasing amount of wastewater. This is supported by UN-Habitat (2006) that, Africa is urbanizing more quickly and has faster growing slums than any other region.

Trading/business and civil service were the major occupations among the respondents as indicated in Table 4.1 that, trading/business accounted to 75.5%, civil servants accounted to 19.4% and farming accounted to only 5.1%. This analysis suggests that the occupational status of people in Kano metropolis, they are mainly traders and this therefore confirm the saying "For centuries, Kano is known as an important trading part for trans-Sahara trade" (Olofin, 1987). Since, majority of the household in the study area engage on commercial activities, this implies that, people in the study area are aware on how commercial activities brought about increasing volume of wastewater generation. Indeed, as shown on Table 4.1, majority of the respondents with 41.8% have qur'anic education, this was followed by tertiary education with 26.3%, 19.1% for primary education while secondary with lowest percentage of 12.8%. This is attributed to the availability of Islamic religion teachers and the trend of the study area as the centre of qur'anic studies in Nigeria. High number of educated people in the study area

contributes toward the development of proper methods of wastewater disposal through the use of canal system.

4.3 Major Sources of Wastewater Discharge

Kano metropolis as one of the most highly populated cities in Nigeria, demands for high quantity of fresh water amounted to about 550 million litres per day (Bello and Abdullahi, 2014). Of course, this resulted to the discharge of large quantity of wastewater from different sources.

There are four major sources of wastewater generation in the study area namely, residential, commercial, industrial and agricultural activities. The result on Figure 4.1 shows that, all respondents' considered residential and commercial activities as among the major sources of wastewater generation in the study area, this was followed by industrial activities with 72.4% respondent, and least percentage goes to agricultural source which is 11.5%. Carrying the major percentage by residential has been due to the fact that, every individual is part and parcel of this activity and therefore, is aware of how it contributes to the generation of wastewater. While as for commercial activities, it is related to how the study area is highly engaged in commercial activities, hence, it is called 'centre of commerce'.

The presence of five industrial zones in the study area, namely, Bompai, Sharada, Hadejia road, Dakata and Challawa leads to the awareness of people that industrial activities bring about the generation of wastewater but because, the majority of the respondents settle in a densely populated part of the metropolis, where there is absence of land for agricultural activities, majority of them are not aware of how agricultural activities contributes to the generation of wastewater, hence, agricultural source takes the lowest percentage. This finding is in conformity with that of Masoke (2013), which

also shows residential and commercial activities as the major sources of wastewater generation, followed by industrial and urban runoff in Limbe urban municipality of Cameroun.

The finding of this study further shows bathing, washing, food preparation, flushing and abattoir waste, as the various categories of residential and commercial sources of wastewater generation. The result is in line with the findings of Kagu, Badawi and Abba (2013) in Maiduguri metropolis that also identified bathing, washing, food preparation and others such as flushing as the various categories of wastewater discharge through domestic activities in the area. These activities through which domestic wastewater are generated appeared to be the sub-categories of wastewater generation in the study area because, they are the main domestic activities that required the use of water, and therefore, determined the volume of domestic wastewater generation.

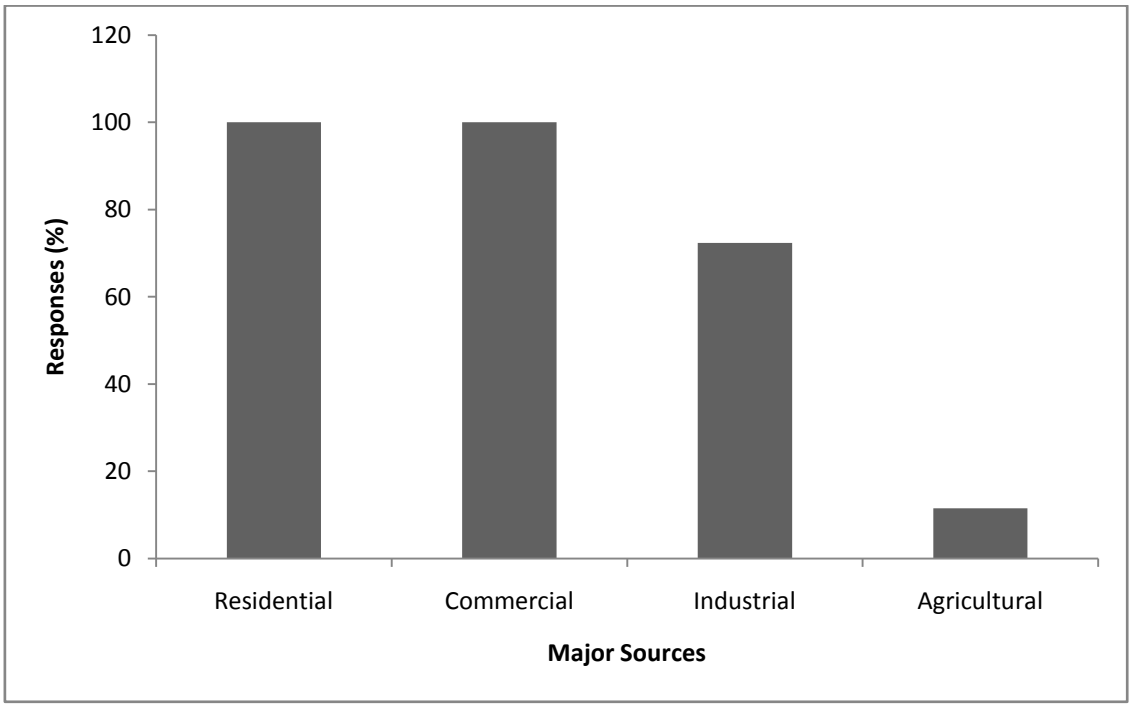

Figure 4.1 Major Sources of Wastewater Discharge in the Study Area
Source: Author's Data Analysis, 2016

Table 4.2 show results of interview on the categories of industries that generate wastewater in the study area, whereby 43.4% goes to plastic industries; this was followed by tannery with 14.5%, textile with 13.3% while dyeing industries has the lowest with only 3.6%. This finding was confirmed by the study of Nabegu (2008) that identified the industrial activities in Kano metropolis to be dominated with the plastic products, textile goods, metal, paper, cosmetics and toiletry, and leather goods. Plastic industries became the dominant industrial activities in the study area due to high population which provide market for its product since goods such as food stuffs are usually packed on plastic bags. Tannery appeared to be the second major industrial activities in the study area due to the availability of raw material (Hide and Skin).

Table 4.2 Categories of Industries that Discharge Wastewater in the Study Area

Categories	Frequency	Percentage
Pharmaceutical	6	7.2
Textile	11	13.3
Tannery	12	14.5
Plastic	36	43.4
Food and drinks	8	9.6
Dyeing	3	3.6
Soap and Chemicals	7	8.4
Total	**83**	**100**

Source: Author's Field Survey, 2016

Tannery and textile industries where regarded by the respondents as the highest contributors of effluents that contaminate water bodies in the study area. This is supported by the findings of Akan et al (2009); Adeogun and Chukwuka (2010); Sheykhi, and Moore (2012); Al-Amin (2013); Massod and Malik (2013); Koki and Jimoh (2015) and Ado et al (2015) that industrial activities especially tannery and textile serve as the major means of contamination in the environment. Tannery and textile industries are ranked as the highest pollutants among all industrial waste due to

the high volume of wastewater they generated and high concentration of substances such as chromium, hydrocarbons, nitrogen and sulphur oxides in the wastewater.

4.4 Environmental and Public Health Implications of Wastewater Discharge

Wastewater produced from residential, commercial, industrial and agricultural activities is discharged into the environment and nearby water bodies in the study area, which therefore, increases both, environmental and public health problems of many communities (UN, 2003). This section therefore, identifies offensive environment and breeding ground for disease vectors as well as spread of various diseases such as malaria, typhoid and diarrhea as the environmental and health implication of wastewater discharged in the study area.

4.4.1 Environmental Implications of Wastewater Discharge in the Study Area

Table 4.3 shows responses on the environmental implication of wastewater discharge in the study area. The result shows that, in Kano metropolis, breeding of disease-causing organisms is the common environmental implication of wastewater discharge with the highest percentage of 54%, followed by bad odour 20.2% and sticky environment 14.3%, but 11.5% of the respondents did not mention any environmental impact. This finding is in line with the finding of Mukhtar, Indabawa and Imam (2010) who asserted that, the presence of wastewater especially sewage ponds in Kano metropolis made the environment unaesthetic offensive, smell and other human activities as well as provide breeding ground for many disease vectors. Breeding of disease-causing organisms and odour has also been reported to be the most common environmental impact of wastewater in Maiduguri (Kagu, Badawi and Abba, 2013). The presence of breeding ground for disease-causing organisms and other environmental consequences in the study area has been attributed to the blockage of wastewater channels and absence of

drainage in some parts of the study area especially newly developed areas, such as Gaida, Danmaliki, Dorayi and Kurna. This shows that, the lives of people in Kano metropolis is at risk of been infected with various kind of diseases.

Table 4.3 Environmental Implication of Wastewater

Variables	Frequency	Percentage
Bad odour	79	20.2
Breeding of disease causing organims	212	54
Sticky environment	56	14.3
None	45	11.5
Total	**392**	**100**

Source: Author's Field Survey, 2016

4.4.2 Public Health Implications of Wastewater Discharge

The most common diseases attributed to the discharge of wastewater as shown in Table 4.4 are Malaria, Typhoid, dysentery and diarrhea, out of which malaria accounted for the highest percentage such as, 42.6%, followed by typhoid with 31.8% , diarrhea with 10% and dysentery with 4.6% while 11% respondents did not mention any disease. This result corresponds to the finding of Mukhtar, Indabawa and Imam (2010) who shows that, malaria scourge is ranked as the most common epidemic known by Kano people. The finding is also similar to that of Nda, Aliyu and Dalil (2013) which reported that, one of the negative impacts of wastewater disposal has been health risk whereby vectors of communicable diseases such as, Malaria, dysentery and diarrhea are present. The researchers went further to stress that, increasing release of domestic wastewater may likely cause an increase in the incidence of several water borne diseases and rapid degradation of the environment.

FRN (2000) shows that, dysentery; diarrhea, gastrointestinal illness and typhoid fever have been found to be associated with the discharge of raw wastewater into storm water in Nigeria. Malaria has been accounted to be the most prominent health implication in the study area due to the fact that, in many areas especially unplanned settlements such as, Dorayi Karama, Kurna, Rimin kebe and Gaida, there are no good drainage system for wastewater which results to the increasing ground for diseases-causing organisms such as mosquito. Therefore, people residing in such areas are under a constant attack of malaria, so long as the problems of wastewater disposal continue. These findings indicated how discharge of raw wastewater in Kano metropolis and Nigeria as a whole is a threat to public health which needs to be checked out through improved wastewater management system in order to find a lasting solution.

Table 4.4 Public Health Implication of Wastewater Discharge

Health risk	Frequency	Percentage (%)
Malaria	167	42.6
Typhoid	125	31.8
Diarrhea	39	10.0
Dysentery	18	4.6
None	43	11.0
Total	**392**	**100**

Source: Author's Field Survey, 2016

4.4.3 Methods of Domestic Wastewater Disposal in the Study Area

Methods of domestic wastewater disposal in the study area, are categorized into black water disposal and grey water disposal. The results of the analysis in Figure 4.2 shows that, the major disposal system of black water in Kumbotso, Tarauni, Nassarawa and Ungogo Local Government Areas has been Soak away with 87.8%, 83.9%, 59.7% and 90.2% respectively. While in Kano Municipal, Fagge, Dala and Gwale LGAs Pit latrine

accounted for 75%, 64.3%, 66.7% and 62% respectively. However, the use of septic tank in the following LGAs Kumbotso, Nassarawa, Fagge and Tarauni has been low and absent completely in other four Local Government Areas. This difference is attributed to the structure of the study area where by Municipal, Fagge, Dala and Gwale LGAs are the ancient parts of the metropolis while the other four LGAs are the extension of the Kano metropolis, therefore, most of their means of black water disposal has been soak away.

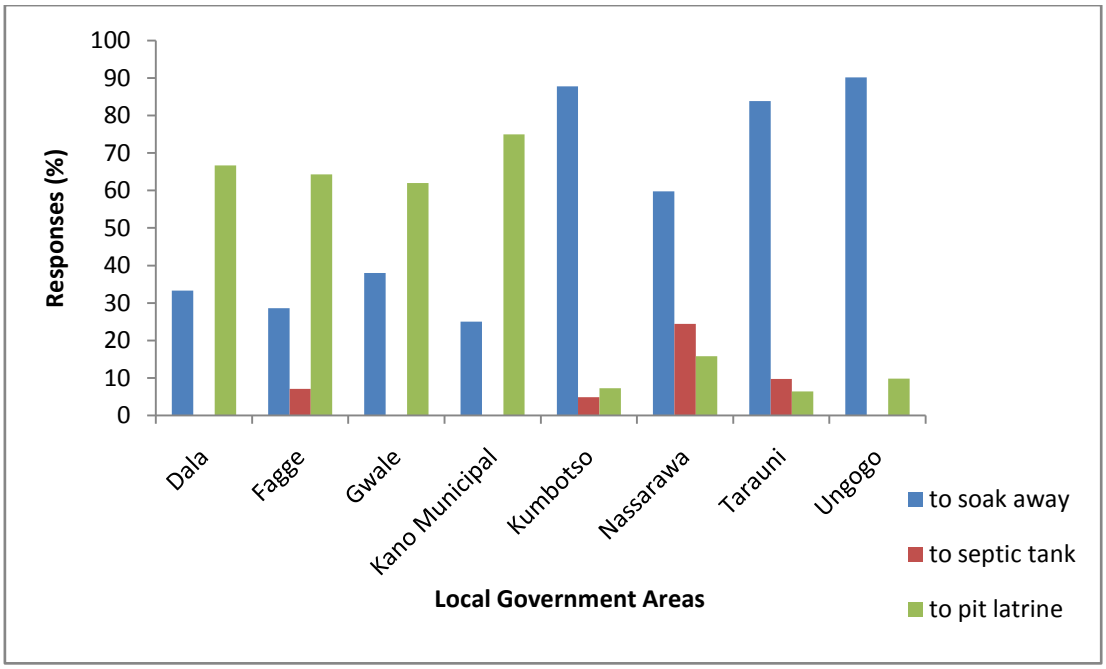

Figure 4.2 Methods of Black Water Disposal in Kano Metropolis
Source: Author's Data Analysis, 2016

This finding is in line with a study on the spatial variation in urban housing quality in Sabon-Gari Local Government Areas, Kaduna state, Nigeria, which reported that in Hanwa and Palladan about 100% and 86% people respectively utilized soak away while 51.2% in Samaru had common toilet in their houses (Akpu, Ogiike and Osumeje, 2015). Soak away has also been reported by Kagu, Badawa and Abba (2013) as the most common means of discharging black water in Maisandari in Maiduguri metropolis of Borno state. The same trend goes to other part of African countries, traditional pit

latrines serve as the most common toilet facility for most urban dwellers in sub-Saharan African countries but improved latrines and septic tanks are utilized by the richest 20% to 40% (Dominguez, 2011). Therefore, the method of discharging black water in Kano metropolis and other parts of Nigeria, such as, Maiduguri is a threat to the environment and public health, because, hand dug wells and bore holes which serve as the major sources of domestic water supply in Kano state as reported by Yalwa (2014) can easily be contaminated by the black water. The finding of Bloch (2012) in Dakar, Senegal also shows that those areas where ground water serves as the major source of their water supply are under a serious threat of water quality due to contamination of nitrate from the nearby black water.

The analysis of grey water disposal system as presented in Figure 4.3 showed that, the use of canal system to discharge grey water has higher percentage in all Local Government Areas of the metropolis, whereby Kano Municipal has the highest percentage such as, 90.4% followed by Gwale LGA and Fagge with 86% and 82.1% respectively while Kumbotso LGA accounted for the lowest percentage of 56.1%. The low percentage of the Kumbotso is attributed to the appearance of many unplanned settlements called "Awon Igiya" in the area where there is the problems of channels for wastewater disposal, respondents when asked about how they disposed wastewater, they replied by "*Muna haka rami, domin bamu da hanyar ruwa"* meaning we make use of dug pit due to the absence of drainage, hence, dug pits in Kumbotso accounted for about 26.8%. Similarly, free flow has also been recorded in six local government areas with the exception of Fagge and Tarauni.

This findings is in contrast with that of Kagu, Badawi and Abba (2013) who observed that 43% of wastewater discharge in Gwange area is through free flow while only 6.7% goes through gutter but in Hausari on street carry the largest percentage of 26.7%

followed by gutter with 22.5% while 21.5% was free flow. This indicates how the grey water discharge method in least developed areas of Maiduguri metropolis is even worse than that of Kano metropolis. The result of this study also contradict that of Nda, Aliyu and Dalil (2013) in Minna who reported that about 65% of wastewater generated in the area flows freely on street. This contrast is attributed to the effort of Kano State Governments in roads rehabilitation through expansions and constructions of drainage systems as well massive campaigns of environmental protection by Kano State Ministry of Environment.

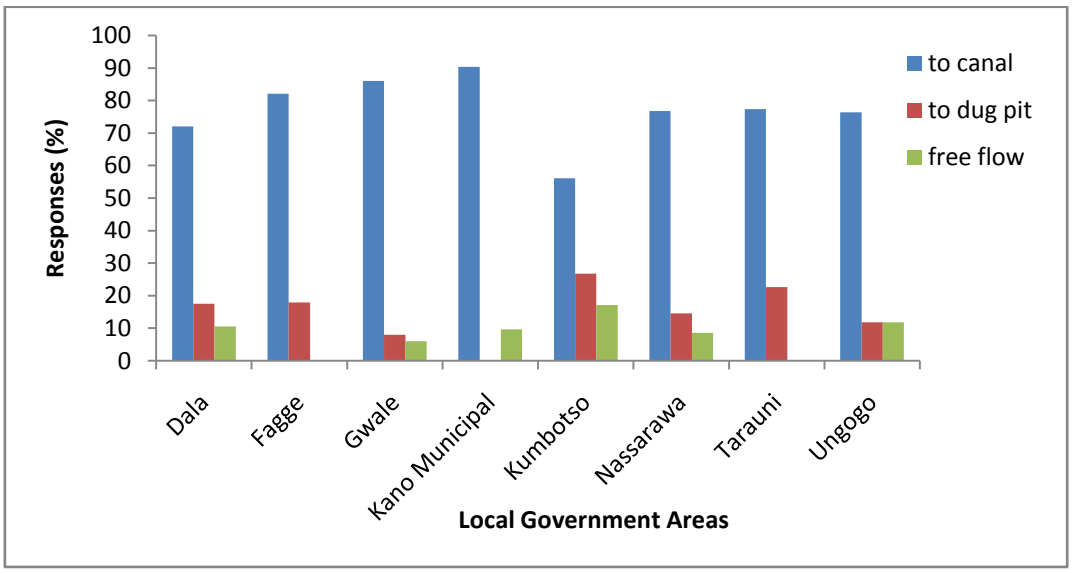

Figure 4.3 Methods of Grey Water Disposal in Kano Metropolis
Source: Author's Data Analysis, 2016

4.5 Best Site for Wastewater Treatment in the Study Area

One of the most fundamental reasons behind the designing and selection of best site for wastewater treatment plant in any community has been protection of the environment and public health. Variables such as land use-land cover, slope, highly populated areas, major roads, surface rivers, Airport and rail line were considered for wastewater treatment plant suitability determination in this study. Therefore, this study identifies

10 best sites for the siting offsite wastewater treatment plant in Kano metropolis based on seven factors suitability determination and 15 acres size criteria.

4.5.1 Land Use/ Land Cover Classification Suitability Determination

Results of the land use – land cover classification shows eight major land uses – land cover classes as shown on Table 4.5 and Figure 4.4.

Table 4.5 Land-use Land Cover Classes of Kano Metropolis

Code	LULC Categories	Area (km^2)	Area (%)
1	Built-up land	186.1	37.3
2	Bare surface	58.6	11.7
3	Scattered Cultivation	183.5	36.7
4	Irrigated Area	2.7	0.6
5	Forest	27	5.4
6	Grassland	40	8
7	Surface water	0.4	0.1
8	Wetland	0.8	0.2
	Total	**499.1**	**100**

Source: Authors Data Analysis, 2016

Built-up area is having the highest percentage such as, 37.3%, followed by Scattered cultivated with 36.7%, while surface water is having the lowest percentage of only 0.1%. The finding is similar to that of Ahmed (2014) in Jos North that identified built-up, water body, wetland, forest, savanna, scattered cultivation, irrigated agriculture, rocky outcrop and bare surface as land use / land cover classes. The result is also similar to that of Umar and Kumar (2014) who identified areas covered by farmland in Kano metropolis to have been larger, followed by built-up. The appearance of scattered cultivation as the second largest land use – land cover class in Kano metropolis is

attributed to the fact that, Kumbotso and Ungogo Local Governments' Areas occupied more farm lands than built-up areas.

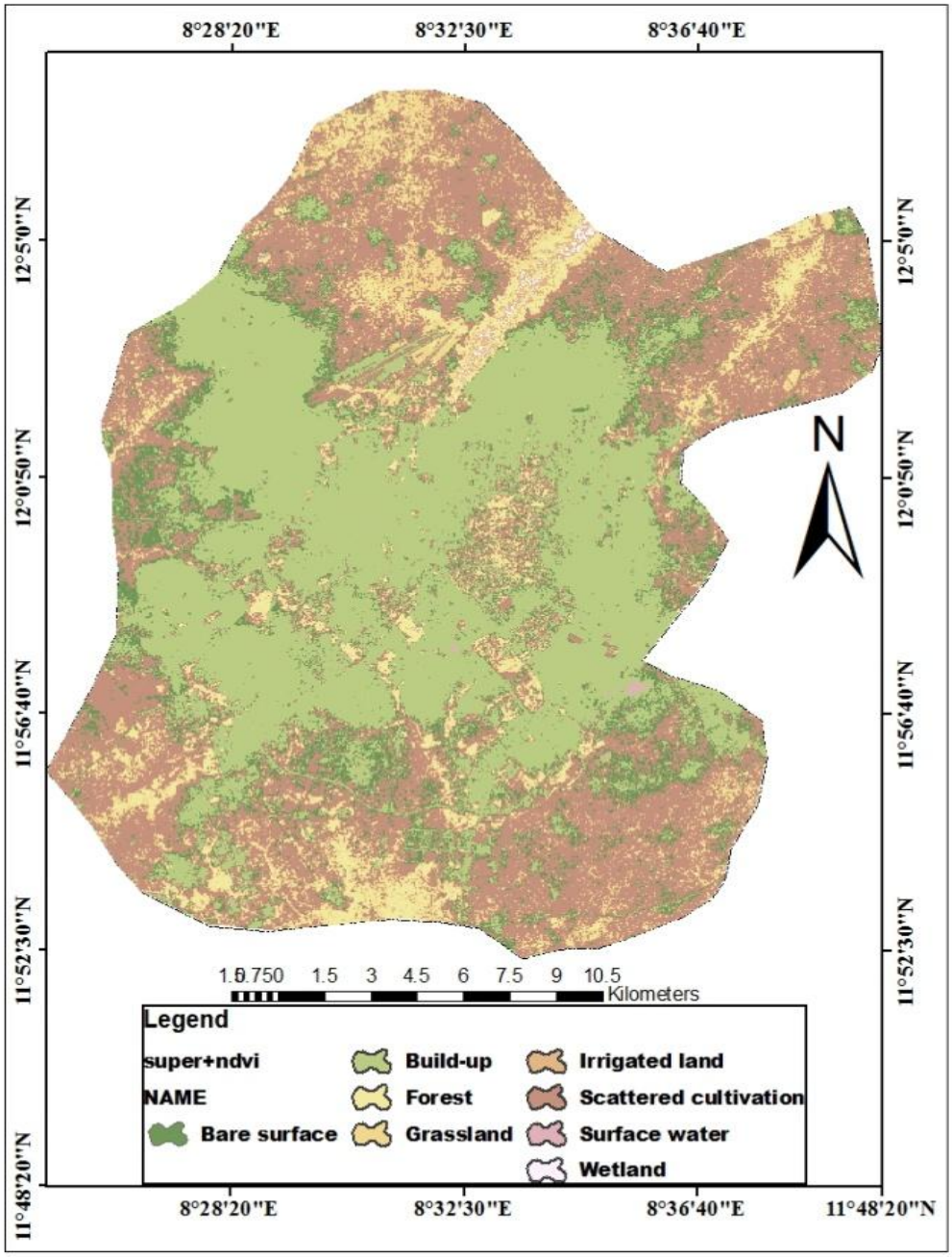

Figure 4.4 Classified Land Use/ Land Cover of the Study Area
Source: Authors Data Analysis, 2016

Results of accuracy assessment for land use/ land cover (LULC) classification presented on Table 4.6 shows the first column to represent the user's classes whereas other columns to represent the number of points for each class as reference data.

The sums of the points representing each class in the classified LULC are shown in the last column while the last row shows the sums of the points in each class on the reference imagery. The error matrix in this study tries to bring out the map quality in relation to the reference data (Google Earth). For example, in the built-up area category, 78 points contain in the classified LULC were built-up area, out of which 64 were correctly classified as built-up area but 5 and 9 points were misclassified in the reference imagery falling as scattered cultivation and bare surface respectively.

Table 4.6: Accuracy Assessment for LULC Classification

	Built-up	Bare surface	Wetland	Surface water	Irrigated land	Scattered cultivation	Grassland	Forest	Total
Build-up	64	9	0	0	0	5	0	0	78
Bare surface	6	59	0	0	0	4	0	0	69
Wetland	0	0	29	3	4	0	0	3	39
Surface water	0	0	4	37	1	0	0	1	43
Irrigated land	0	0	3	2	40	0	0	2	47
Scattered cultivation	2	3	0	0	0	76	4	0	85
Grassland	0	0	0	0	0	2	63	5	70
Forest	0	0	5	0	0	0	3	57	65
Total	72	71	41	42	45	87	70	68	425

Source: Authors Data Analysis, 2016

Therefore, the overall accuracy achieved through error matrix is 85.7% while the kappa coefficient has been 0.98, meaning 98% of the classification agreed with the reference data, and leaving 2% to chance. Similar result of accuracy assessment has been achieved by Yadvendra et al (2015) who recorded an overall accuracy in land use – land cover classification of 89% in Allahbad city of Tanzania.

Figure 4.5 presents the results of land use/land cover suitability analysis and it indicates that, areas which are bare surface are areas that are most suitable with 11.7% of the study area while grassland and other six land use classes with 8% and 80.3% are suitable and unsuitable respectively. The unsuitable sites occupied more area due to the presence of highly valuable materials which must be avoided in siting wastewater facilities. This result is in line with the assertion of FSC (2003) that siting of wastewater facilities should be in a site with low value materials so as to reduce looking for permitting constraints, resulting in extensive buffer and in some cases outright prohibition of development.

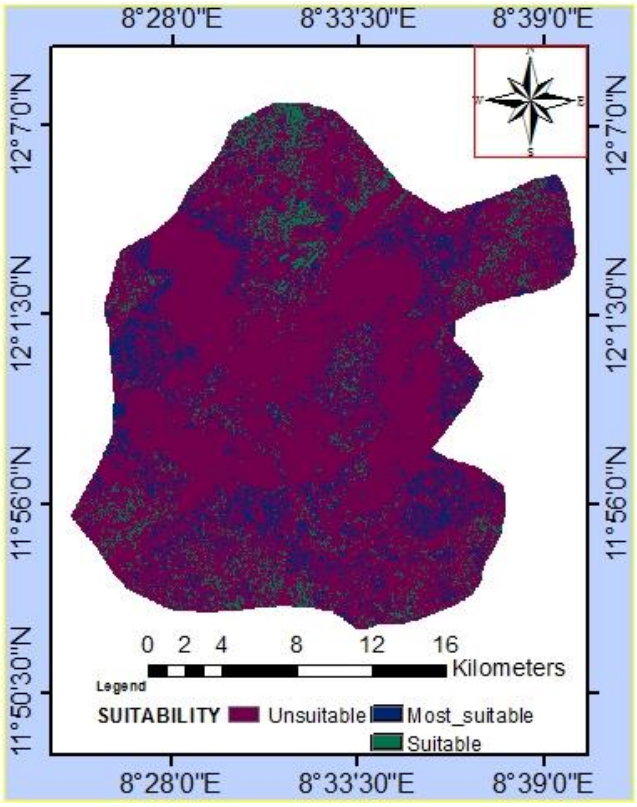

Figure 4.5 Land Use/Land Cover Suitability Analyses
Source: Author's Data Analysis, 2016

4.5.2 Slope Suitability Determination

Figure 4.6 shows results of slope values of the study area in degrees. The highest slope values in degrees have been 7.6^{o} – 22.2^{o} in areas such as Gwauron Dutse and Dala and

are described as areas with poor runoff while the lowest slope values of 0^o - 1.05^o fall within areas of smooth flow, such areas include Jakara River and Sabongida while slope values of 3.15^o – 7.59^o are described as zones of moderate slope.

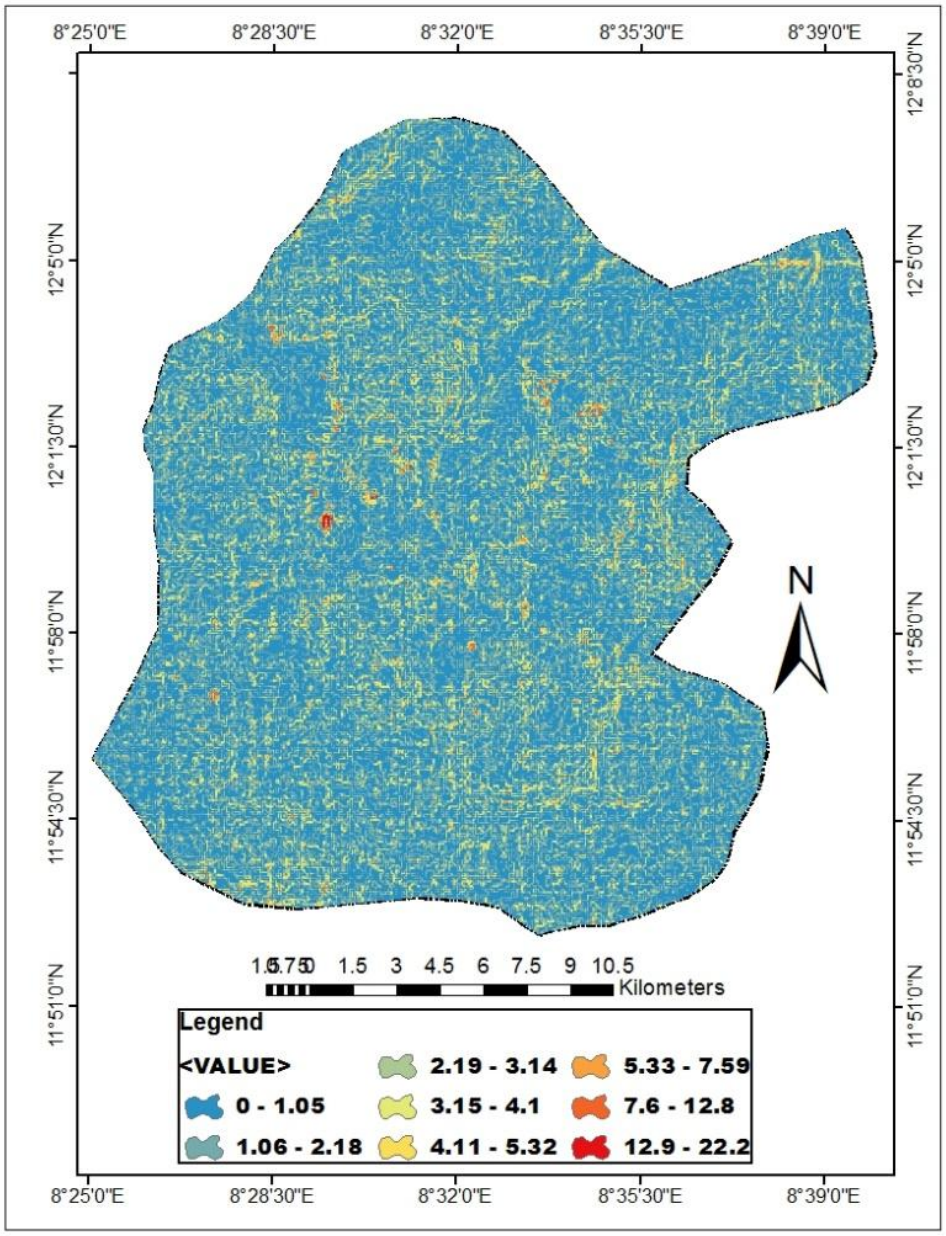

Figure 4.6 Slope Gradients in Degrees
Source: Author's Data Analysis, 2016

It is therefore deduced that, areas having slope between 0^o and 5.32^o are most suitable, 5.33^o to 7.59^o are suitable while those between 7.6^o to 22.2^o are those considered to be unsuitable for siting wastewater treatment plant in the study area as shown on Figure

4.7. This is because, moderate to low slopes attract free flow of wastewater under gravity while too flat and higher slope affect runoff. This result is substantiated by Anagnostopoulos, Gratziou, and Vavatsikas, (nd); Subramani, Subramanian, Kathirvel, and Bharathi Devi (2014); Benujah and Devi (2013) that the appropriate slope for siting wastewater treatment plant should not be greater than 7.59^{o} because, too flat and high slope would affect the runoff drainage.

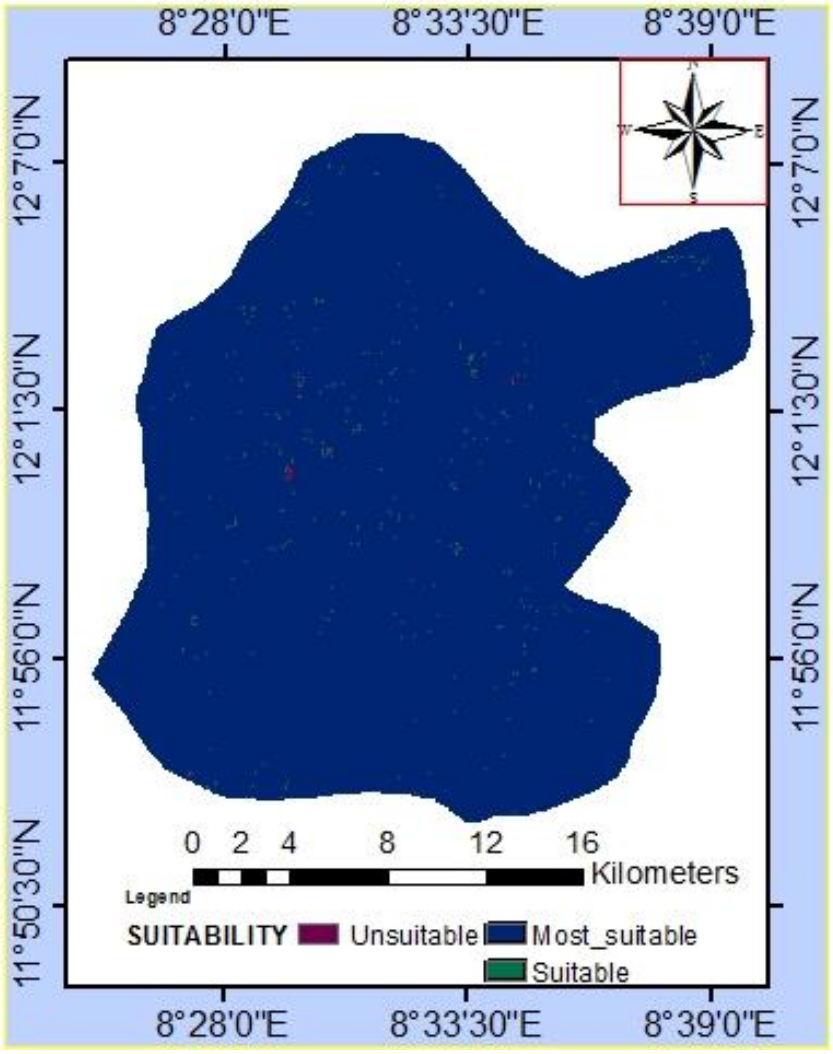

Figure 4.7 Slope Suitability
Source: Author's Data Analysis, 2016

4.5.3 Highly Populated Areas Suitability Determination

The result of highly populated areas suitability is shown on Figure 4.8, it shows that, the central part of the study area is the most highly populated area; this is followed by the southern part which is moderately populated in areas such as, Gaida, Kumbotso,

Kantama, Kuyan and Panshekara, while the northern part is sparsely populated. This is because, the higher the population density the more the negative impacts of wastewater treatment plant to people and environment.

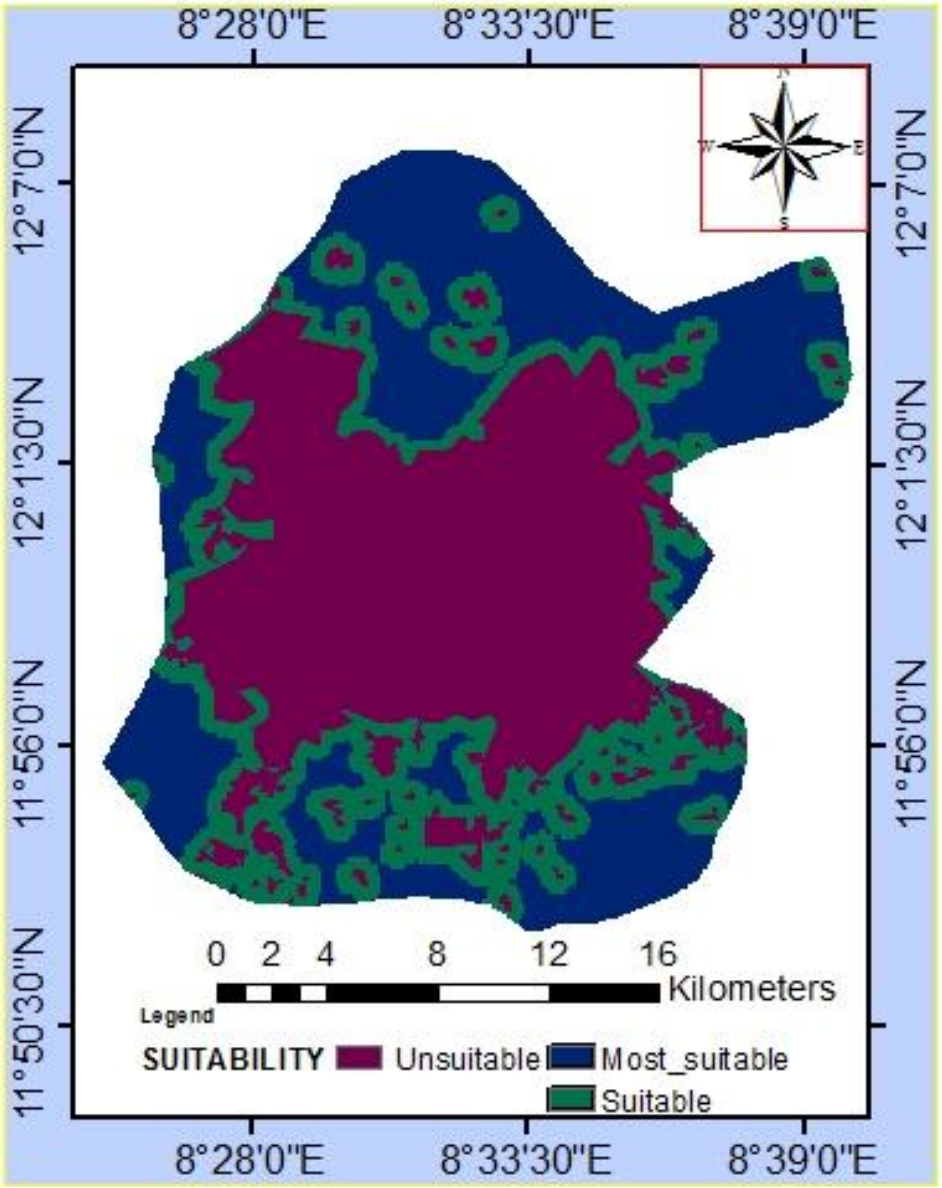

Figure 4.8 Highly Populated Areas Suitability
Source: Author's Data Analysis, 2016

Therefore, all areas with moderate to high population are buffered, and this resulted to 255.4 Km^2 (51.2%), 86 Km^2 (17.2%) and 157.7Km^2 (31.6%) as unsuitable, suitable and most suitable areas respectively. This is supported by the work of Anagnostopoulos, Gratziou, and Vavatsikas, (nd) who suggested that, highly populated areas should be

buffered for wastewater treatment plant, because, it helps to protect public against mitigation of the wastewater and future expansion of development. Buffering of highly populated areas is also supported by Subramani, Subramanian, Kathirvel, and Bharathi Devi (2014) and Zhao (2015) who stated that, for a successful siting of wastewater treatment facilities, a buffer distance around densely populated areas must be created.

4.5.4 Major Roads Suitability Determination

The result of major roads suitability in the study area is shown in figure 4.9. The highest concentration of major roads is shown in central part, followed by southern part around Sabontitin Madobi and Kwankwasiya city while the density has been low in northern part around Ungogo. The result also revealed that, 363.3km^2 (72.8%) of the study area has been most suitable for siting wastewater treatment plant while about 71.3 km^2 (14.3%) and 64.5 Km^2 (12.9%) as suitable and unsuitable respectively. This therefore, indicates the availability of land for WWTPs as per as this factor is concerned. This result is in agreement with that of Zhao(2015) who conducted a similar research in Guangyuan of western China and revealed that there is more suitable land than unsuitable as per road network constraints.

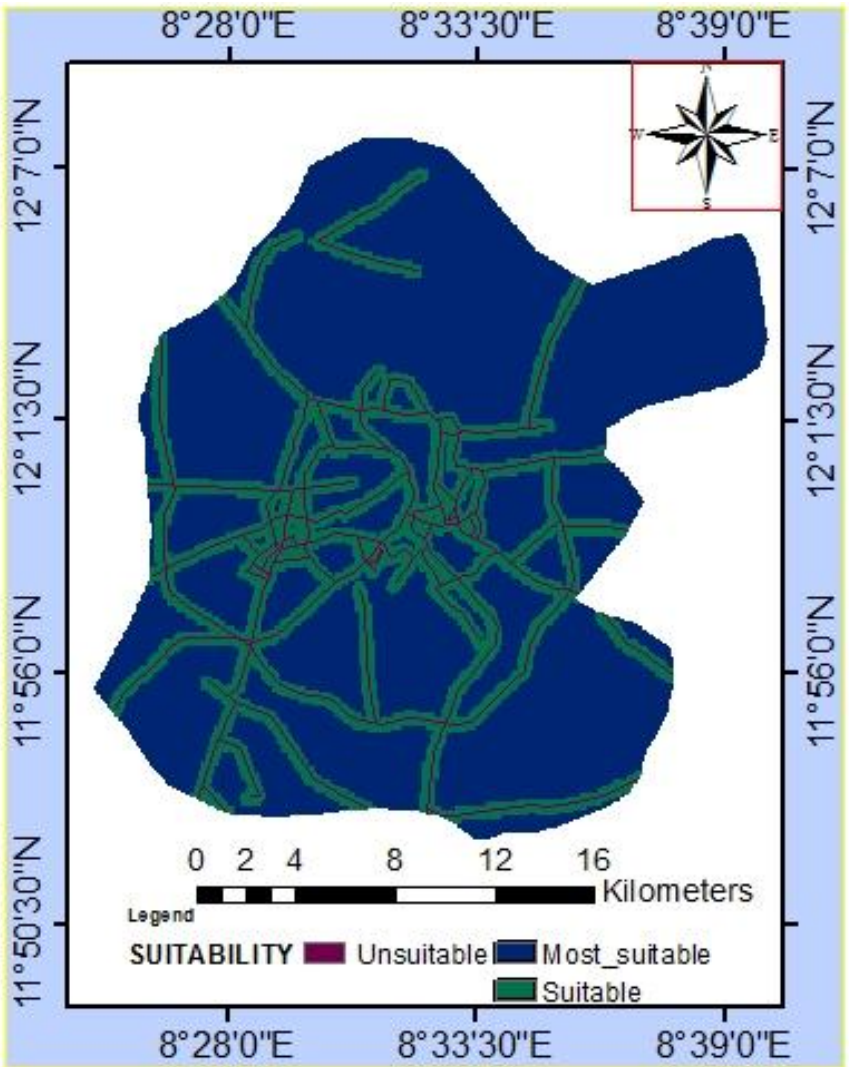

Figure 4.9 Major Roads Suitability
Source: Author's Data Analysis, 2016

4.5.5 Surface Rivers Suitability Determination

The result of surface rivers in Figure 4.10 shows that there are no rivers in the central, western, south-western and extreme northern parts of the study area, but in the southern part there are rivers such as river Salanta and River Tsatsarwaki and by the northern to the north east there is River Jakara. The result further, shows most suitable sites for WWTPs in the study area occupied higher land area of 421.2 km^2 (84.4%) while land mass of 41.3 km^2 (8.3%) and 36.6 Km^2 (7.3%) as suitable and unsuitable respectively. The result therefore shows WWTPs suitability for surface rivers to be far away from water bodies, this is in conformity with assertion of Zurita, Roy and White (2012) that

WWTPs should not be sited near the source of water supply such as, rivers, lakes and ponds, due to the fact that, conventional technical WWTPs exhibit numerous uncertainties associated with performance failure risk as far as design and operation is concerned.

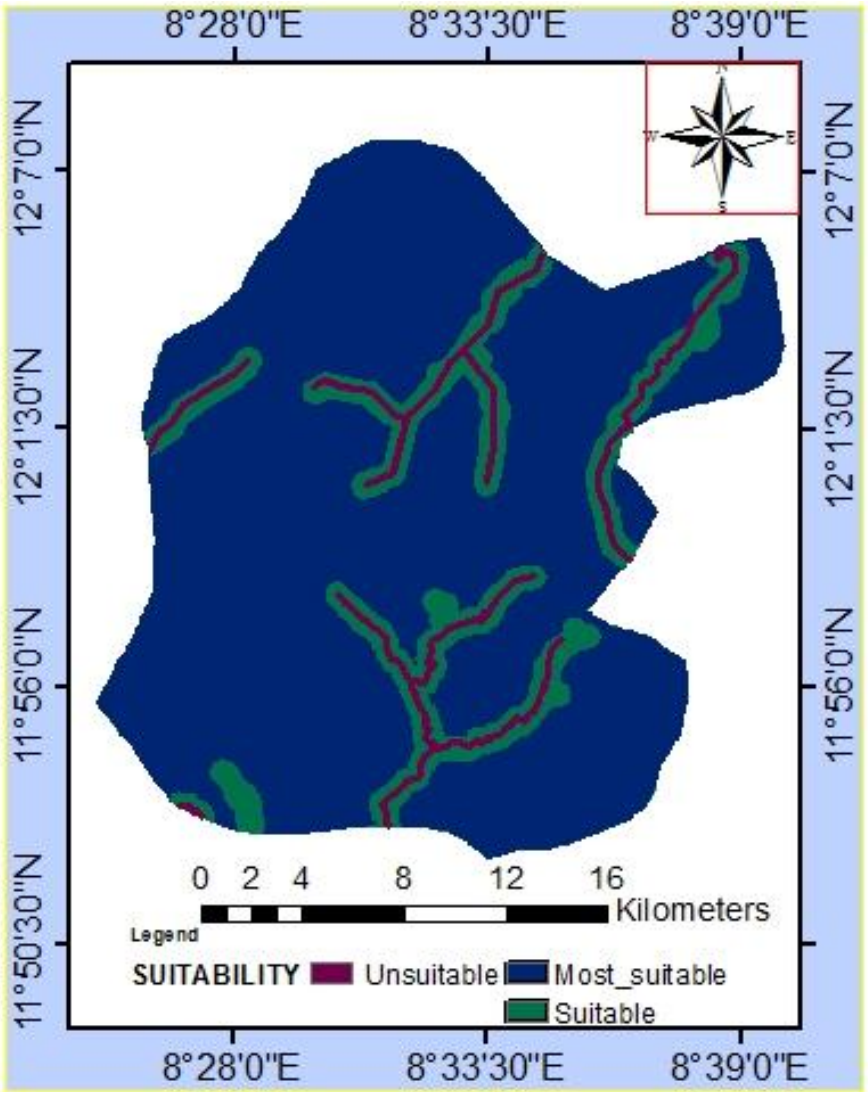

Figure 4.10 Surface Rivers Suitability
Source: Author's Data Analysis, 2016

4.5.6 Airport Suitability Determination

The result of Airport suitability in the study area is shown in Figure 4.11. One of the International Airports of Nigeria has been situated within the study area, the Airport premises consist of several land uses which involved housing, transportation,

commercial, educational and agricultural activities; these land uses must be relocated if the site is to be selected for WWTPs. In this case, this study revealed areas far away from Airport with 97.8% to be the most suitable area for this activity; this was followed by suitable and unsuitable sites with 0.7% and 1.5% respectively. This finding is therefore supported by FSC (2003) who stated that, sites not requiring a change in land use would be scored higher in siting WWTPs.

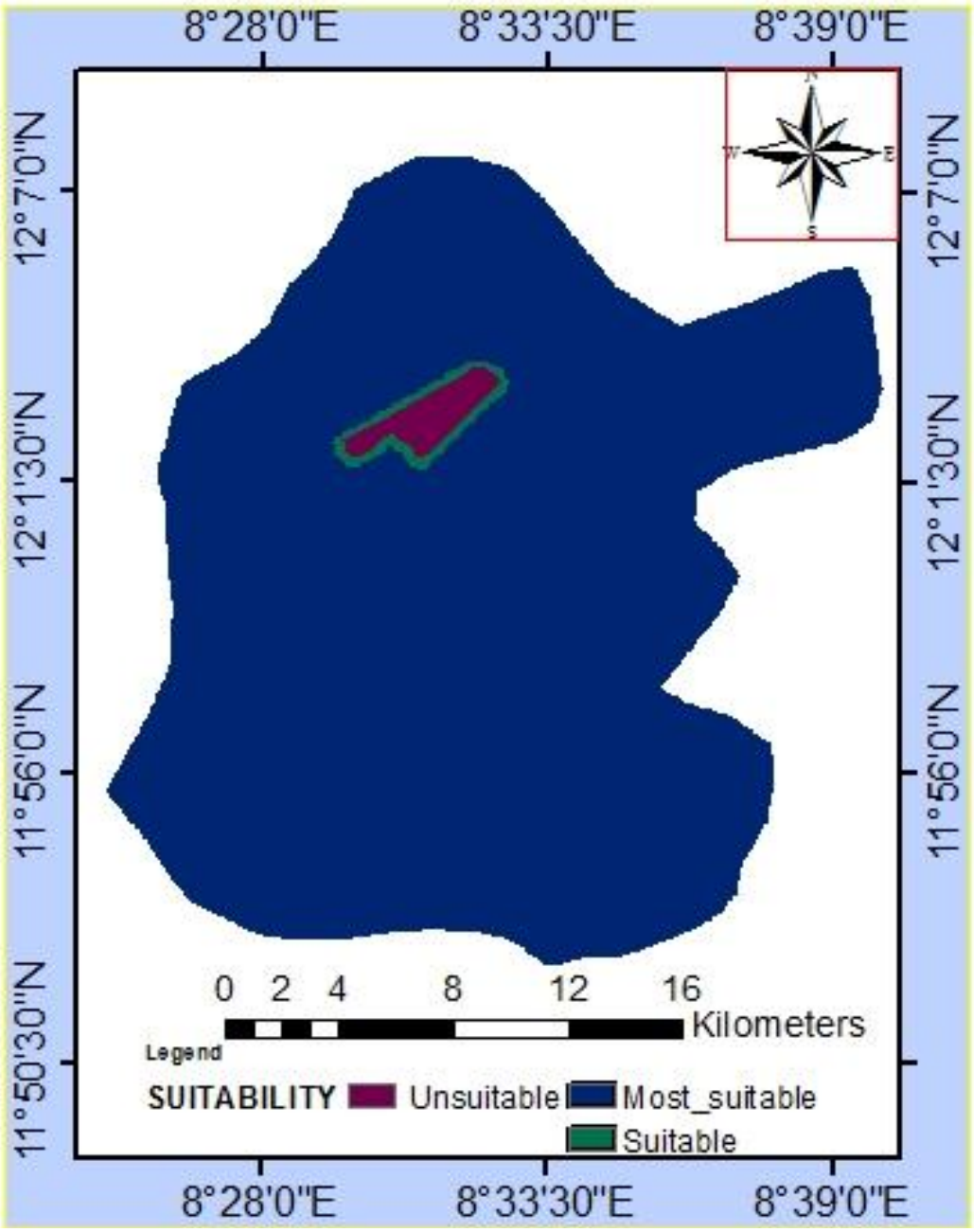

Figure 4.11 Airport Suitability
Source: Author's Data Analysis, 2016

4.5.7 Rail-line Suitability Determination

Figure 4.12 shows the result of rail line suitability determination for WWTPs in the study area, it shows that rail line crosses the study area from the south western part through Kumbotso Local Government Area passing Kano Municipal behind Rumfa College through Nassarawa Local Government Area and left Kano metropolis by the eastern part; displacement of these giant projects is costly and time consuming. The result therefore shows sites that required less capital for wastewater treatment facilities as far as rail line suitability is concerned to occupy higher percentage such as, 96.9% as the most suitable while areas with 1.9% and 1.2% as suitable and unsuitable respectively.

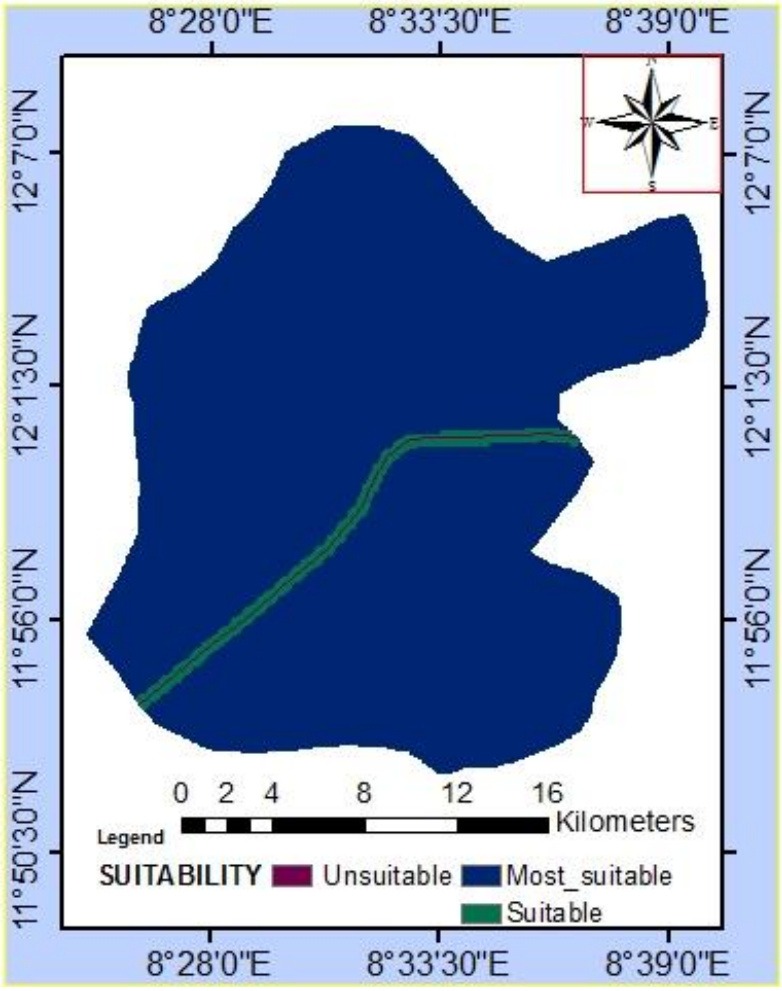

Figure 4.12 Rails - Line Suitability
Source: Authors Data Analysis, 2016

4.5.8 Comparison Matrix for the Seven Factors of Suitability Determination

Table 4.7 shows the result of the weight determination for the comparison matrix of the seven factors considered in determining best sites for offsite wastewater treatment plants in the study area.

The result shows Lambda (λ) to be 7.13, Consistency Index (CI) as 0.022 and consistency Ration (CR) to be 0.02, within the acceptance level of 0.2 which indicated 2% of CR and 98% confidence of the consistency, and therefore, the matrix computed is adequately satisfactorily. Land use/ land cover, highly populated areas and surface rivers is having the highest weight of 24.7% each and this indicates that they are the most important factors in the study area with respect to siting wastewater facilities while rail line having the lowest percentage such as, 3.8% is the one with lesser importance. Based on this, it is deduced that, factors with the lower weight are those with higher suitability for siting WWTPs and are therefore sites in the suburb of the metropolis.

Table 4.7: Comparism Matrix

								AHP Normalized	
Factors	Land use	Highly Populated	Rivers	Roads	Slope	Airport	Rail	Weight	%
Land use	1	1	1	3	3	5	6	0.247	24.7%
Highly populated	1	1	1	3	3	5	6	0.247	24.7%
Rivers	1	1	1	3	3	5	6	0.247	24.7%
Roads	1/3	1/3	1/3	1	1	3	3	0.087	08.7%
Slope	1/3	1/3	1/3	1	1	3	3	0.087	08.7%
Airport	1/3	1/5	1/5	1/3	1	1	3	0.048	04.8%
Rail	1/6	1/6	1/6	1/3	1/3	1	1	0.038	03.8%

Source: Authors Data Analysis, 2016

The result on Table 4.7 is in line with the finding of Manjubashini, Rinsitha, and Singh, (2014) and Ahmad (2014) where LULC scores highest weight in siting waste facilities. It is also in agreement with finding of Zhao (2015) in Guangyuan of western China where water bodies scored the highest weight followed by vegetation and built-up areas in siting WWTPs. LULC scores the highest weight in the study area because it contains all other factors such as roads, surface water as well as built-up areas.

4.5.9 Categories of Sites Suitable for Wastewater Treatment Plant

The study shows, three categories of sites suitability for wastewater treatment plants in Kano Metropolis, that is unsuitable sites with the total land mass of 477.3 Km^2 (95.6%), suitable sites 14.6 Km^2 (2.9%) and most suitable sites with 7.2 Km^2 (1.5%). The analysis on Figure 4.13 shows that, the unsuitable sites occupy more land area followed by suitable and finally most suitable with the lowest land mass. Unsuitable sites scores the highest percentage because built-up areas and scattered cultivation occupy more land area than other classes and presence of more social amenities, such as, major road, rail line and airport which need to be protected.

In this case, care must be taken by the authority and public who intend to build wastewater treatment plants either on-site or off-site so as to protect public, animals and plants against the consequences of construction of the plants. Subramani et al (2014) also identified three categories of site suitability for wastewater treatment plant in Salem Corporation, India that is good with the area of 5.53 Km^2, moderate with 18.06 Km^2 and poor with 0.18 Km^2. The finding is also in line with the finding of Benujah and Devi (2013) in Nagercoil Municipality, Tamil Nadu where good, moderate and poor suitable sites were identified for sewage treatment plant. This finding is also similar to that of Manjubashini, Rinsitha and Singh (2014) in Chelgalpattu Taluk of

India where four categories of suitable sites were identified as unsuitable, less suitable, moderate suitable and most suitable sites for liquid waste treatment plant..

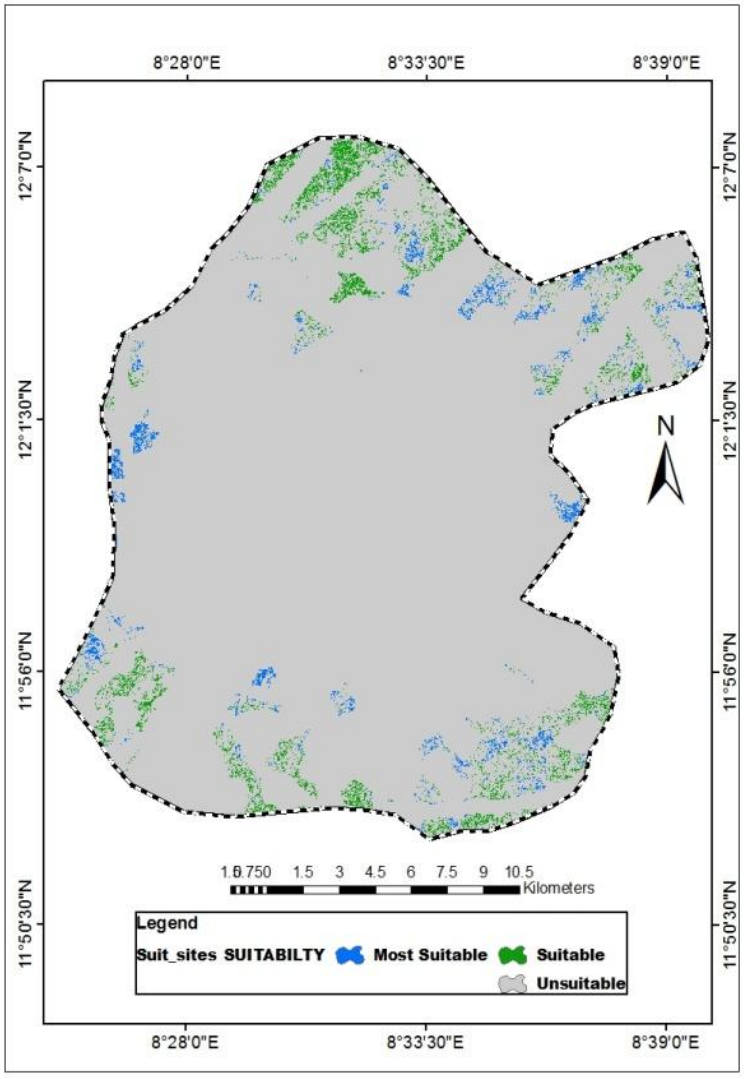

Figure 4.13 Sites Suitability for Wastewater Treatment in the Study Area
Source: Author's Data Analysis, 2016

4.5.10 Best Sites for Offsite Wastewater Treatment Plants

Table 4.8 and Figure 4.14 present the size and locations of the best sites for offsite wastewater treatment plants in Kano metropolis. The study shows 10 best sites for offsite wastewater treatment plants in the study area where by the largest sites have been in the western part of the study area with 77 acres and 61.6 acres each, followed

by site in the eastern part with 51.7 acres, the north west with 17.8 acres and north east with 16.9 acres are those with the lowest land area.

Table 4.8 Size and Centroid Location of Best Sites for Offsite Wastewater Treatment Plants

Sites	Area (Acres)	Direction	Longitude (^{0}E)	Latitude (^{0}N)
1	40.987	North	8° 33' 13''	12° 05' 10''
2	28.486	north-east	8° 36' 59''	12° 04' 35''
3	16.905	north-east	8° 34' 55''	12° 04' 24''
4	17.785	north-west	8° 26' 56''	12° 02' 40''
5	77.002	West	8° 26' 54''	12° 01' 10''
6	61.557	West	8° 26' 18''	12° 00' 28''
7	51.720	East	8° 48' 50''	11° 59' 29''
8	20.313	West	8° 26' 21''	11° 58' 49''
9	31.157	north-west	8° 25' 52''	11° 56' 24''
10	45.415	South	8° 29' 45''	11° 55' 55''
Total	391.327			

Source: Authors Data Analysis, 2016

The sites by the east and by the south are the best for offsite industrial wastewater treatment plants as shown on Table 4.7. Because industrial zones of the study area run from the eastern border to the south and since that of the south is more closer to the built-up areas, the expansion of the study area may reach it more quickly. Site by the east is considered to be the most appropriate; while the other nine sites could be used for offsite domestic wastewater treatment. This result is in agreement with the assertion of Zhao (2015) that traditionally, sewage treatment plants are usually placed in the downstream of a river or city suburb. The location of the best sites in the suburb of the

metropolis as revealed in this study is also in line with the study conducted by Mukhtar, Indabawa and Imam (2010) who revealed that, siting wastewater within the vicinity of public like Kano metropolis is a real threat to public health and therefore call for proper siting of wastewater ponds, which should be outside the city.

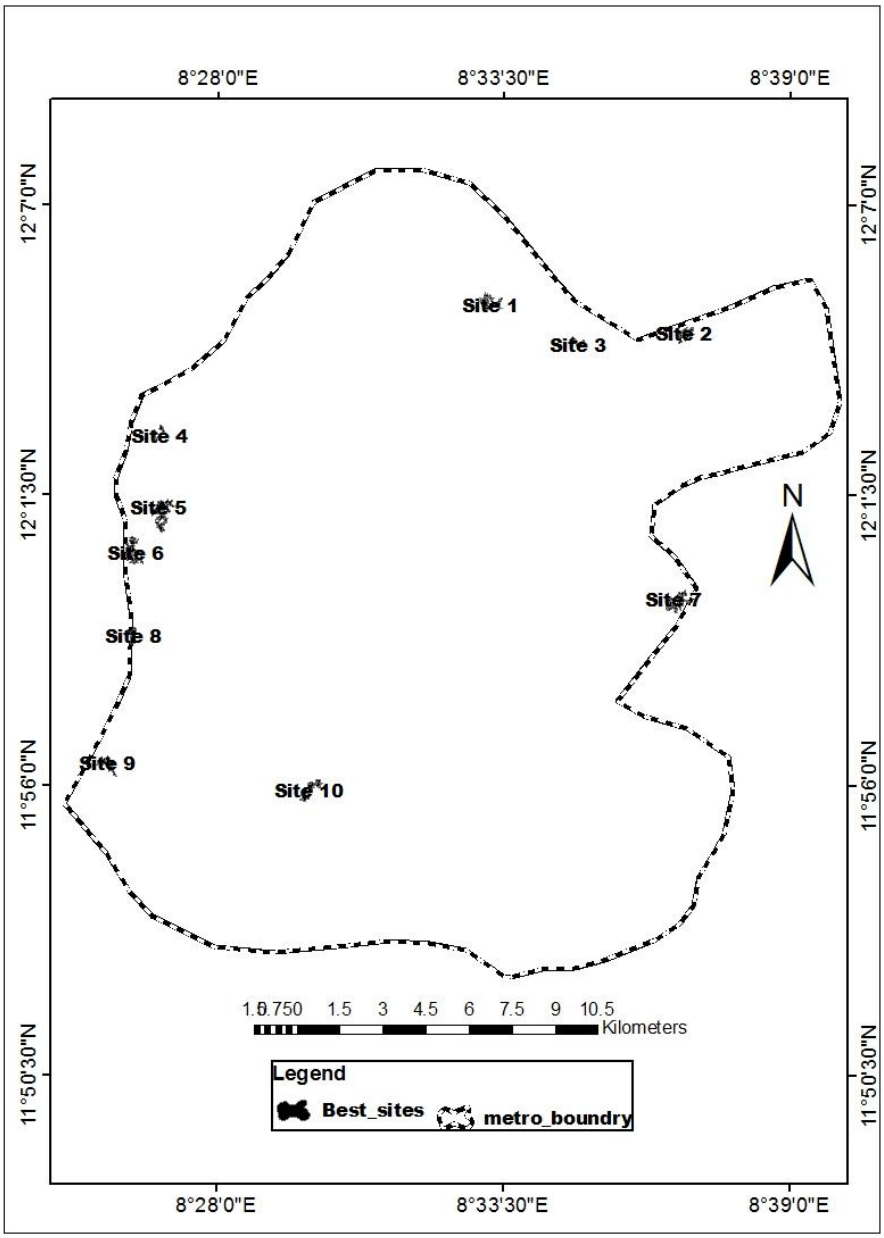

Figure 4.14 Best Sites for Offsite Wastewater Treatment in the Study Area
Source: Author's Data Analysis, 2016

Identification of best sites for wastewater treatment in this study is in conformity with the result of the study conducted by Msangi and Liwa (2014) who identified eight best

sites for sewerage pond in Tanzania. This finding is also in line with that of Chelsea (2011) where two best sites for wastewater treatment plant were identified in Chelsea Municipal Area (CMA).

Figure 4.15 serves as guide for easy identification of features that are found in the sites during field visit to determine the accuracy of the result as adapted from Ahmed (2014); during the visit, it was observed that the selected sites actually avoid the factors considered as constraint for siting offsite WWTPs in the study area.

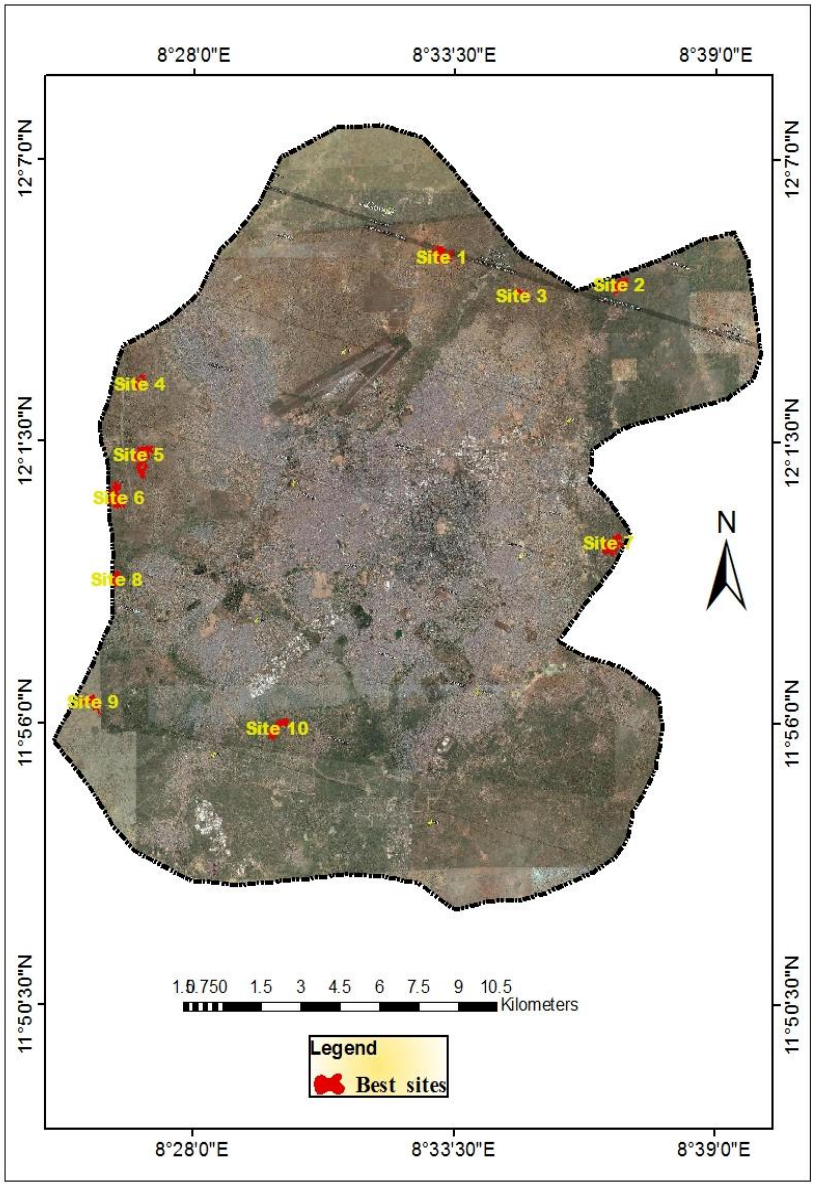

Figure 4.15 Overlays of Best Sites on Google Earth Imagery of the Study Area
Source: Author's Data Analysis, 2016

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter presents the summary of major findings, conclusion and recommendations and suggestion for further studies.

5.2 Summary

Questionnaire survey and interview in this study, shows various sources of wastewater discharge and its implication on environment and public health. The use of GIS-based Multi-Criteria Decision Analysis shows ten best sites for offsite wastewater treatment plant as shown below.

- Residential, commercial, industrial and agricultural activities are the major sources of wastewater discharge identify in the study area.
- Plastics, tannery, soap and cosmetics, textiles, food and drinks, pharmaceuticals and dyeing are the major industrial wastewater sources identified in the study area.
- It was established from the study that, the major means of discharging black water in the area have been soak away even though in the ancient Kano Pit latrine serves as the most common method but the use of canal serves as the most prominent method for grey water discharge.
- Bad odour, breading of disease-causing organism and sticky environment are the most frequent environmental consequences of wastewater disposal in the study area.

- Respondents interviewed associated wastewater with health risk, whereby malaria, typhoid, diarrhea and dysentery have been mentioned.
- The study also revealed eight land use/ land cover classes in the study area namely: buildup, bare surface, wetland, surface water, irrigated land, scattered cultivation, grassland and forest.
- Among the seven factors analysed using AHP highly populated area, surface rivers and land use are the most important considered while rail line is the lowest in term of site suitability determination in the study area.
- The study came out with ten best sites for offsite wastewater treatment plant in the study area based on 15 acres size criteria.

5.3 Conclusions

Site selection analysis for wastewater treatment is a complex procedure which involves careful observation of numerous factors of region's land use and developmental patterns, such as, sufficient area, site alteration, and availability of utilities, environmental impacts and mitigation of community impacts. From the finding of this study, it is concluded that, residential, commercial, industrial and agricultural activities are the major sources of wastewater generation in Kano metropolis. It is also concluded that, tannery and textile industries serves as the major contaminants of Challawa River which supplies water to the conventional water treatment plant in Kano metropolis. It is also proved from the results of this study that, wastewater discharge serves as one of major sources of environmental destruction and health risk in the study area.

In the GIS-based MCD Analysis the study arrive at an output map of three (3) categories of suitability: unsuitable, suitable and most suitable sites for wastewater

treatment in the study area. The outcome of this study finally identifies 10 best sites for offsite wastewater treatment plants in the study area. These sites are located in the suburb of the following settlements: Rimaye, ‘yan Ali, Bechi, Kuyan, Rimin Gata, Rimin Zakara, and Kurna.

5.4 Recommendations

Based on the findings of this study, the researcher forward the following recommendations to the government, non-governmental organization, public and other researchers:

i. people should be encouraged towards construction of on-site wastewater system such, as septic tanks on individual and community basis through advice and assistance.
ii. government should make use of the result of this study and other studies alike to establish wastewater treatment plants in Kano metropolis.
iii. all laws related to primary treatment of wastewater before discharge by industries should be put in place together with constant supervision.

5.5 Suggestion for Further Studies

As mentioned before in the methodology section, households and staffs of Kano State Ministry of Environment were interviewed to gather information on the environmental and public health implications of wastewater discharge in the study area. In the future study, it is suggested that, irrigation farmers should be interviewed, because, they are among the custodians of using wastewater. The data used for the extraction of factors

for site suitability analysis has been DEMs and Land sat OLI with 30m by 30m spatial resolution each, this size might not be detailed enough for some important work in designing wastewater treatment facilities, such as, layout of pipes. Hence, for future study, that will involved wastewater drainage zones and lying out of pipes, data with higher resolution such as, 5m by 5m is recommended.

The limited number of factors to only seven in this study is a significant deficiency, therefore, more factors, such as, hydrogeology, urban water supply pipes network and closeness to the source of power supply are also vital factors to be considered in the future studies.

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APPENDICES

APPENDIX I

List of Evaluating Criteria for the Wastewater Treatment Plant Siting Analysis by HDR Engineering, Inc; for Spokane County Wastewater Facilities Plan forwarded in March 2002 and published by Spokane County in February 2003

1. TECHNICAL AND ECONOMIC CRITERIA

A. Sufficient area

1. Useable area of approximately 15 acres
2. Opportunity for buffer around the useable area of at least 100 foot
3. Area for potential upgrade site with area above 25 acres would be more advantageous
4. Site Shape, a rectangular shaped area with length – width ratio in the range of 2 : 1 to 4 : 1 is more desirable

B. Avoid Extensive Site Alteration

1. Slope and terrain area with approximately 20 feet of elevation change across the site would be advantageous
2. Geohazards site with landslide potential may require substantial preparation and increasing cost of construction
3. Soil, dense and hard soil is more desirable than loose, soft soil which need pile supports, backfilling and over – excavation during construction process
4. Proximity to ground water; A depth of 20 feet or more to groundwater is desirable so as to reduce the work of dewatering during construction
5. Existing structures, sites without structures are considered desirable because removing of structures and disposal of waste materials increased construction cost

C. Site hydrology

    1. Storm drainage, sites will be evaluated for the stormwater bio – filtration treatment and disposal facilities, a low score will be assigned if construction required extensive drainage facilities.
    2. Floodplain, sites outside floodplain is more desirable otherwise a site against 100 years floodplain would be chosen

D. Minimize Distance and complexity of conveyance routes: the length of the conveyance system the pump stations to the treatment plant site should be evaluated accurately in such a way that sites close to the outfall with the potential to gravity flow would receive higher scores for this criteria

E. Level and Type of site contamination: sites with no suspected site contamination in term of soils, groundwater facility footprint would be given high scores

F. Site Constructability constraints: This has to do with assessment of access to the site during the conveyance of facilities such as availability of all weather roads or rail line and available area for equipment storage, field offices and material fabrication

G. Availability of utilities: A site with the minimal distance to infrastructural facilities such as Electric power, Gas and Potable water would receive a high score in this criteria

H. Reuse of Treated Effluents: Availability of options for the reuse of the treated effluents is also very important such as aquifer recharge and irrigation.

I. Land Costs: a high score should be given to properties listed for sale on a real estate market so as to avoid long discussion with the owners, legal restrictions and disposition of property

2. ENVIRONMENTAL

A. All measures should be taken so as to minimize impacts to threatened or endangered Species Habitat such as Forest
B. Minimize impacts to Wetlands: extensive buffer and mitigation should be created around wetlands
C. Minimize impacts to surface waters: Streams and their corridors serve as fish and wildlife habitat and need to be protected through setbacks, buffers and other restrictions that could constrain development at the site
D. Minimize impacts to potable and groundwater sources: A water supply well that can serves an average of 25 or more persons for at least 60 days should be protected using extensive buffer and mitigation
E. Minimize impacts to Historical and Archaeological Resources: presence of this type of resource leads to delay construction because high level of regulatory requirements must be fulfilled therefore site without historical and archaeological resources would be rated high in this criteria
F. Environmental Permitting: sites with less complex permitting requirements at local level, state level, national level or even international level would be given a higher score for this criteria

3. COMMUNITY

A. Compatible with adjacent land use: siting a treatment plant in areas not requiring a change in land use would be scored higher in this criteria than situation whereby existing land use must be relocated and siting should be compatible with existing land use for instance siting near Tannery industry is score higher than near food processing factory

B. Land use permitting or zoning: A site whose zoning allowed treatment and conveyance of wastewater facilities “outright” would be given the high ranking than site requiring conditional use or rezone due to the uncertainty, it leads to and schedule delay

C. Mitigation of community impacts: Sites that do not require displacement of housing or businesses, low anticipating odour, not anticipated to cause adverse visual impacts, good access, as well as low traffic congestion would be rated highest for this criterion

D. Public benefits beyond wastewater treatment: sites where a specific amenity would appear feasible and may lead to more investigation for public benefits such as educational facilities and the potentiality of the site to combine the project with another project in the same area such as park improvements projects would receive a higher score in this criterion.

APPENDIX II

Department of Geography

Faculty of Science

Ahmadu Bello University, Zaria

RESPONDENTS QUESTIONNAIRE

Dear Respondent

I am a M.Sc. student of the above mention department, carrying out a research on "**Spatial analysis of site suitability for wastewater treatment plant in Kano metropolis, Kano state, Nigeria.**" Your cooperation is kindly needed for the provision of adequate and accurate information to the questions; all information will be used for academic purpose and shall be treated as highly confidential.

Thank you

Ahmad Hamza Abdullahi

Please Tick ☑ where appropriate

Section A: Biodata of Respondents

Age: a) 18years – 25 years ☐ b) 26years – 35 years ☐

c) 36years – 45 years ☐ d) 46 years and above ☐

Sex: a) Male ☐ b) Female ☐

Educational qualification

a) Qur'anic education ☐ b) Primary education ☐

c) Secondary education ☐ d) tertiary education ☐

Occupation _____

Local Government Area of residence _____

Section B:Wastewater, Health and Environment Research questions

1. What do you think are the major sources of wastewater supply in Kano metropolis and their categories?

   a) _____

   b) _____

   c) _____

   d) _____

2. Which of the following environmental wastewater related problems do you experience?

   a) Bad odour ☐ b) presence of disease-causing organisms e.g. mosquito ☐

   c) Sticky environment ☐ d) both ☐ e) other _____

3. Are you aware of any health risks associated with wastewater?

   a) Yes ☐ b) No ☐

4. If yes, what health risks do you know of?

   i_____

   ii_____

   iii_____

5. How do you discharge black water (excreta)?

   a) soak away ☐ b) septic tank ☐

   c) Pit Latrine ☐ d) other _____

6. How do you discharge grey water (e.g. washing water) from your house?

   a) to river ☐ b) to canal ☐

   c) dug pits ☐ d) other _____

APPENDIX III

INTERVIEW GUIDE

Dear Sir/Madam

I am a M.Sc. student of Ahmadu Bello University, Zaria carrying out a research on "**Spatial analysis of site suitability for wastewater treatment plant in Kano metropolis, Kano state, Nigeria.**" Your cooperation is kindly needed for the provision of adequate and accurate information to the questions; all information will be used for academic purpose and shall be treated as highly confidential.

1. May I know the department you belong to?
2. How long have you been with the department?
3. What are the categories of domestic wastewater supply in Kano metropolis?
4. What are the industrial areas in Kano metropolis?
5. What are the industries that discharge wastewater from the areas mentioned?
6. Which of the aforementioned industries that discharge more harmful wastewater?
7. How can you assess the measures taken by Kano state government in protecting public health and environment against wastewater implication?
8. What are your opinions on construction of wastewater treatment plant in Kano metropolis?