TITLE PAGE

EFFECT OF URBAN WASTE ON THE WATER QUALITY OF MMIRIOCHA RIVER INABAKPA, ENUGU STATE

BY

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APPROVAL PAGE

This is to certify that this project work on the ñEffect of Urban Waste on the Water Quality of Mmiriocha River in Abakpa, Enugu east Local Government Area of Enugu Stateòwas carried out by AnyanwuOnochieNnadozie, Registration number PG/M.sc/12/61370. He has satisfactorily completed the requirements for the project work (EMC 692) in partial fulfilment for the award of Master of Science (M.Sc.) degree in Environmental Management and Control.

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DEDICATION

This work is dedicated to God Almighty who his unfailing love saw me through this piece of work.

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ABSTRACT

The indiscriminate dumping of urban wastes in surface water bodies in urban and semi-urban areas in Nigeria has become a growing menace to humans and natural ecosystem. This study tried to access the effect of urban waste on Mmiriocha river quality located in Abakpa, Enugu state. Water samples were collected at four different points considering various human activities that generate and discharge wastes into the river such as abattoir, raw sewage from homes, open dumps along the river course, and were analysed following established standard for water quality analysis. Parameters assayed includes pH, turbidity, temperature, total hardness, biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, total suspended solids, total dissolved solids, nitrates, phosphates, electrical conductivity, coliform count, e.coli and aerobic mesophilic count. Data collected were analysed using analysis of variance statistical technique and the result obtained show that there is a significant difference between the concentration of the physicochemical and microbiological water quality parameter and the WHO standard and that the concentration of these parameters also vary significantly amongst the sampling points (P=0.000). There was an unacceptable increase of some of the assayed parameters above the threshold limit of WHO for domestic use such as the e.coli, coliform count, aerobic mesophylic count in all the four sampling points. Other parameters such as turbidity, electrical conductivity, total dissolved solids, total hardness, chemical oxygen demand also showed increase above WHO threshold limit in various sampling points. The study has revealed that the indiscriminate dumping and discharging of urban waste into the river especially from the abattoir, drainages, from homes, open dumps has a significant adverse effect on the concentration of some of the assayed physicochemical and microbiological water quality characteristics and this poses a threat for the local community and ecosystem at large. It is recommended that effective management and provision of waste management facilities in addition to enforcing legal framework and public enlightenment is urgently required to ameliorate its nuisance level on water, health and environment at large.

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INTRODUCTION

1.1 Background of the Study

Water is an indispensable environmental resource essential to the existence and sustenance of life. Without water, manôs existence on the earth would be threatened and he would be driven close to extinction. All biological organisms depend on water to carry out complex biochemical processes which aid in the sustenance of life on earth. Though water covers about 70 percent of the earthôs surface, only 3 percent is fresh water while the remaining is salt water (UNESCO, 2003). The World Water Council also records that of the 3 percent of fresh water, only 0.3 percent is found in rivers and lakes available as fresh water that humans can use, the rest being frozen as glaciers and ice caps (World Water Council, 2005). This suggests that man has a relatively low amount of fresh water resources with which he can carry out his activities.

Global freshwater consumption rose six-fold between 1900 and 1995 ï at more than twice the rate of population growth (GEO-2000; UNEP, 1999). Yet for many of the worldôs developing countries, one of the greatest environmental threats to health remains lack of access to safe water and sanitation. Over 1 billion people globally lack access to safe drinking-water supplies, while 2.6 billion lack adequate sanitation; diseases related to unsafe water, sanitation and hygiene result in an estimated 1.7 million deaths every year (WHO, 2002). About one-third of the world's population live in countries with moderate to high water stress, and problems of water pollution and scarcity are increasing, partly due to ecosystem depletion and contamination. Two out of every three persons on the globe may be living in water stressed conditions by the year 2025, if present global consumption patterns continue (GEO-2000. UNEP, 1999).In view of this, the concept of water being an infinite resource is rapidly disappearing with steps being taken to ensure the conservation and responsible use of water. Efforts made by governments especially in Eastern Asia over the past twenty years have greatly improved the water status of these nations. This gives a lead that a comprehensive and proper approach to the management and use of water will contribute to the conservation of the resource and can be a critical factor in the integration of the three substituent of sustainable development; economic development, social development and environmental protection.

According to UNESCO (2003), some 2 million tons of waste per day are disposed off within receiving waters, including industrial wastes and chemicals, human waste and agricultural wastes such as fertilizers, pesticides and pesticide residues. Freshwater resources all over the world are threatened not only by over exploitation and poor management but also by ecological degradation. Industrial growth, rapid urbanization and the increasing use of synthetic organic substances have serious and adverse impacts on freshwater bodies. Water ecosystems both replenish and purify water resources essential to human health and well-being. But the sustainability of many such ecosystems has been impacted by development, land use changes, contamination by waste and discharges from industry and transport, as well as from household and human waste. The increasing concern about the environment in which man lives and rivers have always provided a focus of attention for environmental studies (Petts, 1983). An acceptable water quality is therefore crucial in order that man can benefit from rivers by a series of uses Oliveira, (2006).

Water quality refers to the chemical, physical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact and drinking water. When the quality of water is impaired however, a lot of problems arise. A 1971 United Nations report defines water pollution as the introduction by man, directly or indirectly, of substances or energy into the water environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities, including fishing, impairment of quality of rivers or seas for use as amenities. The impairment of water quality can be caused by point or non-point sources(Akhionbare, 2009).

As the earth's population continues to grow, people are putting on increasing pressure on the planet's water resources. Our rivers and other inland waters are being ñsqueezedò by human activities, not only that they are over exploited, but their quality is reduced. According to Akaninwor, (2007) pollution of fresh water bodies in our urban society such as rivers, streams, lakes and ponds is mostly experienced as a result of indiscriminate and uncontrolled discharge of wastes by industries, careless municipal waste disposal, sewage, and surface runoff which impact negatively on river ecosystems and human health (Odukuma and Okpokwasili, 1993; Kinnersley, 1994; Benka-Coker and Ojior, 1995; Nwachukwu and Otukunefor, 2003; Ubalua and Ezeronye, 2005).

Rivers are potential sources for fresh water flow through major cities and towns of the world. Urban areas provide the economic resources to install water supply and sanitation systems but they also concentrate waste. In Nigeria, one of the greatest challenges of environmental managers, hydrologists, and water resourceanalysts has been the problem of surface water pollution. Where good waste management is lacking, urban areas are among the worldôs most life threatening environments (UNESCO, 2003). Accelerated urbanization, domestic and industrial activities have greatly contributed to increasing scale of pollution of rivers and other water bodies (Ibeh and Mbah, 2007).

Recent researchesshowed that surface waters in some parts of Nigeria are heavily loaded with wastes resulting from human activities. It is estimated that each Nigerian generate about 0.85kg of waste per day totalling about 119 million tons of municipal and industrial waste per annum (Cookey, 2008). The problem of how to manage these wastes is reaching critical proportion. In the recent past, the present democratic government has gone extra mile to invest in the services of waste management especially in urban areas, which has lead to quantum improvements in the level of urban cleanliness. But unfortunately haphazardly located solid waste dumps keep on emergingand proliferating at different parts of the urban landscape without careful consideration of environmental and public health Nkwocha*et al*,(2011). Also of great concern are residential and industrial establishments being situated along waterways which take advantage of rapid urbanization and institutional failures to channel waste into rivers. The effect of these waste loads can be easily seen in changes in the physicochemical and biological parameters or indicators of water quality. For instance, increase in organic load indicated by Biochemical oxygen demand (BOD) values, dissolved and suspended solids, temperature, metallic contents, among others are all indicators of pollution of water ways.

Enugu, like most other urban centres of the developing world is experiencing rapid and uncontrolled population growth which has not been accompanied by an increase in the delivery of essential urban services such as water supply, sewage and sanitation, and collection and disposal of solid wastes but rather typified by poor planning,inadequate amenities and poor sanitation. This has created waste management problems for the city as evidenced by heaps of open dumps as well as domestic and trade wastes easily noticeable at every refuse collection point. Many residents, markets and industries see available streams as veritable safe places to dump their refuse. During rainy season, flood carries the refuse from dumpsites into river courses thereby increasing the deterioration. These streams equally serve the residents as sources of water because town water supply is inefficient and only very few homes have portable water supply.

Mmiriocha River in Abakpa provides alternative source of water supply to the residents and also serves as a receptacle for some of these wastes. As surface water in a developing country, it may be predisposed to pollution due to high population growth and indiscriminate disposal of wastes into the river and along its channel which generates concern about the ecological integrity of the river as well as the quality of the river water and human health.Mmiriocha River serves the economic, domestic and agricultural needs of local population living close to the river. Peasant farmers use water from the river to irrigate their farms. Vegetables and other seasonable crops are planted on its banks, making farming an all year round activity for people living near its banks. The present study on the physiochemical and microbiological parameters will therefore show the status of the river with its pollutant characteristics and a step forward in addressing the effect and deteriorating conditions of it with a view to recommend concretemeasures to enforce good policies for protection, sustainable use and management.

1.2 Statement of Problem

Abakpa area of Enugu has over the years experienced uncontrolled population growth and urbanization and this has raised a serious concern and challenge on urban waste disposal and management facilities and practices. Mmiriocha River which runs through Abakpa is potentially vulnerable to variouspoint and non-point sources of pollution which would likely degrade the water quality. All through its course especially during rainy season, there is a steady input of large volumes of detergents from laundry activities, runoff carrying agricultural wastes, raw sewage and solid wastes from domestic and municipals through drains and pipes, chemicals from automobile workshops, abattoir wastes and from improperly designed and sited waste dumps in close proximity to the streamand these could impair the quality and aesthetic of the river. Settlementsdownstream that depend heavily on the river water for domestic activities might be forced to look for more expensive alternatives especially as they are not fitted with efficient pipe borne water.

These resulting environmental ills raise questions on the extreme health hazards, compounded by the institutional and environmental policy failure of the Enugu State Waste Management Authority to efficiently manage wastes generated within the area which can degrade the quality of the river as it flows through the community. The study therefore will create awareness to the public on the effect of indiscriminate disposal of urban wastes into Mmiriocha River and the need for considerable improvement on effective sustainable waste and water management and also stimulate an improved attitude by the public and appropriate authorities concerned.

1.3 Aim and Objectives of the Study

The aim of this study is to examinethe effect ofurban waste disposal on the quality of Mmiriocha River. This will be achieved by pursuing the following objectives:

I. To identify the point and non-point sources of urban waste pollution ofMmiriocha River.
II. To determine the concentration level of pollutants in Mmiriocha River by urban waste using selected physicochemical and bacteriological water quality parameter.
III. To compare the concentration level of water quality parameters of Mmiriocha Riverwith the set limit of regulatory bodies such as WHOwater quality standards.

IV. To evaluate the effect of indiscriminate urban waste disposal on Mmiriocha River.

V. To provide recommendation for appropriate and effective water and urban waste management strategiesto safeguard human health and ecological integrity of the river.

1.4 Relevant Research Questions

I. What are the point and non-point sources of urban waste disposal into the river?

II. What is the concentration level of pollutants in Mmiriocha River by urban waste using select physicochemical and bacteriological water quality parameters?

III. Does the concentration level of water quality parameters of Mmiriocha River differ from the set limit by bodies such as WHO?

IV. What is the effect of indiscriminate urban waste disposal to the river water quality?

V. What relevant recommendation will be appropriate for effective water and urban waste management in safeguarding human health and ecological integrity?

1.5 Statement of Hypothesis

I. H_0: There is no significant difference between the concentration level of the physicochemical and biological water quality parameters of the river water samples in the study area and the WHO standard.

II. H_0: There is no significant difference in the concentration level of river water samples amongst the four sample point considered in the study area.

1.6 Scope of the Study

Urban wastes within the scope of this study means wastes generated by any activity in urban or peri-urban areas which includes domestic and commercial wastes from open dumps, homes, market, restaurants, abattoir, automobile workshops, runoff from farmlands and sewage discharge from drains and pipes. Hazardous and special wastes are not considered in this study.The study would involve the collection and laboratory analysis of water samples from the Mmiriocha River. It will also analyze and evaluate the various sources of urban waste discharged into the water body and the select physicochemical and biological water quality parameters taking into consideration rainy season alone. The analysis and evaluation will be achieved through results obtained from laboratory analysis to provide strategies for urban waste management.

1.7 Limitations

- Restriction placed on some relevant journals, articles and books found in the internet and information by relevant ministries which could be helpful in the progress of this work.
- Financial constraint due to project budget which may not permit inclusion of more parameter and sampling points for analysis.

1.8 Definition of Terms

Biological Oxygen Demand (BOD): This is the quantity of oxygen utilized by microorganisms in aerobic degradation of urban waste (organic matter) in the water body.

Environment: Combination of the natural, built environment and socio ecosystem.

Pathogens: Pathogens are disease causing organisms which grow and multiply into their hosts (human and animals) considering pathogens in water.

Point Source Pollution: This occurs when harmful substances are discharged directly into a body of water. The source of pollution is well defined.

Water Pollution: Is the contamination of water in such a manner as to cause real or potential harm to human health or wellbeing or damage to human nature without justification.

River: This is anybody of fresh water flowing from an upland source to a large lake or sea, fed by such sources as springs and tributary streams.

Sediments: Minerals or organic matter deposited by water, air or ice matter which settles to the bottom of the liquid.

Streams: Small River; a narrow or shallow river with a constant flow of liquid or water current.

Urban Runoff: Is the water that comes from human activities such as from domestic cleanings, drainage etc.

Urban wastes: This means waste generated by any activity in urban or peri-urban areas, such as garbage and rubbish materials from homes, restaurants, commercial establishments, sewage, abattoir, open dumps etc.

Water Quality Assessment: The examination of water samples to determine their physical, chemical and microbiological characteristics and their comparison with WHO, NESREA and NAFDAC.

Water Quality Standard: An objective that is recognized in enforceable environmental control laws or regulations by a level of government

WHO: World Health Organization.

CHAPTER TWO

THEORITICAL FRAMEWORK

2.1 Basic Concepts

Theories can be considered milestones of scientific development and are usually introduced when previous study of a class of phenomena has revealed a system of uniformities. Theory will always be thought of as formulated within a linguistic framework of a clear specified continuous logical structure, which determines, in particular, the rules of deductive inference. (Hempel, 1965)

Watershed*:*A watershed is the boundary of highland from which runoff (from rain, snow, and springs) drains to a stream, river, lake, or other body of water. Its boundaries can be identified by locating the highest points of lands around the water body. Streams and rivers function as the "arteries" of the watershed. They drain water from the land as they flow from higher to lower elevations. Using the watershed survey approach, enables you become familiar with their watershed's boundaries, its hydrologic features, and the human uses of land and water that might be affecting the quality of the streams within it.

The River System: As streams flow downhill and meet other streams in the watershed, a branching network are formed. When observed from the plan this network resembles a tree. The trunk of the tree is represented by the largest river that flows into the ocean or large lake. The "topmost" branches are the headwater streams. This network of flowing water from the headwater streams to the mouth of the largest river is called the river system.Water resource professionals have developed a simple method of categorizing the streams in the river system. Streams that have no tributaries flowing into them are called first-order streams. Streams that receive only first-order streams are called second-order streams. When two second-order streams meet, the combined flow becomes a third-order stream, and so on.

Water Cycle: The water cycle is the movement of water through the environment. It is through this movement that water in the river system is replenished. When precipitation falls to earth in a natural (undeveloped) watershed, for example, in the mid-Atlantic states about 40 percent will be returned to the atmosphere by evaporation or transpiration (loss of water vapour by plants). About 50 percent will percolate into stream channel, the ground water is discharged into the stream as spring. The combination of ground water discharges to a stream is defined as its base flow. At times when there is no surface runoff, the entire flow of a stream might actually be base flow from ground water. Some streams, on the other hand, constantly lose water to the ground water. This occurs when the water table is below the bottom of the stream channel. Stream water percolates down through the soil until it reaches the zone of saturation. Other streams alternate between losing and gaining water as the water table moves up and down according to the seasonal conditions or plumage by area wells.

The interactions between the watershed, soils, and water cycle define the natural water flow (hydrology) of any particular stream. Most significant is the fact that developed land is more impervious than natural land. Instead of percolating into the ground, rain hits the hard surfaces of buildings, pavement, and compacted ground and runs off into a storm drain or other artificial structure designed to move water quickly away from developed areas and into a natural watercourse. Surface runoff increases and ground water recharge decreases as watersheds become developed. These conditions typically change the fate of precipitation in the water cycle.

2.2 The Living Stream Environment

A healthy stream is a busy place. Wildlife and birds find shelter and food near and in its waters. Vegetation grows along its banks, shading the stream, slowing its flow in rainstorms, filtering pollutants before they enter the stream, and sheltering animals. Within the stream itself are fish and a myriad of insects and other tiny creatures with very particular needs. For example, stream dwellers need dissolved oxygen to breathe; rocks, overhanging tree limbs, logs, and roots for shelter; vegetation and other tiny animals to eat; and special places to breed and hatch their young. For many of these activities, they might also need water of specific velocity, depth, and temperature. Human activities shape and alter many of these stream characteristics. We dam up, straighten, divert, dredge, dewater, and discharge wastes to streams. We build roads, parking lots, homes, offices, golf courses, and factories in the watershed. We farm, mine, cut down trees, and graze our livestock in and along stream edges. We also swim, fish, and canoe in the streams themselves.These activities can dramatically affect the many components of the living stream environment.

Whether streams are active, fast moving, shady, cold, and clear or deep, slow moving, muddy, and warm--or something in between--they are shaped by the land they flow through and by what we do to that land. For example, vegetation in the stream's riparian zone protects and serves as a buffer for the stream's streamside cover, which in turn shades and enriches (by dropping leaves and other organic material) the water in the stream channel. Furthermore, the riparian zone helps maintain the stability of the stream bank by binding soils through root systems and helps control erosion and prevent excessive siltation of the stream's substrate. If human activities begin to degrade the stream's riparian zone, each of these stream components--and the aquatic insects, fish, and plants that inhabit them also begins to be affected adversely

2.3 Water Quality and Pollution

The concept of water resources is multidimensional. It is not limited only to its physical measure (hydrological and hydro-geological), the ‗flows and stocks', but encompasses other more qualitative, environmental and socio-economic dimensions. Rivers supply our drinking water; irrigate our crops; power our cities with hydroelectricity; support fish and other aquatic species; and provide countless recreational and commercial opportunities. Small streams (such as headwater streams) and their associated wetlands are equally important. These streams, including streams and wetlands that do not have water year round, play a key role in providing critical habitat, food and shelter for waterfowl, fish, and other aquatic species. They also mitigate damage from floods, provide sources of drinking water, filter pollutants, and support economically important local and downstream recreational and commercial uses. Not surprisingly, the condition of the nationȏs rivers, streams, and wetlands varies widely. Cities and town, farmlands, urban wastes, mines, factories, sewage treatment facilities, dams, and many human activities on the land have significant impacts on the quality of our waters.

Understanding the condition of rivers, streams, and wetlands is critical if we are to develop effective plans to maintain, manage, and restore them. The water in a stream is always moving and mixing, both from top to bottom and from one side of the stream to the other. Pollutants that enter the stream travel some distance before they are thoroughly mixed throughout the flow. For example, water upstream of a pipe discharging wastewater might be clean. At the discharge site and immediately downstream, the water might be extremely degraded. Further downstream, in the recovery zone, overall quality might improve as pollutants are diluted with more water. Far downstream the stream as a whole might be relatively clean again. Unfortunately, most streams with one source of pollution often are affected by many others as well.

Water Pollution is broadly divided into two classes according to its source. Point source pollution comes from a clearly identifiable point such as a pipe which discharges directly into a water body. Examples of point sources include factories, wastewater treatment plants, and illegal straight pipes from homes and boats.Nonpoint source pollution comes from unidentifiable sources. It originates from a broad area and thus can be difficult to identify. Examples of nonpoint sources include agricultural runoff, mine drainage, construction site runoff, and runoff from city streets and parking lots. More impacts are caused by sediments and silt from eroded land and nutrients such as the nitrogen and phosphorus found in fertilizers, detergents, and sewage treatment plant discharges. (Akhionbare, 2009).

Common sources of pollution to streams include:

- ***Agricultural activities***such as crop production, cattle grazing, and maintaining livestock in holding areas or feedlots. These contribute pollutants such as sediments, nutrients, pesticides, herbicides, pathogens, and organic enrichment.
- ***Municipal dischargers*** such as sewage treatment plants which contribute nutrients, pathogens, organic enrichment, and toxicants.
- ***Urban runoff*** from city streets, parking lots, sidewalks, storm sewers, lawns, golf courses, and building sites. Common pollutants include sediments, nutrients, oxygen-demanding substances, road salts, heavy metals, petroleum products, and pathogens.

Other commonly reported sources of pollutants are mining, industrial dischargers (factories), forestry activities, and modifications to stream habitat and hydrology. Differences in water quality may be significant locally but are difficult to aggregate in a meaningful way at national level. In addition, water quality must be expressed not only in terms of physical, biological and chemical variables, but also according to quality standards that vary according to use.

Funding from government and other donor institutions is not able to meet the budgetary needs of government departments and agencies due to rapid increase in population growth causing institutional failures. This makes it difficult to enforce bye-laws on environmental protection and sanitation, build sewage systems and monitor river water quality. The increasing numbers of people living in the river basin triggers an increase in demand for sanitation and waste management services. The mismatch between sanitation infrastructure and population growth affords some residents the advantage to dump rubbish as well as domestic waste into the Mmiriocha River. The interplay of rapid population growth, institutional failure and industrial activity significantly yield a variety of behavioral patterns of residents which lead to the pollution of Mmiriocha River. These behavioral patterns include the indiscriminate dumping of refuse into the river, channeling of raw sewage into the river, open defecation into or along the banks of the river and the dumping of industrial waste into the river which has far reaching implications for persons living in the river basin as well as communities downstream. One of the far reaching implications is that of health.

2.4 Industrial Ecology and Waste Management

The Theory of Waste Management is a unified body of knowledge about waste and waste management, and it is founded on the expectation that waste management is to prevent waste to cause harm to human health and the environment and promote resource use optimization. Waste Management Theory is to be constructed under the paradigm of Industrial Ecology as Industrial Ecology is equally adaptable to incorporate waste minimization and/or resource use optimization goals and values. Industrial Ecology, as applied in manufacturing, involves the design of industrial processes and products from the dual perspectives of product competitiveness and environmental interactions. A systems-oriented vision, built on the principle that industrial design and manufacturing processes are to be considered in partnership with the environment, is what sustainable waste management needs to grow into (Graedel& Allenby 1995).

On the plane of waste management,ò WMT seeks to optimise resources use from virgin raw material, to discard. The goals, values for resources optimization originate from the paradigm of Industrial Ecology. It was argued that the goals in IE have to be adapted by WMT and to translate the goals of IE so that they are applicable to an industrial unit (Pongrácz, 2004). To be able to adopt the most appropriate waste management system, a proper theoretical background has to be established. It can be asserted that when one is looking for a scientific systematization, and ultimately aiming at establishing an explanatory and predictive order among the domain problems of waste management, a theory is required. The Theory of Waste Management is based on the considerations that waste management is to prevent waste causing harm to human health and the environment, and application of waste management leads to conservation of resources such as water. However, Industrial Ecology successfully combines waste minimization and resources use optimization measures, and ensure that resources are effectively circulated within ecosystems.

2.5 Integrated Water Resource Management

Integrated Water Resource Management (IWRM) is an empirical concept which was built up from the on-the-ground experience of practitioners. Although many parts of the concept have been around for several decades - in fact since the first global water conference in Mar del Plata in 1977 - it was not until after Agenda 21 and the World Summit on Sustainable Development in 1992 in Rio that the concept was made the object of extensive discussions as to what it means in practice. The Global Water Partnership's definition of IWRM is widely accepted. It states: 'IWRM is a process which promotes the co-ordinate development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.' Water is a key driver of economic and social development while it also has a basic function in maintaining the integrity of the natural environment. However water is only one of a number of vital natural resources and it is imperative that water issues are not considered in isolation. In addition to problems of water quantity there are also problems of water quality. Pollution of water sources is posing major problems for water users as well as for maintaining natural ecosystems.

In many regions the availability of water in both quantity and quality is being severely affected by climate variability and climate change, with more or less precipitation in different regions and more extreme weather events. In many regions, too, demand is increasing as a result of population growth and other demographic changes (in particular urbanization) and agricultural and industrial expansion following changes in consumption and production patterns. As a result some regions are now in a perpetual state of demand outstripping supply and in many more regions that is the case at critical times of the year or in years of low water availability. Managers, whether in the government or private sectors, have to make difficult decisions on water allocation. More and more they have to apportion diminishing supplies between ever-increasing demands. Drivers such as demographic and climatic changes further increase the stress on water resources. The traditional fragmented approach is no longer viable and a more holistic approach to water management is essential. This is the rationale for the Integrated Water Resources Management (IWRM) approach that has now been accepted internationally as the way forward for efficient, equitable and sustainable development and management of the world's limited water resources and for coping with conflicting demands.

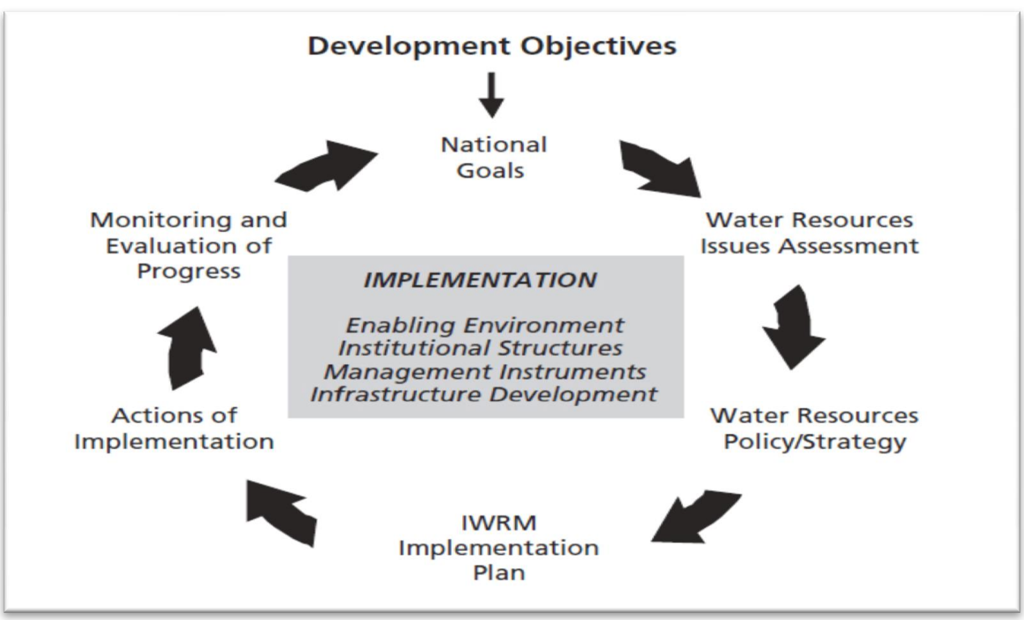


Fig 2.1: Stages in IWRM planning and implementation

There are great differences in water availability from region to region - from the extremes of deserts to tropical forests. In addition there is variability of supply through time as a result both of seasonal variation and inter-annual variation. All too often the magnitude of variability and the timing and duration of periods of high and low supply are not predictable; this equates to unreliability of the resource which poses great challenges to water managers in particular and to societies as a whole. Most developed countries have, in large measure, artificially overcome natural variability by supply-side infrastructure to assure reliable supply and reduce risks, albeit at high cost and often with negative impacts on the environment and sometimes on human health and livelihoods. Many less developed countries, and some developed countries, are now finding that supply-side solutions alone are not adequate to address the ever increasing demands from demographic, economic and climatic pressures; waste-water treatment, water recycling and demand management measures are being introduced to counter the challenges of inadequate supply.

2.6 The Concept of Sustainability in Water Resources Management.

Sustainability is a concept that describes a dynamic condition of complex systems, particularly the biosphere of Earth and the human socioeconomic systems within it. It reflects both our fundamental values and our knowledge of the fundamental nature of life on Earth. A fundamental basis for the concept is the recognition in biology and ecology that sustainability is a result of the underlying organization of life in Earthôs biosphere which has endured for over 3 billion years. Ecology has also provided a concept of sustainability that is somewhat more applicable to the human situationð the notion of carrying capacity. The population of a given species must of necessity ñlive within the carrying capacityò afforded it by the ecosystem of which it is part. That carrying capacity results from the flows of food, water, light, and shelter needed by the individuals of the species. These flows are provided by processes that are cyclical and renewable.

In the history of human kind, water management (coping with the availability or unavailability of water resources) has been essential to humanôs strategy for survival and well-being. With growing human population, human development and industrialization among other issues, the concept of sustainable development has emerged. Sustainable development simply put, is development that meets present needs without undermining the ability of future generations to meet their own needs. The need for sustainable development is buttressed with growing human population, scarce resources and unlimited and diverse human wants, it ties together the concern for the carrying capacity of natural systems with human social challenges. The United Nations 2005 world summit outcome document identified the interdependent and mutually reinforcing pillars of sustainable development as economic development, social development and environmental protection (Figure 2).

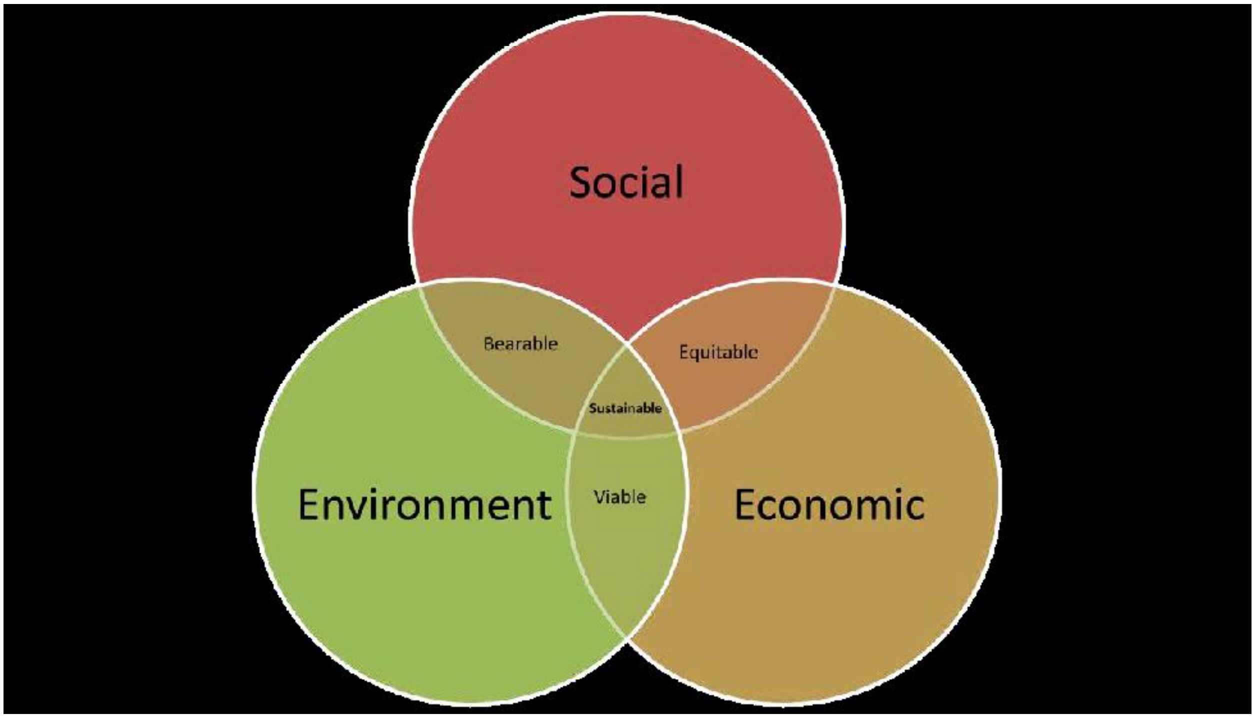


Figure 2.2: Scheme of sustainable development at the confluence of three constituents.

Source: Adams, WM (2006)

Sustainable development therefore has to be economically viable, socially equitable and environmentally bearable. Though historically regarded as an infinite resource the perception of water has changed in recent times as population growth, economic expansion and climate change among other factors have accelerated and intensified the use and abuse of water creating an imbalance between water availability and water demand. This document is an attempt to present water as a viable tool for sustainable development.

Water represents the origin of life and a key component of life sustenance. Climate changes, population growth, human development among other factors have put stress on the earthǿs vast water resource and has brought about the need for development that can be sustained. Water represents a global human need irrespective of race, religion or gender and if properly enhanced and well managed, water can play a pivotal role in sustainable development.

According to Thomas Jefferson, September 6th, 1789… then i say the earth belongs to each generation during its course, fully and in its right no generation can contract debts greater than maybe paid during the course of its existence. Much effort has been devoted to identifying and promoting actions that are consistent with the principles of sustainable development. This effort is as important for water resources management as it is for any other sector. In fact, the example set for humanity by the biosphereȇs achievement of sustainability shows us that it is a condition achieved through an ongoing process of adaptation and evolution. Thus, to achieve sustainability over the long run, we need to strengthen our capacity for making continual improvements in human activities, adapting them to fit the biosphere as it changes. We need to be able to identify what is working and what is not so that we can repeat and extend our successes and solve the problems revealed by our failures.

CHAPTER THREE

LITERATURE REVIEW

3.1 Pollution and Waste

The utilization of natural resources in manôs environment to meet his needs results in generation of waste and pollution of the environment. Waste in industrial and consumptive processes must be disposed of. The improper disposal of waste results in the ópollutionô of manôs environment which threatens the sustenance of life on earth. This threat is on the increase and has attracted and received attention in recent times.

Dix, (1981) defines pollution as the deliberate or accidental contamination of the environment with manôs waste and in tracing the roots of pollution, he provides us with an idea as to how pollution emerged into manôs spatial environment. He maintains that ópollutionô must have started at a time when man began to use the natural resources of the environment for his own benefit. As he began to develop a settled life in small communities, the activities of clearing trees, building shelters, cultivating crops, and preparing and cooking food which all lead to waste generation must have altered the natural environment. Later, as the human population increased and became concentrated into larger communities which developed craft skills, there were increasing quantities of human and animal waste and rubbish to be disposed of. In the early days of manôs existence the amount of waste was small. It was disposed of locally and had virtually no effect upon the environment. Later, when larger human settlements and towns were established, waste disposal began to cause obvious pollution of streets and water courses.

Adenyinka and Rim-Rukeh, (1999) indicated that at concentrations where wastes or contaminants become dangerous to human health and ecological balance and are culturally offensive, it is labelled pollution. Pollution ultimately makes good quality water increasingly scarce by leaving less volume of flow suitable for use. Pollution may be accidental and sometimes with grave consequences, but most often it is caused by uncontrolled disposal of sewage and other liquid and domestic wastes from homes. Industrial wastes containing a variety of pollutants, agricultural effluents from animal husbandry, drainage of navigation water and urban runoff are other sources of water pollution. Pollution as a result of improper waste disposal ends up reducing the quality of air, water, or land from which man draws resources. Of particular concern to this research is water quality and examples of water resources are rivers, lakes, lagoons, streams, ground water and estuaries. A river may be said to be polluted when it is altered in composition or condition, directly or indirectly as a result of the activities of man, so that it is less suitable for all or any of the purposes for which it would be suitable in its natural state. Meybeck, (1996) however maintains that the concept of pollution is relative in that it reflects a change from some reference value to particular values that causes problems for human use. With reference to water pollution, no reference value exists because of the high variability in the chemical quality of natural waters.

Waste generally is defined as useless, unwanted or discarded material resulting from municipal, agricultural, commercial, communal and industrial activities. Waste includes solids, liquids and gases. On the other hand, one personṡ waste can be a source of income - a resource - for another. This potential for recycling and reuse can support people by buying, collecting, sorting, selling and recycling waste. Unfortunately, not all waste can be regarded as a resource such as many hazardous and toxic materials which cannot be safely recycled or reused.Atuegbu (2007) reports that between 500 and 850 metric tons of waste is generated daily in Enugu city. Also,Uwadiegwu and Chukwu, (2014) identified that the rate of waste generation in Abakpa is so high that in one night, a refuse dump site that was cleared the previous day could be replaced with an equal volume of waste the following morning, thus creating the erroneous impression that it was never clearedbefore. Urban waste means the waste generated by any activity in urban or peri-urban areas. This implies that urban waste is not only that generated in households, but also that from commercial establishments and services, street sweeping, green areas and industry (Akhionbare, 2009). The improper and ineffective disposal and management of these waste constitutes environmental nuisance leading to pollution.

Waste is usually generated by the following variety of sources:

- **Households.** Household waste or domestic waste is the waste generated by households. It must be discerned from municipal solid waste, which is the waste collected by the municipal collection systems.

- **Commercial Establishments.** It includes waste from shops and other service providers (restaurants, etc.) and it is essentially composed of packaging waste and organic waste from markets and restaurants.
- **Institutions**(schools, hospitals and government offices). This kind of waste includes wastes from public and private offices and institutions which belong to the so-called service sector. The amount of waste and the composition are often not very well known. Although similar to household waste, some extra fractions of paper, medical hazardous waste, glass and plastics can be expected.
- **Factories.**It is the waste from industrial production, including related functions like canteens, administration, etc. This category of waste can be split into various fractions depending on the main industries in the city concerned. They often contain a fraction of hazardous waste that has to be collected and treated separately.

The quantity and the rate of urban wastes generation in Nigeria have outgrown the capacity of nature to naturally absorb them. Its management generally suffers set back due to urbanization and rapid population growth, unwholesome waste disposal habits of the citizens as well as funding and sanitation laws enforcement impotency. Lack of advanced technology, facility for separation at source, strength of solid waste management policy and enforcement, environmental education and awareness and income status of individuals among others, are factors affecting solid waste scenario in Nigeria. Abel (2009) showed that educational status, income status, occupation, age, gender, cost of waste collection services and the location of residence, among others, arefactors influencing solid waste generation and management in Nigeria.Open dump of solid waste is a common practice in Nigeria. While some directly dump their solid wastes by the road sides, some employ the service of streams to transport their solid wastes out of their sight. Though the level of awareness of waste collection services and waste management regulations are relatively high in Nigeria, there is still yet an observed increase in the percentage of those who use other indiscriminate solid waste disposal methods which lead to river pollution and subsequently alter water quality for various defined purposes.

3.2 Water Pollution and Sources

In Nigeria, contamination of surface water sources is a major environmental issue that attracts a lot of interest because of the importance of water quality on human health and on environmental quality (Obeta and Ajaero 2010).Water bodies have become both resources for fresh water and receptacles for domestic and industrial wastes leading to ñwater pollutionò. According to Chapman (1996), ñPollution of the aquatic environment refers to the introduction by man, directly or indirectly, of substances or energy which results in such deleterious effects as harm to living resources, hazards to human health, hindrance to aquatic activities including fishing, impairment of water quality with respect to its use for domestic, agricultural, industrial and often economic activities, and reduction of amenities. According to National Bureau of Statistics (2009), at least 27% of Nigerians depend absolutely on streams, ponds, rivers and rainwater for their drinking water source.

Available literature on environmental monitoring of surface water indicated that streams and rivers in the country are showing increasing trend of water pollution due to increase population, intensive agriculture, industrialization and urbanization. Ude(2001) on highlighting the sources of pollution of these streams posited that most streams in Enugu urban drain some heavily ï fertilized agricultural land as well as some uncultivated land. Some of these rivers receive effluents from abattoir as well as kitchen wastes and septic tanks overflow from homes. In some places, streams are used as a ñnatural lavatoryò so that there are concentrations of human excrement. Livestock are regularly watered in streams; therefore animal faeces are common features. Since certain foods are washed in the water and people washing in the stream sometimes accidentally swallow some of water. Waste generations by the industries and households have continued to increase andare indiscriminately disposed-of into the water bodies. This has led to pollution of inland water bodies and coastal waters and thereby increasing concentration of water quality parameters such as heavy metals, nutrients and organic matter, soluble ions, oil and grease, and organic chemicals such as pesticides and poly-nuclear aromatic hydrocarbons (PAHs),(Solomon 2009).

River water pollution is broadly categorized into two sources namelypoint and non-point sources. Point sources discharge pollution from specific sources such as drain pipes, ditches, or sewer outfalls. Examples of point sources are factories, power plants, sewage treatment plants, underground coal mines and oil wells. Non-point sources or diffuse sources on the other hand have no specific sources from where they discharge into a principal body of water. Examples of non-point sources of pollution include run off from farm fields and feed lots, golf courses, lawns and gardens, construction sites logging areas, roads, streets and parking lots. Cunningham and Saigo(1999);Chapman (1996) assert that an important difference between a point source and a diffuse source is that a point source may be collected, treated or controlled. Non-point sources of pollution pose a major challenge to environmental management due to the diverse sources of pollution and multiple and often complicated pathways of pollutant transport.

3.3 Causes of River Pollution

Surface water pollution is a major environmental health challenge in many developing countries such as Nigeria and that it is mainly due to human activities resulting from rapid population growth and increased productive activities which lead to indiscriminate disposal of wastes into or along stream channels. It has attracted a lot of interest because of the importance of water quality on human health and on environmental quality (Uting*et al*., 2007; Ocheri*et al*., 2008 and Obeta and Ajaero, 2010) Anthropogenic factors such as agricultural development, population growth, urbanization, industrialization as well as market policy failures have been identified as the root causes of water pollution (UNEP, 2006).

3.3.1 Municipal and Agricultural Wastes

In most cases, sewage and waste water from homes are routed into the rivers and streams. Jaji*et al*. (2007) found elevated water quality parameters in some sampling locations of Ogun River. These were partly attributed to the activities of abattoir located close to the River at a notable market in Abeokuta metropolis. The work of Arimoro*et al*. (2007) on the impact of sawmill activities on the water quality of River Benin reported high BOD and low DO values at the discharge point of the wastes into the River. Trace metals, suspended solids, nutrients, heaps of solid wastes, pesticides, petroleum products, and E. coli and faecal coliform bacteria are generally found in higher concentrations in urbanized and urbanizing areas than in natural systems, due to increased numbers of people, vehicles, roads, and building materials introduced into the landscape and all these constitutes storm water runoff which is found to be a major source of pollution to surface water quality and groundwater resources.

ñAbattoir to waterò pollution is a great problem with common phenomenon across the country. Blood, faeces and related wastes from animal slaughter find their ways into gutters and the so called ñdrainage systemò, the final destinations are rivers, lakes, hand dug wells and reservoirs used by people as sources of household water. (Magaji et al., 2012) in his study on the impact of abattoir wastes on water quality discovered that most of the wastes are untreated and discharged directly into open drainage which flows into a nearby stream thereby contaminating it.Amadi et al., (2010) in the study of impact of anthropogenic activities on Otamiri and Oramiriukwa Rivers as a result of the increasing rate of urbanization in Owerri, used the application of Water Quality Index (WQI) in evaluating the quality of Otamiri and Oramiriukwa Rivers for public usage using the APHA standard methods of analysis. The overall WQI for the samples was high. The high concentration of conductivity, colour, total solids, turbidity, total coliform, iron, manganese, COD, BOD and nitrate were responsible for the high pollution value of WQI which may be attributed to the anthropogenic activities along the river bank. The results of the analysis when compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limit showed that the rivers were polluted and that the water is not safe for domestic use and would need treatment.

The eutrophication of surface water causes degradation of aquatic ecosystems and problems such as algal blooms, loss of oxygen, fish kills and loss of biodiversity. Apart from fertilizer application, sewage disposal from urban areas contribute significantly to nitrogen loadings in river systems leading to eutrophication. Taiwo (2010) has also observed high water quality parameters of a stream in Abeokuta due to direct discharge of poultry wastes into the stream. However, agriculture remains the major source of nitrate and phosphate pollution of surface water.

3.3.2 Population Growth, Urbanization and Urban Run-Off

In the last few decades, there has been a tremendous increase in the demand for water due to rapid growth of population and the accelerated pace of industrialization and urbanization and this havesignificant roles in contributing to urban waste generation and water pollution. An increase in population growth leads to an increase in the demand for housing and an increase in the generation of heaps of waste everywhere.Leslie, (2010) in his study identified rapid population growth, institutional failures and industrial activities as remote anthropogenic causes of pollution of Aboabo River through waste generation. The main anthropogenic causes were identified as indiscriminate dumping of refuse, channeling of raw sewage, open defecation, discharge of untreated effluents and dumping of industrial waste into the River. This has reduced the water quality and yields a significant health effect to the people living in the river basin. Also a recent study of the Nworie and Otamiri rivers in Imo State, Nigeria showed a strong relationship between nitrate concentration and urbanization. As urbanization increased, so did the nitrate concentration of the rivers and this was attributed to surface water flow from farm lands, recreational areas, industrial effluents and the indiscriminate disposal of solid waste into the rivers. Potential sources of these nitrates were identified as being the use of soaps, detergents and agricultural fertilizers (Ibe and Njemanze, 2008).

During rainfall, some of these wastes from houses, farmland, dumpsites etc., are washed into the poor drainage systems and subsequently, into nearby rivers (Taiwo et al. 2011). Poor or implementation of town planning principles, strategies and poorly managed drainage system in Nigeriaὂs cities and towns had aggravated the risks of urban run-off with resultant effect on surface water impairment due to erosions during rainfall. The effect of urban run-off has been studied on the Epie Creek in the Niger Delta by Izonfuo and Bariweni (2001). The impact of human activities around the Creek was felt on the water body as low DO values were recorded during the wet season due to urban run-off.

The work of Mustapha (2008) had linked the periodic eutrophication of OyunReservoir in Offa, Kwara state to run-off of phosphate fertilizers from nearby farms in addition to cow dungs washing from the watershed into the Reservoir. Akubugwo et al., (2011) analysed the effect of human activities on physicochemical parameters and microbiological quality of Otamiri river and discovered that though all the metals and most physicochemical parameters investigated fall below the WHO accepted standards indicating that the river is not heavily polluted, the observed fluctuation of the investigated parameters along the sampling points could be as a result of human activities such as farming, bathing, discharge of waste water etc. Water pollution through surface run-off has been reported in literatures with subsequent effects on nutrient enrichment, water quality impairment, marine lives spawning ground destruction and fish kill.

3.3.3 Institutional and policy failures

The laws prohibiting the indiscriminate dumping of refuse or pollution of rivers in Nigeria in particular exist but the enforcement of these laws proves difficult. Omane (2002) asserts that water pollution still persists perhaps due to the fact that these laws were varied and each narrowed towards particular purposes other than pollution prevention. In some areas in less developed countries, toilets, latrines or proper drains are non-existent or have broken down. Wastes are disposed of near or in the same river, lakes or wells used for drinking and food preparation (Kaufman and Franz, 1996). In addition, these laws were fragmented under so many governmental departments and they were too many, too weak. In the case of Kumasi in Ghana, Obuobie*et al*., (2006) indicate that many people attribute the increasing water pollution in the Kumasi metropolis to the failure of Kumasi Municipal Authority (KMA) to collect, treat and dispose of waste water efficiently. In addition, government institutions like hospitals and learning institutions contribute to water pollution, making the prosecution of individuals, private and public institutions a farce.Most houses, public offices, and schools do not have toilets causing individuals to excrete anyhow in the bushes, rivers and open spaces and is a pointer to the fact the Nigerian environment has been deteriorated. This is in addition to the poor sanitation culture exhibited by Nigerian populace in urban waste disposal.

3.3.4 Natural Factors

Although the major proportion of all water quality degradation world-wide is due to anthropogenic influences, it is by no means the only cause. Natural events such as hurricanes, mudflows, torrential rainfalls and unseasonal lake outbursts do cause water quality degradation. Some natural events are, however caused by human activities, such as soil erosion associated with heavy rainfall in deforested regions. Letterman (1999) also argues that natural factors such as climate, watershed characteristics, nutrients and wild fires could have significant impacts on water quality. Periods of heavy precipitationcan re-suspend bottom sediments, debris and increase turbidity, microbial loading, affect colour, metals and other contaminants. Dry conditions could also increase the impact of point-source discharges by reducing the effect of dilution by the source.

Topography, vegetation and wildlife are factors that affect the quality of water bodies. Vegetation could have an effect on water quality by serving as a natural filter for run-off of non-point source contaminants. The subsurface geology also determines ground as well as surface water quality. Robbins *et al*., (1991) asserted that weathering characteristics of local geology could have an effect on erosion rates. Wildfires can destroy vegetative cover and increase the potential for erosion. Wildfires also increase peak flows, sediment, turbidity, stream temperature and nutrients. Letterman, (1999).

3.4 Water Quality

With rapid urbanization, population growth, wealth and economic activities generally, there is a corresponding increase in the demand for water supply globally. Water quality refers to the overall quality of the aquatic environment (Chapman, 1996). Water pollution affects water quality. It is estimated that currently in Nigeria, only about 50% of the urban and 20% of the semi-urban population have access to reliable water supply of acceptable quality (i.e. something better than a traditional source). Overall effective urban water supply coverage may be as low as 30% of the total population due to poor maintenance and unreliability of supplies. Rural coverage is estimated at 35% (FGN,2000)

The importance of the provision of potable water supply in any nation cannot be over emphasized. Studies on water quality in the aquatic environment are still popular in the evaluation and management of river ecosystems in many countries (Njenga, 2004). River water quality monitoring is necessary in our present day society, especially for rivers affected by urban waste. This is due to the changes in water chemistry of river and drainages which can be the results of domestic, industrial or agricultural discharges which may in turn lead to aquatic ecosystem degradation (Pereira, 2007).

The description of the quality of the aquatic environment can be carried out through a variety of ways. It can be achieved through quantitative measurements such as physico-chemical determinations (in the water, particulate material, or biological tissues) and biochemical/biological tests (BOD measurement, toxicity tests) or through semi-quantitative and qualitative descriptions such as biotic indices, visual aspects, species inventories, odour, etc. The quality of freshwater at any point on a landscape reflects the combined effects of many processes along water pathways and both quantity and quality of water are affected by human activity on all spatial scales.Ololade(2009) investigated The impact of indiscriminate dumping of waste, particularly household wastes within certain locality in Ondo State, in the western part of Nigeria and the effect on the quality of surface and underground water. The result showed that surface water recorded threatening values of health concern especially in Pb, Ni, and Cd and almost all the samples analysed exceeded the WHO and Federal Ministry of Environment (FMENV) limits. Therefore, it becomes imperative to regularly monitor the quality of the water by determining the physicochemical and bacteriological parameters of the water samples which can act as indicators of water pollution due to both natural and anthropogenic inputs and to device ways and means to protect it.

3.5 Features of Water Quality

The principal features of water quality in streams, rivers and lakes with which water engineers are most concerned are categorized into three main groups- Physical, Chemical and Biological (Shaw, 1994).

Solids form the most common matter to be carried along by a flowing river. These solids could be from organic or inorganic sources. Examples include refuse, tree barks, tree trunks, silt, and boulders. When evaluating water quality, suspended solids (SS) are measured in mg l^{-1}. Color, taste and odor are properties that are subjectively determined. They are caused by dissolved impurities either from natural sources or from the discharge of noxious substances like excreta, oil, bathwater into the water course by man (Shaw, 1994). Turbidity refers to the cloudiness of water due to fine suspended colloidal particles of clay or silt, waste effluents or microorganisms and is measured in turbidity units (NTU). Electrical conductivity (EC) is a physical property of water which is dependent on the level of dissolved salts. It is measured in micro Siemens per centimeter ($\varepsilon S\ cm^{-1}$) and it gives a good estimate of the dissolved salt content of a river. Temperature is measured in °C and is a good measure for assessing the effects of temperature changes on living organisms.

The chemical features worth studying in water quality analyses are very extensive since water is a universal solvent and many chemical compounds can be found in solution in naturally occurring water bodies. As such, only a selection of the most significant would be discussed. pH measures the concentration of hydrogen ions (H^+) and it is an indicator of the degree of acidity or alkalinity of water. On the scale from 0 to 14 a pH of 7 indicates a neutral solution. Where pH is less than 7, the water is acidic and if pH is greater than 7, the water is alkaline (Shaw, 1994). Dissolved Oxygen (DO) plays a key role in the assessment of water quality. Fish and other forms of aquatic life require dissolved oxygen for their sustenance. Dissolved oxygen affects the taste of water and high concentrations of dissolved oxygen in domestic supplies are encouraged by aeration. Dissolved Oxygen is measured in $mg1^{-1}(O_2)$. Nitrogen may be present in the form of organic compounds usually from domestic wastes. Examples of these compounds are ammonia or ammonium salts. Nitrogen could be in the form of nitrites or fully oxidized nitrates. Measures of nitrogen give an indication of the state of pollution by organic wastes. It is measured in $mg1^{-1}$(N). Chlorides are found in brackish water bodies contaminated by sea water or in ground water aquifers with high salt water content. The presence of chlorides ($mg1^{-1}Cl$) in a river is indication of sewage pollution from other chloride compounds (Shaw, 1994).Some harmful diseases are transmitted by water-borne organisms. An example is Bilharzia caused by schistosoma. The common organism found in all human excreta is Escherichia coli (E.Coli) and this gives an indication of sewage pollution or pollution from human sources. This is measured in Most Probable Number (MPN) per 100ml which is determined statistically from a number of water samples (Shaw 1994).

3.6 Water Quality of Rivers in Nigeria

Surface water pollution is a major environmental health challenge in many developing countries such as Nigeria and that it is mainly due to human activities resulting from rapid population growth and increased production activities,unfortunately this has not been accompanied by an increase in the delivery of essential urban services such as water supply, sewage and sanitation, and collection and disposal of solid wastes, and this has led to indiscriminate disposal of wastes into or along stream channels. This attracts a lot of interest because of the importance of water quality on human health and on environmental quality (Uting, 2007; Ocheri, 2008 and Obeta and Ajaero, 2010).

Several researches on physicochemical parameters of some important rivers in Nigeria as monitored indicate high Total Suspended Solids (TSS). High TSS found in rivers in Nigeria has tendency of reducing the light penetration into the river leading to a reduced photosynthesis with consequent effects on both phytoplankton and zooplankton populations of the aquatic environment. A study by Ajibade (2004) has shown high TSS values in Asa River (Kwara state) while Osibanjo(2011) has also reported similar findings for Rivers Ona and Alaro in Ibadan. Clogging of TSS on fish gills could also result into stress, reduced growth, suppressed-immune system leading to increased susceptibility to disease and osmotic dysfunction and death (Bilotta and Brazier, 2008). Elevated values of TSS are capable of shielding harmful organisms in drinking water. TSS could also act as a vector of nutrients such as phosphorus and toxic compounds such as pesticides and herbicides from the land surface to the water body (Kronvang et al., 2003) leading to proliferation of phytoplankton in rivers.

Ajibade (2004), Adefemi (2007) have also reported elevated turbidity values in rivers in Nigeria. This could be linked to run-off effects as well as domestic and industrial discharges (urban wastes) on the rivers. Low BOD and COD values have been reported in New Calabar River and Kubanni River in Kaduna. However, a high BOD and COD values have been observed for Challawa River in Kano State with mean concentrations ranging between 10 to 30 mgl^{-1} and 170 to 260 mgl^{-1} respectively (Wakawa, 2008). Very low DO values (2.67-3.30 mgl^{-1}) were also observed in Challawa River. Osibanjo et al. (2011) also reported high COD values for the water samples from Rivers Ona and Alaro. The authors attributed these to leachate from waste dumpsites, agricultural and urban runoffs. Nutrient enrichment is predominant in most rivers in Nigeria.

For instance, Olajire and Imeokparia(2001) observed high concentrations of nitrate, ammonia and phosphate in Osun River, as consequence of human activities. Human activities observed along the study area include agricultural land-use, anthropogenic activities and industrialization. Farming operations around the area were said to have contributed immensely to elevated values of ammonia and phosphate. The study by Chima (2009) on the effects of urban wastes on the quality of Asata River in Enugu shows higher values of parameters (pH, turbidity, colour, conductivity, suspended solids, total dissolved solids, dissolved oxygen and biochemical oxygen demand and faecal coliform). The study also indicates that the river water quality was poorer in higher density and more urbanized areas of Enugu urban where waste generation and management is a growing problem. The study identifies the need for the development of a sustainable municipal waste management strategy that will encourage source reduction, reuse and recycling of solid wastes as this will lead to the enhancement of the ecological integrity of Asata River and its tributaries.

Metal pollution of some rivers in Nigeria may be due to industrial discharges, corrosion of iron and steel materials in building, leachates from dumpsites and vehicles etc. Iron concentrations in most Nigeriaǿs rivers are usually greater than WHO standard of 0.3 mgl^{-1} in drinking water (Offiong and Edet, 1996). Taiwo (2010) found elevated values of lead at a sampling site of Alakata stream in Abeokuta and dry deposition of particulate lead on water bodies is capable of increasing lead level of surface water. Lead is a potential killer especially in children. In some villages in Gummi and Bukkuyum Local Government area of Zamfara state, more than 400 deaths were reported due to lead poisoning (Galadima, 2011).

Besides the oil region of Niger Delta, which is synonymous with oil spill pollution, elevated levels of oil and grease have been reported by Osibanjo, (2011) at the downstream of Rivers Ona and Alaro in Ibadan, South-western Nigeria. The authors attributed these to urban run-off from auto repair workshop and petroleum depot. The high values of coliform reported for some river water samples confirm faecal pollution from domestic sewage, dumping sites, abattoir activities etc. High coliform values are typical characteristics of many rivers in Nigeria. Nwankwu (1992) reported coliform values in the range of 3100-150, 000 cfu 100 ml^{-1} at Iddo area of the Lagos lagoon. The high population of these microbial pollutants was linked to contaminations from the waste dumpsites around the Lagoon.

Ekere(2012), examined the effect of urban wastes on some streams in Enugu by analyzing some physiochemical features. Results show gross pollution at the city centre and some recovery after the city centre.Obeta and Ochege (2014) analysed and linked evidence of surface water pollution to leachate migration from waste dumps.Ubani et al., (2014) believed that various human activities have contaminated selected surface water in Enugu thus making them unsafe for human consumption. In his assessment of pollution levels in most of the rivers, there exist some levels of pollution in virtually all the rivers sampled, though there was no much variance from the NAFDAC acceptable standard. Also observed was the presence of faecal coliform in Abakpa River which suggests a possible outbreak of such water-borne diseases as dysentery, cholera, and typhoid fever if the water is consumed untreated. Pollution of surface water in Nigeria by urban waste therefore calls for great attention. Some people see water body as medium for waste disposal. Faecal pollution of rivers in Nigeria signifies poor sanitation management as well as unhygienic manner of living among people, especially those living close to the riverine areas.

3.7 Effects of River Pollution

The primary effect of river pollution is the reduction in the quality of water being carried by the river. In the less developed countries of South America, Africa and Asia, 95 per cent of all sewage is discharged untreated into rivers, lakes or the ocean and in India for example it is estimated that two-thirds of the surface waters are contaminated sufficiently to be considered dangerous to human health.One of the fundamental problems affecting millions of Nigerians is lack of access to safe sources of water supply and adequate means of disposal of human waste, refuse and drainage facilities. This is compounded by lack of adequate awareness of proper hygiene and sanitary behaviours that result in water and sanitation related diseases (Ochekpe,2011).

A 2008 study of the Huluka River in Ethiopia revealed a worsening trend of pollution through the stretch of the River. Water samples collected and analyzed downstream revealed eight to ten timeös higher values of BOD and COD and in addition, measured ions also showed an increasing trend (Prabu*et al*., 2008). Thus research evidence suggests that the effects of the degradation of a water resource by urban wastes are not limited to the area of discharge but could have widespread implications for the entire watershed.

Peters and Meybeck (2000) assert that water quality degradation is a principal cause of water scarcity and could reduce the amount of freshwater available for portable, agricultural and industrial use. The quantity of available freshwater is thus linked to quality which may limit its use. Human activity such as the indiscriminate dumping of refuse and the channeling of untreated domestic and industrial effluents into rivers reduce water quality, reduce water quantity and also reduce the uses to which water can be put.

Manös health to a large extent is dependent on access to potable water. Polluted water could be a carrier of many diseases and when it is ingested into the human system, could have negative implications for human health.

The greatest microbial risks are associated with ingestion of water that is contaminated with human faeces from humans and birds (Ivana et al., 2012). Faeces can be a source of pathogenic bacteria, viruses, protozoa and helminthes which cause water borne diseases (WHO, 2011). Most of the pathogens could be from human faeces and diseases transmitted by the consumption of faecal contaminated water known as ñfaecal-oralò diseases. Examples of faecal-oral diseases include cholera, typhoid, amoebic dysentery and diarrhoea. Water-contact diseases are contracted when an individualös skin is in contact with pathogen infested water. An example is schistosomiasis (bilharziasis) in which the eggs of the pathogen (*schistosoma*spp.) are present in the faeces and or urine of an infected individual. Water-habitat vector diseases are transmitted by insect vectors that spend all or part of their lives in or near water. Some previous investigations indicate that 19% of the whole Nigerian population is affected, with some communities having up to 50% incidence. This has raised serious concerns to World Health Organisation, in an attempt to improve cultural and socio-economic standards of people in the tropical region.

In Sub-Saharan Africa, it is estimated that 42 per cent of the population is without improved water and about 80 percent of all infectious diseases in the world are associated with insufficient and unsafe water (WHO, 2004). An adequate provision of good drinking water is therefore essential for the promotion of good health and sanitation. Where there is too little water for washing oneself, flushing toilets, properly cleaning food, utensils and clothes, the likelihood of contracting diseases such as diarrhoea could be very high.

The pollution of rivers also has socio-economic implications. An inadequate supply of water and sanitation facilities could reduce the likelihood of safe disposal of human waste thereby increasing risks or exposure to disease and death. An adequate water supply promotes good health and improves the prospects of new livelihood activities which are otherwise denied and are a key step out of poverty (UNESCO, 2006). Where water and sanitation investments are not made, the likelihood of contracting diseases such as diarrhoea, dysentery, cholera, typhoid and schistosomiasis is high. When the ôbread winnerô or household head becomes victim to these diseases, it has implications for the livelihood of the household, particularly that of the poor. Working days as well as productivity are lost and household incomes are greatly reduced where alternative sources of income are limited or non-existent. Household incomes might not be able to support the buying of water from expensive alternatives thus the household is caught up in the cycle of poverty due to the lack of good quality water for drinking, irrigation and sanitation (WHO, 2001).

According to the WHO, almost 70 percent of the 1.3 billion people living in extreme poverty are women and often trapped in a cycle of ill health (WHO, 2001). Any improvements in environmental health can have long-term impacts on householdsô ability to move out of povertyò. An improved water supply could therefore trigger a reduction in working hours and increase rest for women and children who hitherto, had to walk long distances or join long queues to fetch water of questionable quality.

3.8 Management Strategy for Surface Water Quality Monitoring in Nigeria

At present, the monitoring of surface and groundwater in Nigeria is carried out mostly by individual researchers in the Universities, Research Institutes, Government Agencies and some other organizations. The monitoring is haphazard, short term and based on individual interest and the reagents and equipment available to the Scientist. The monitoring is not properly coordinated and quality assurance programme is not incorporated in most of the studies. Therefore, comprehensive data on the water quality of most major rivers in the Nigeria is not available. Recalling that water quality monitoring is a scientifically designed system of long-term, standardized measurement, systematic observation, evaluation and reporting of water quality in order to define status and/or trends, the need to improve the monitoring of the countryȏs surface water cannot be overemphasized. The goals for water quality monitoring should be directed towards expansive information needs, determination of compliance within objective and standard framework, assessment of environmental trend and effects, mass transport estimation, and performance of general surveillance.

The Federal Ministry of Water Resources and Rural Development were established in 1984 to among other functions, safeguard the water resource of the nation through periodic monitoring. The Federal Environmental Protection Agency ï FEPA (established in 1988) which later transformed to the Federal Ministry of Environment also had the mandate of monitoring the environment of the country. The functions of FEPA also included regulation of effluents discharge by industries and several other Institutions. Statutory power was given to the Agency to prosecute any offender. The essence of this is to protect the water resource of Nigeria from pollution. Water quality degradation had been found most severe in Lagos, Rivers, Kano and Kadunawhere most of the countryȏs industries are located with subsequenteffects on public health and economic development.There is need for protection of water bodies in Nigeria from urban wastes as millions of the populace rely on it fordaily water supply.

Reviewed Literature indicates studies on surface water pollution, frequency and magnitude by urban wastes generated by human activities at various levels in Enugu (Chima*et al.,*2009, Ekere 2012, Onuigbo 2013, and Ubani 2014), but comparatively little work has been reported on effect of different sources of urban waste disposal practices such as open dumps, abattoir effluents, municipal and surface run-offs, domestic and raw sewage from homes on the quality of Mmiriocha river as it runs through Abakpa in Enugu. Therefore, this study will critically examine the various point and non-point sources of contamination to Mmiriocha River and to address key issue of developing sustainable strategies for management of urban wastes and improving the quality of the river.

CHAPTER FOUR

STUDY AREA

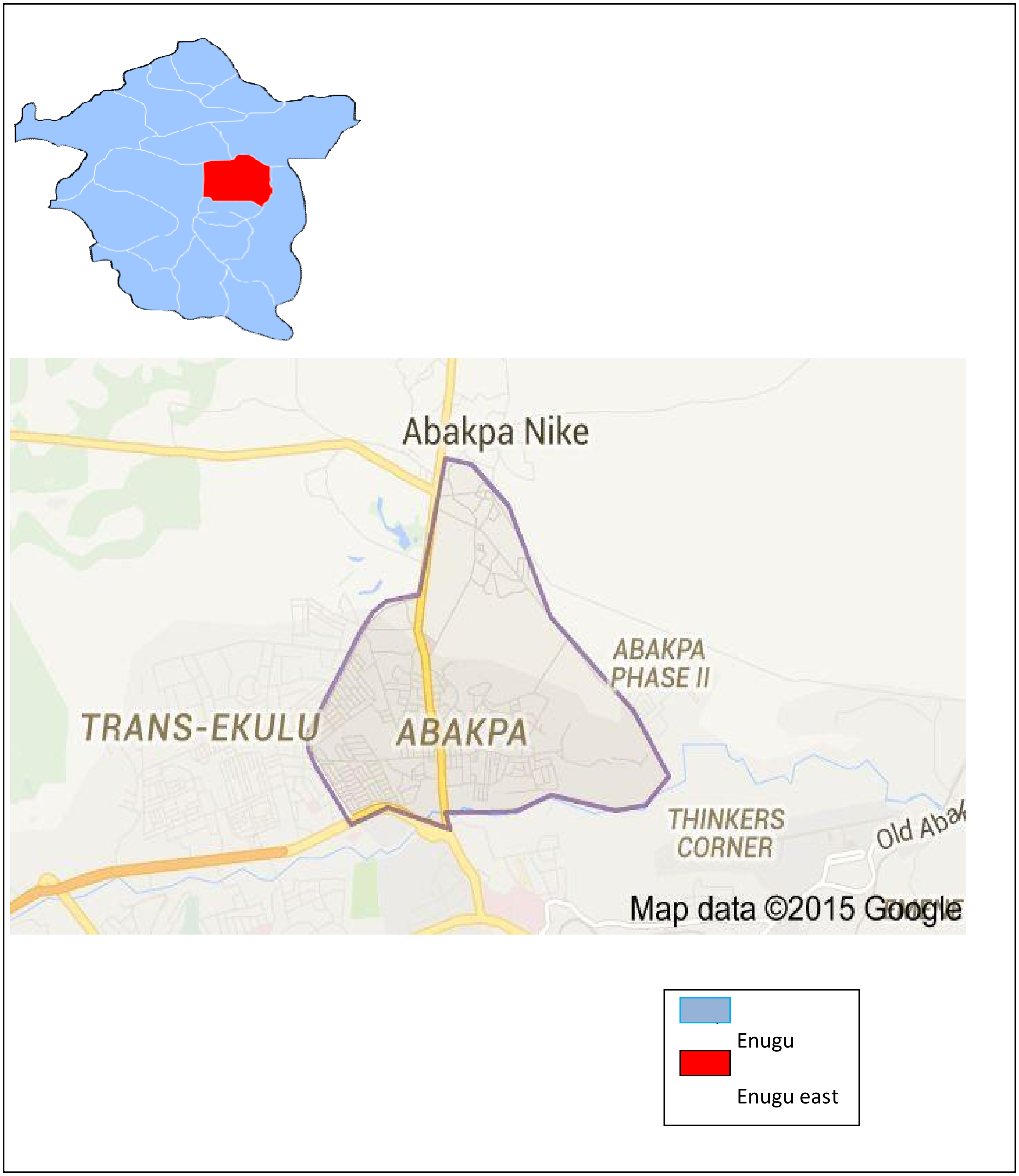
4.1 Historical Background

The study area is Enugu, the capital of Enugu State, Nigeria. The city is made up of three Local Government Areas (LGAs), viz Enugu East, North and South LGAs. The city lies approximately between latitudes 6^{o} 21ˆ and 6^{o} 30ˆN and longitudes 7^{o} 26ˆ and 7^{o}37ˆE of the Equator and Greenwich Meridian respectively. ñIt lies on the plains close to the foot of the east facing escarpment of Enugu-Awgu Cuestaò (Okoye, 1975). It has a total area of 612 square kilometres with a population of 722,664 persons according to 2006 census (National Population Commission, 2007). The coal industry established by the colonial government in Enugu and construction of rail between the Enugu and Port Harcourt in 1915 as well as the strategic role of the city as the capital of former Eastern Region, defunct Republic of Biafra, East Central State, and old Anambra State were particularly responsible for the rapid growth of the city.

The rapid population growth, urbanization and industrialization from the 1960s has contributed to exacerbating myriad challenges typical of cities in developing countries and this resulted in two factors which accelerated the waste management problems. The first was the increase in population influx from rural to the urban area and the second is a poor and inadequate solid waste management system being put in place.Enugu Metropolis has some surface waters which have their routes through various parts of the town. The population engages in various domestic, commercial, industrial and agricultural activities to earn a living. All of their activities generate wastes of various types and with the inefficient waste disposal system, it is estimated that at least a substantial portion of the generated wastes are disposed into these surface waters.

Enugu East Local Government of Enugu State Nigeria were Abakpa is situated has a total land mass of $383km^2$ (148 sq. mi) and total population of 279,089 based on the 2006 census (NPC, 2010). It lies within latitude $6^0$32N and longitude $7^0$32E and is bordered on the North by Trans-Ekulu, to the west by New Haven, to the East by Iji Nike and to the south by Emene (www.enugustate.gov.ng. accessed 23.11.2012). It is part of the urban section of the Nike community with an undulating topography and the soil is good for farming. Commonly grown crops are yams and vegetables.

Waste management in Abakpa Nike is becoming an increasing problem daily and a complex task for The Enugu State Waste Management Agency (ESWAMA) which was established to develop and implement policies on the management of solid and liquid wastes that would promote the health and well-being of the people. Especially within Abakpa Nike, human activities have generated waste in various forms in gaseous (abattoirs), liquid and solid. These wastes have often been discarded because they were all considered as negative value goods. The more prevalent method of disposal of these wastes have been to first collect them from their source and then burn them in dumpsites or throw them into rivers or the surrounding deep erosion gullies in the state. However, the steady increase of dumpsites, deposition in the gullies, and waste generally has caused a lot of havoc to the potable water being extracted from downstream and ground water. In most parts of Abakpa Nike, there are no public facilities for disposing refuse within reasonable distance, dump sites or waste bins are more or less non-existent and in locations where dumpsites are made available, they are sited wrongly near a water body where they overflow into streams with refuse within few hours of disposal due to the rate of waste generated by populace within the area constituting health hazards.



Source: www.igboguide.org/map-Enugu.jpg. (2010)

Fig 4.1Satellite map of Abakpa in Enugu state

Source: Field observation(2014)

Plate4.1:Pictures showing Mmiriocha River and sources of waste discharge into the river.

4.2 Population Structure and Distribution

The population history of Enugu city shows that there have been a steady increase of people in the city with the population census of 1991 recording a population of 407,756 people, 2002 census also showing an increase to 595,000 people and the most recent population census report also recording an increase to 722,664 people within Enugu city and having a high population density in the urban centre with densities ranging between 300 and 600 per sq.km. (Population statistics of Nigeria Population Census, 2006)

The Table below gives the distribution of population over the years).

Table4.1:Table showing Population Distribution in Enugu over the years

Years	Population
1921	3,170
1931	12,959
1953	62,764
1963	138,874
1982	349,587
1983	385,735
1987	446,535
1991	407,756
2002	595,000
2006	722,664

Source: National Population commission report, 2006.

The estimated population of the city by 2010 has exceeded the 0.8 million mark (actually 878,403 people) with high densities of about 400 persons/sq.km in some places.

4.3 Topography and Climate

Climatically, Enugu city enjoys tropical climate. The rainfall received is mainly of convective type. The annual rainfall varies between 100 to 200 meters with its peak occurring between mid-March and September. The rainfall average is 1412 millimetres per month, with the lowest rainfall in February. The onset and cessation of the wet season in the city are characterized by violent squalls, thunderstorms, heavy flooding, soil leaching, and extensive sheet out wash, ground infiltration and percolation. The annual rainfall of the area is over 2000mm. The wet season lasts from mid-March to October with double maxima in June/July and September/October. The dry season is brought in by the tropical continental air mass and it lasts from November to early March inclusive.

Temperature ranges between 25^0C in mid wet season to about 30^0C before the on-set of the rainy season with maximum monthly temperature ranging between 28.1^oC and 32.2^oC. The mean monthly minimum has been recorded at 22^oC and 24.9^oC in July and March respectively Thus, Enugu city is in the Koppenôs humid tropical (Aw) wet dry climate (Chukwu, 2004). The vegetation is generally losing its original rainforest nature to Guinea Savanna type. The scarp slopes which formed the eastern edge of the Enugu escarpment are heavily dissected by headwaters of six main streams, which drain the entire city and flow in the direction of low gradient more or less eastward into the Cross River plain, hence enhancing effective drainage as runoffs easily empties into the network of natural drainage channels crossing the city like Mmiriocha River, which is a tributary of Ajalli River (Government of Enugu State of Nigeria, 1992). These streams are Nyaba river (a sixth and the highest segment order), Ekulu river (a fifth order), Idaw and Asata rivers (both, fourth order), Ogbete (third order) and Aria River (second order). These natural streams form the potential outfall for the urban storm water drainage eastward of the city. The soil characteristically consists of hydro-orphic soil which is mineral rich soil and whose morphology is influenced by seasonal water logging caused by underlying impervious shale.

CHAPTER FIVE

RESEARCHMETHODOLOGY

5.1ResearchDesign

Research designcompasses the strategic method and procedures employed to conduct scientific researchin a coherent and logical way, thereby, ensuring that the researcher addresses the research problem effectively.It defines the study type and sub-type, research question, hypothesis, independent and dependent variables, experimental design etc. This research focused on experimental investigation.

5.2 Types and Sources of Data

In the course of carrying out this research, research methods of data collection wereemployed to ensure that appropriate data required to investigate and solve the identified problem are made available. Data for the study were basically collected through both primary and secondary sources. The sources are presented as follows.

5.2.1 Secondary data collection

The main secondary source was the internet while other secondary sources include: textbooks, newspapers, maps, magazines, periodical articles and journals written by individuals and organization relevant to this project topic for up to date information.

5.2.2 Primary Data Collection

In order to assess the effect of urban waste on Mmiriocha water quality, surface water samples were collected from four designated points on the river running through Abakpa community. These water samples were subjected to laboratory analysis of which variables of selected relevant physicochemical and biological water quality parameters wereanalyzed. In addition personal observation was also used and the evidence was recorded by means of pictures taken with a camera at the site.

5.3 Sample Frame

Four designated sampling points was created at different points in the river course considering flow, stretch and human activities. Grab samples were collected in duplicatesfrom the four different sampling points making it a total of eight samples. The first sampling point designated (S1) was located 100m upstream before the abattoir and sewage discharge which served as the sample control point. The second sampling point (S2) was at the point of drains and pipe discharge from abattoir, residents and sewage discharge. The third sampling point (S3) was at the point of dumpsite 80m interval from the second point. The fourth sampling point (S4) downstream was 150m interval from the third point.

5.4 Water Sample Collection

The samples were collected during the rainy season between the month of July and September. This was collected during morning hours under controlled temperature conditions using clean 1000ml properly labeled screw capped sterile plastic bottles. These bottles were rinsed with the water sample and submerged to a depth of about 20cm below water surface with the bottle facing the water current and corked underwater to avoid air entrainment. Samples for BOD and DO analysis were collected in air tight 60ml BOD bottles. Obtained representative samples was immediately put in a portable cooler box containing ice boxes in it which maintained a $40^{o}C$ temperature before reaching the Laboratory as recommended by (USEPA, 1985; APHA, 1992) and this was within a maximum of 6hours for analysis of relevant water quality parameter.

5.5 Determination of Water Quality Parameters

Analytical methods for the selected parameters were carried out in accordance with the standard procedural methods of American Public Health Association (APHA, 1992).

pH: The pH value of water is determined by the relative concentrations of H^+ ion and OH- ion. Water with a pH of 7 has equal concentrations of H^+ ion and OH^- ion and is considered to be neutral. If a solution is acidic (pH<7), the concentration of H+ ion is greater than the concentration of OH- ion. If a solution is basic (pH>7), the concentration of H^+ion is less than the concentration of OH^- ion. The pH meter is the instrument used in measuring pH of samples according to APHA (1998). A multi-parameter digital water testing meter was used in testing the pH of the water sample.

Apparatus: 2 beakers, 1 electrode (external), multi-parameter digital water testing meter

Reagent: Consort Buffer solution

Procedure: The pH electrode was pre-calibrated by immersing it in the buffer solution with distilled water and finally with a portion of the sample. The electrode was dipped and retained in a 50ml beaker containing the sample, and the pH button pressed. The value was displayed on the liquid crystal display (LCD) panel and left to stabilize before the readings were taken.

Temperature: This is the degree of hotness or coldness and the flow of heat from a region of high temperature to a region of low temperature. High temperature affects the concentration of dissolved oxygen in water by reducing the amount of dissolved oxygen. Temperature was measuredinsitu with the aid of a calibrated thermometer.

Apparatus: Centigrade thermometer

Procedure: The thermometer was dipped into the river and then at the various sampling points.Theliquid crystal display (LCD) panel displayed the values and was left to stabilize before the readings were taken. The readings were duplicated and the average taken.

Colour: The colour of water is commonly caused by the extraction of colouring material from the humus of forests or from deposits of vegetable matter in swamps and low-lying areas. The colour of the water samples was measured using a colorimeter and the results expressed inTC_u^a.

Apparatus: Colorimeter.

Electrical Conductivity (EC): This is a measure of the ability of ions in a solution to carry electric current. This ability depends on the presence of ions, their total concentration and temperature. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminiumcat ions (ions that carry a positive charge). EC is affected primarily by the geology and anthropogenic factors of the area and so varies considerably in different geographical regions owing to differences in the solubility of minerals. Hence there is no standard value for it but high levels of it in drinking water may be objectionable to consumers (WHO, 2006).

Apparatus: 2 beakers, 1 electrode (external), HANNA HI 991300 multi-parameter digital water testing meter. EC was measured in-situ at all the sampling points channel and in the river using the digital meter.

Procedure: The digital meter was switched on and its probe dipped into the sampling point. The electrical conductivity was read directly and the readings duplicated and the average taken and recorded in microsiemens per centimetre (ε S/cm)

Turbidity*:* This is the optical effect caused by dispersion of and interference with light rays passing through water containing small particles in suspension. It may be caused by silt extracted from soil, surface wash containing suspended organic and mineral matter, precipitated calcium carbonate, iron oxides, microscopic organisms etc. in waters typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity in water gives it a cloudy appearance which is objectionable. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Turbidity levels were measured in Nephelometric units (NTUs) using the HACH water analysis kits (Model DR 2010).

Apparatus: 2 beakers, HACH water analysis kits (Model DR 2010).

Procedure: Turbidity was measured in-situ both in all the sampling points and in the river using a HACH water analysis kits (Model DR 2010). The meter was switched on and its probe dipped into the sample points. The turbidity was read directly and the readings duplicated and the average taken and recorded.

Biological Oxygen Demand: This is the quantity of oxygen utilized by micro-organism in aerobic degradation of organic matter in a water body. It is generally proportional to the amount of organic matter present in water. It can be used as a measure of waste strength and also an indicator of the degree of pollution. It is the most widely used parameter. The 5-day BOD (BOD_5) was applied to test for BOD in the samples.

Apparatus: Beakers, BOD bottles, incubator

Procedure: Biochemical oxygen demand (BOD_5) was determined by conventional methods according to Association of Official Analytical Chemists (AOAC), 2002. A sample of the water (50 ml) from each sample point was placed in a 500 ml BOD bottle and filled to the mark with previously prepared dilution water. A blank of the dilution water was similarly prepared and placed in two BOD bottles. A control without dilution water was also prepared and placed in a BOD bottle. The bottles were closed tightly, sealed and incubated for five days at room temperature. BOD was calculated from the relation:

BOD= (DO1-DO2)/S

Where:DO1= dissolved oxygen 15 minutes after preparation,

DO2= dissolved oxygen in diluted sample after incubation for 5days

S= amount of sample used.

Chemical Oxygen Demand (COD): This is a test commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers) or wastewater, making COD a useful measure of water quality. It is expressed in milligrams per litre (mg/L) also referred to as ppm (parts per million), which indicates the mass of oxygen consumed per litre of solution. In determining the Chemical Oxygen Demand (COD) the Permanganate method was employed.

Apparatus: Incubator, beakers,

Reagents: sodium trioxosulphate, sulphuric acid, potassium permanganate, potassium iodide, starch indicator.

Procedure: for each water sample, a blank sample was prepared and 10ml of sulphuric acid added to each sample after which an extra 10 ml of potassium permanganate is added until a pink colouration is observed. The samples and the blanks were then transferred to the incubator for four hours at 27ºC, later 3mg of potassium iodide was added to the samples and their blanks, to each sample and blank add five drops of starch indicator, then each sample and each blank was titrated with sodium trioxosulphateuntillthe blue colour disappeared and the solution became colourless. The COD was determined as follows:

COD = (A – B) ×1000(mg/l) a × volume of sample used

Where:A = Volume of 0.0125N potassium trioxosulphate for blank

B = Volume of 0.0125N potassium trioxosulphate for sample

a = ml of sodium trioxosulphate required for 10 ml of potassium permanganate.

Dissolved Oxygen (DO): Thismeasures the amount of gaseous oxygen (O_2) dissolved in water. Oxygen gets into water by diffusion from the surrounding air, by aeration, and as a waste product of photosynthesis. Adequate dissolved oxygen is necessary for good water quality and elemental to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. Dissolved Oxygen was carried out in-situ and measured with DO meter.

Apparatus: beakers, digital DO meter YSI Pro20

Procedure: The digital DO meter YSI Pro20 was switched on and its probe dipped into the various sampling points. The dissolved oxygen was read directly and the readings duplicated and the average taken and recorded in milligram per litre (mg/l)

Total Suspended Solids (TSS): Total suspended solids are the portion of solids that usually remains on the filter paper. Suspended solids consist of silt, clay, fine particles of organic and inorganic matter, which is regarded as a type of pollution because water high in concentration of suspended solid may adversely affect growth and reproduction rates of aquatic fauna and flora.

Apparatus: Vacuum pump and manifold, Forceps, Desiccator and desiccant that contains a colour indicator for moisture content, Drying oven for use at 103° -105° C, Muffle furnace for use at 550° C, Analytical balance - capable of weighting to 0.1 mg, Magnetic stirplate and stirbar, Magnetic stirbar retriever, Crucible tongs, Heat resistant gloves,Glass-fiber filter disks (Whatman AH-934 or equivalent), 40 mL Gooch crucible (permanently labelled),Aluminium dish for drying filter disks, Side arm erlenmeyer flask, pipette,250 mL glass graduated cylinder

Reagents: Distilled or deionized water

Procedure: The Gooch crucible was weighed and filtered (at room temperature) on an analytical balance. Crucible tongs was used to transfer the crucible from the desiccator to the balance pan. The weight of the crucible and filter was recorded.The prepared crucible and filter was placed on the vacuum manifold with vacuum gasket. The filter was wet with deionized water in order to seat the filter against the crucible. The sampleanalysedwas thoroughly mixed. The volume of sample transferred to the Gooch crucible was carefully measured. The volume of sample used left at about 2.5mg of residue on the filter.The filter was then rinsed with three successive 10 mL portions of deionized water. The vacuumcontinued until no traces of moisture were present. The crucible was placed in the oven to dry for 1 hour at 103° C and transferred to a desiccator to cool. The dried and cooled crucible was weighed on an analytical balance and the weight recorded. The crucible was returned to the drying oven for another thirty minutes and allowed to cool, reweighed and then recorded its weight. This procedure was repeated until the change in the weight of the residue remained within 4% one weighing to the next. (This is referred to as constant weight.) The final dry weight was recorded on the bench sheet and the total suspended solids calculated.

Calculation:

$$\textbf{Total suspended solids (mg/L)} = \frac{\textbf{Final weight – initial weight}}{\textbf{Sample volume in litres}}$$

Total Dissolved Solids TDS: This is a measure of salt dissolved in a water sample after removal of suspended solids. TDS is residue remaining after evaporation of the water. The concentration of total dissolved solids (TDS) is related to electrical conductivity and TDS is also directly related to the purity of water and the quality of water purification systems and affects everything that consumes, lives in, or uses water, whether organic or inorganic, whether for better or for worse. The conductivity is a relative term and the relationship between the TDS concentration and conductivity is unique to a given water sample and in a specific TDS concentration range. The conductivity increases as the concentration of TDS increases.

Apparatus and Procedure: same as that of Electrical Conductivity. TDS was measured in milligram/Litre (mg/L)

Total Hardness: When water passes through or over deposits such as limestone, the levels of Ca^{2+}, Mg^{2+}, and $HCO^{3ï}$ ions present in the water can greatly increase and cause the water to be classified as hard water. This term results from the fact that calcium and magnesium ions in water combine with soap molecules, making it ñhardò to get suds. High levels of hard-water ions such as $Ca^{2+}$and Mg^{2+} can cause scaly deposits in plumbing, appliances, and boilers. These two ions also combine chemically with soap molecules, resulting in decreased cleansing action. EDTA titrimetric method was used to measure the level of hardness of water.

Apparatus: beaker, burette, pipette, conical flask

Reagent: Eriochrome Black T indicator, ethylenediaminetetracetic acid (EDTA)

Procedure:A 10cm3 of the sample was added to $2cm^3$ buffer of pH10 in a beaker, followed by two drops of Eriochrome Black T indicator and thoroughly mixed. The mixture was then titrated against 0.01M ethylenediaminetetracetic acid (EDTA) until a light blue end point colour appeared and the value recorded.

Calculation:

Hardness in mg/L $CaCO_3$= $\frac{V \times M \times 1000}{\text{mL of sample used}}$

Were M = Molarity of EDTA Used

V =Volume of EDTA used.

Nutrient Analyses ï Nitrate and phosphates in surface waters.Increased inputs of nitrogen andphosphorous into water resources are linked to eutrophication of the systems.Management of water resources requires an understanding of nutrient levels and cycles.

Nitrate: This is taken up by plants as a nutrient and assimilated into proteins and therefore can have a great influence on the amount of plant growth in water.Anthropogenic inputs of nitrate include fertilizers, domestic and industrial wastewaters.Excessive nitrate in drinking waters has been associated with ốblue babyô syndrome; inwhich, nitrate is reduced to nitrite, which reacts with haemoglobin to formmethahaemoglobin, which is not an effective carrier of oxygen in the blood. When nitrate is passed through a column or mixed with a solution containing Cadmium it is reduced to nitrite and the nitrite level is read. A Once reduced, a separate determination of nitrite is done by coupling nitrite with N-(1 naphthyl)-ethylenediaminedihydrochloride to form a pinkish-colour dye, which isread calorimetrically with a spectrophotometer set at 520 nm.

Phosphate: This is the limiting nutrient in freshwater systems. Natural inputs of phosphorous include decay of organic matter, excretion by organisms and weathering ofsedimentation. Excessive inputs of phosphorous (as found in fertilizers, detergents andSewage) can lead to eutrophication. Phosphate reacts with vanadomolybdate to formvanadomolybdophosphoric acid. Vanadomolybdophosphoric acid forms a yellowishcolour, which is read colormetrically with a spectrophotometer set at 470 nm.

Apparatus: Spectrophotometer

Reagents:N-(1 naphthyl)-ethylenediaminedihydrochloride, vanadomolybdate.

Procedures: The spectrophotometer was turned on and allowed to warm-up for 15 minutes prior to use and the A/T/C button pressed to set units to absorbance.The nm__ was used to set the wavelength and insert blank (use an unamend portion of your sample) then press 0 ABS/100% T to set the blank, zero the instrument. An amended sample was inserted and the absorbance recorded.

Microbiological Analysis: Pathogens are bacteria and viruses that can be found in water and cause diseases in humans. Pathogens found in contaminated runoff may also contain parasitic worms (helminths). Coliform bacteria and faecal matter may also be detected in runoffs. These bacteria are a commonly used indicator of water pollution, but not an actual cause of disease. Total coliform gives a clear indication of the general sanitary condition of water since this group includes bacteria of faecal origin.

Faecal Coliform: 5ml of the samples were inoculated into multiple tubes containing McConkey agar and incubated at 37^{o}C for 24 hrs. Production of acid and gas bubbles indicated positive presumptive test. Two lumpful of samples was transferred to a McConkey broth and the formation of gas bubbles and fermentation leaving empty space at bottom of inverted tubes indicated the presence of *Escherichia coli*. The sample was then transferred to a Petri-dish and *E.coli*colonies developed and counted with a digital counter.The purpose of bacteriology is to indicate the degree of sewage pollution of river water at the time of sampling and thus the possibility that disease may be transmitted by the polluted surface water.

5.6 Statistical Tool

The model specification used for this study to test the two hypotheses is Analysis of Variance (ANOVA)using statistical package for social sciences(SPSS).It is a statisticaltool that explains if any of the independent variables means are significantly different from that of the dependent variables. It clearly showed whether there are significant differences between the mean values of the sampling points and WHO guidelines on drinking water.

CHAPTER SIX

DATA PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

6.1 Data Presentation

The physicochemical and biological parameter presented, analyzed and discussed in this chapter are result of laboratory analysis of samples from the river in the study area, based on the objectives, research question and hypotheses that guided the research. Four samples were collected in duplicates from four sampling points in the river considering flow, stretch and human activities. The first sampling point upstream designated upstream sampling point (UPSSP) was located 100m upstream before the abattoir and sewage discharge points which served as the sample control point. The second sampling point, pipes and drain discharge sampling point (PDDSP) was at the point of pipes and drain discharge from abattoir, residents and sewage discharge which is 100m from the first sampling point. The third sampling point was located close to the open dump designated open dump sampling point (ODSP) which is 100m interval from the second sampling point. The fourth sampling point downstream (DWSSP) is 100m interval from the third sampling point.

The physicochemical water quality parameter analysed included Colour, Taste, Odour, Temperature, Turbidity, pH, Total Hardness, Dissolved Oxygen, Biochemical Oxygen Demand, Total Dissolved Solids, Total Suspended Solids, Electrical Conductivity, Chemical Oxygen Demand, Phosphate, Nitrate, E- Coli, Coliform Count, AerobicMesophilic Count. Their values were measured within 24hrs of sample collection to avoid error due to sample deterioration. Their variation from the WHO guidelines (2004) for river water quality was used as index for measuring how indiscriminate dumping of urban waste into the river has affected the water quality. The data were presented inform of tables, graphs and charts.

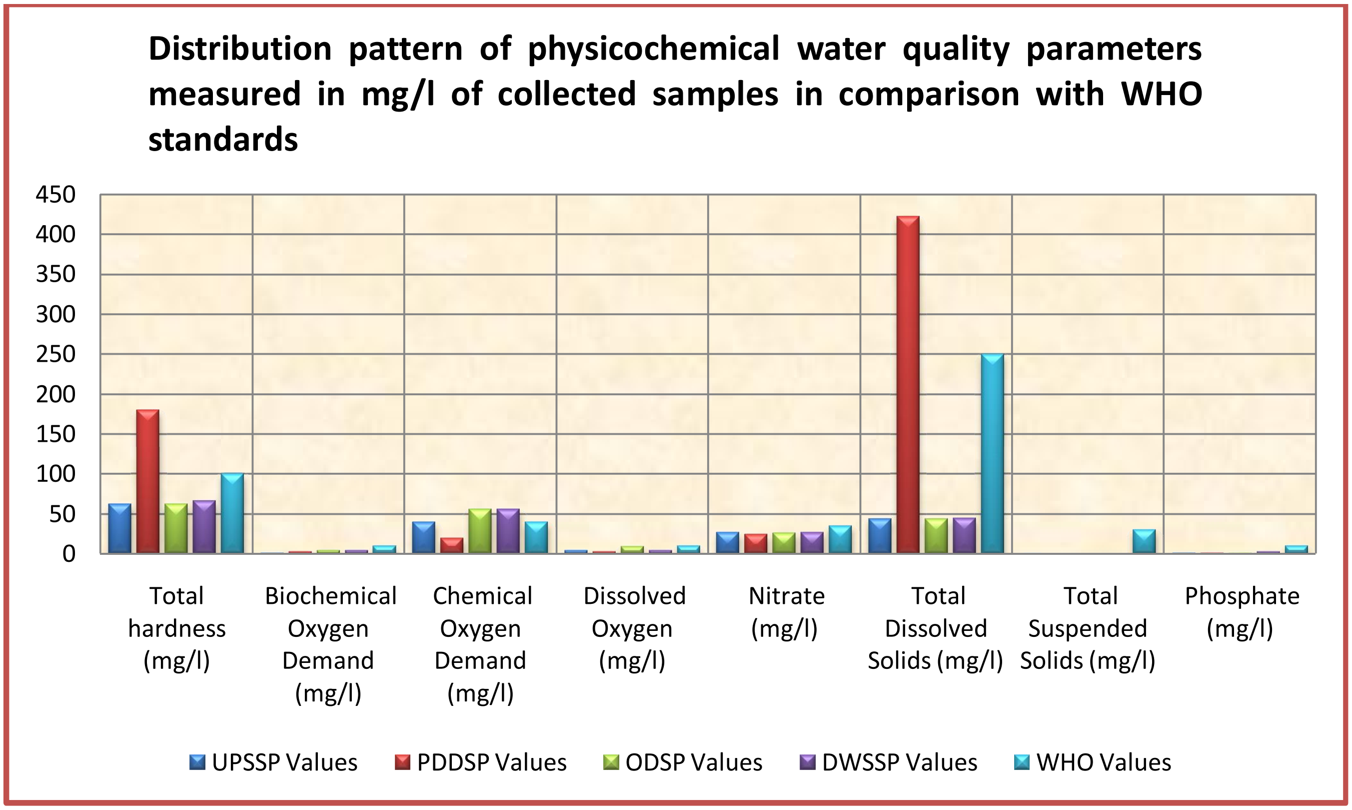
Table 6.1 Mean values of the physicochemical and microbiological water quality parameters of the different sampling points (UPSSP, PDDSP, ODSP and DWSSP).

PARAMETERS	UPSSP	PDDSP	ODSP	DWSSP	WHO 2004
Appearance (TC_u^a)	Slight Colour	Slight Colour	Slight Colour	Slight Colour	15.0 TC_u^a
Taste	Slight Taste	Slight Taste	Slight Taste	Slight Taste	Unobjectionable
Odour	Slight Odour	Slight Odour	Slight Odour	Slight Odour	Unobjectionable
pH	8.40	7.60	7.60	7.50	6.5-8.5
Temperature (^oC)	23.00	23.00	23.00	23.00	20-30
Turbidity (NTU^b)	9.20*	0.70	9.20*	8.70*	5.0
Total Hardness (mg/l)	62.00	180.00*	62.00	66.00	100.00
Biochemical Oxygen Demand (mg/l)	1.60	3.20	4.80	4.80	10.00
Chemical Oxygen Demand (mg/l)	40.00	20.00	56.00*	56.00*	40.00
Dissolved Oxygen	4.80	3.20	9.60	4.80	10.00

(mg/l)					
Nitrate (mg/l)	26.85	24.76	26.50	26.90	35.00
Total Dissolved Solids (mg/l)	44.00	422.00*	44.00	45.00	250.00
Total Suspended Solid (mg/l)	0.15	0.01	0.08	0.02	30.00
Electrical Conductivityε S/cm	96.80	928.40*	96.80	99.00	500.00
Phosphate (mg/l)	1.54	1.40	0.93	3.14	10.00
E. Coli (CFU/ml)	23.00*	35.00*	19.00*	35.00*	10.00
Coliform Count (CFU/ml)	120.00*	239.00*	90.00*	159.00*	0.00
Aerobic Mesophilic Count (CFU/ml)	179.00*	70.00	135.00*	200.00*	100.00

Source: Author's laboratory Result (2014).

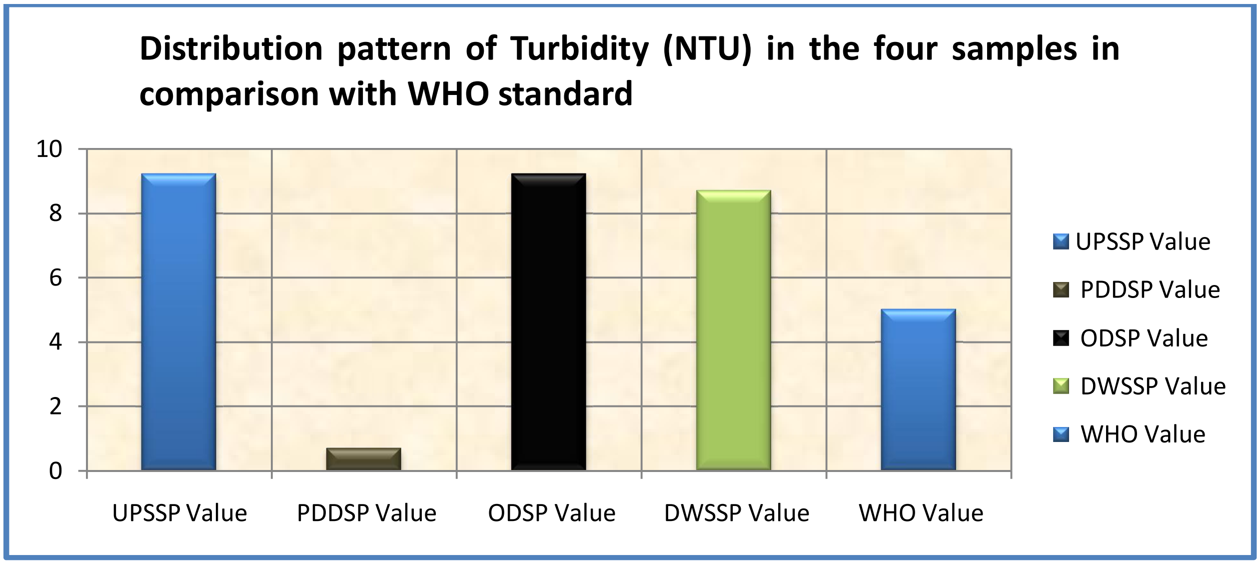
Keys: UPSSP= Upstream Sampling point, PDDSP = Pipes and drain Sampling point, ODSP = Opendump Sampling point, DWSSP = Downstream Sampling point. µS/cm =Microsiemens per centimeter, Mg/l = milligram per litre. *=values exceeding WHO



Source: Author's laboratory Result from table 6.1 (2014).

Fig 6.1: Distribution pattern of physicochemical water quality parameters of collected samples in comparison with WHO standards.

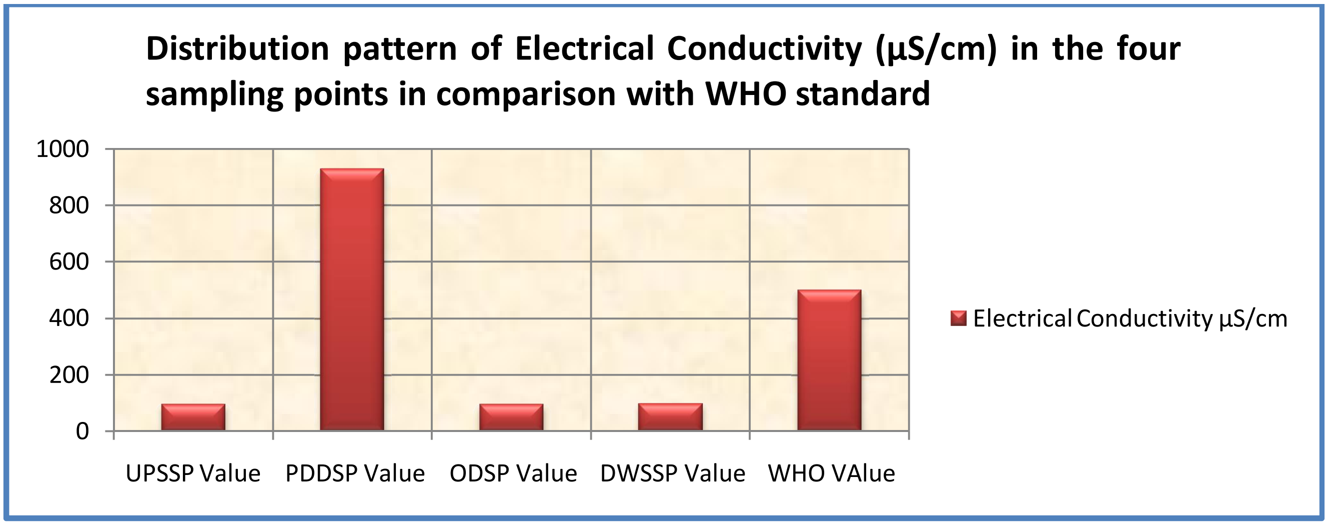
The chart in Fig 6.1 shows the sample value for the physicochemical water quality parameters in comparison with WHOstandard in the four sample points. The first four different bars in parameter group represent the four sample points for a parameter while the last bar in the group represents the WHO standard.Some of the parameters fall below or are within the WHO standard in the various sampling points. For example, column 3 in the chart above shows in bars the concentration in mg/l for chemical oxygen demand in the four different sampling points and also the WHO standard value.



Source: Author's laboratory Result from table 6.1 (2014).

Fig 6.2: Distribution pattern of turbidity measured in the four samples in comparison with WHO standard

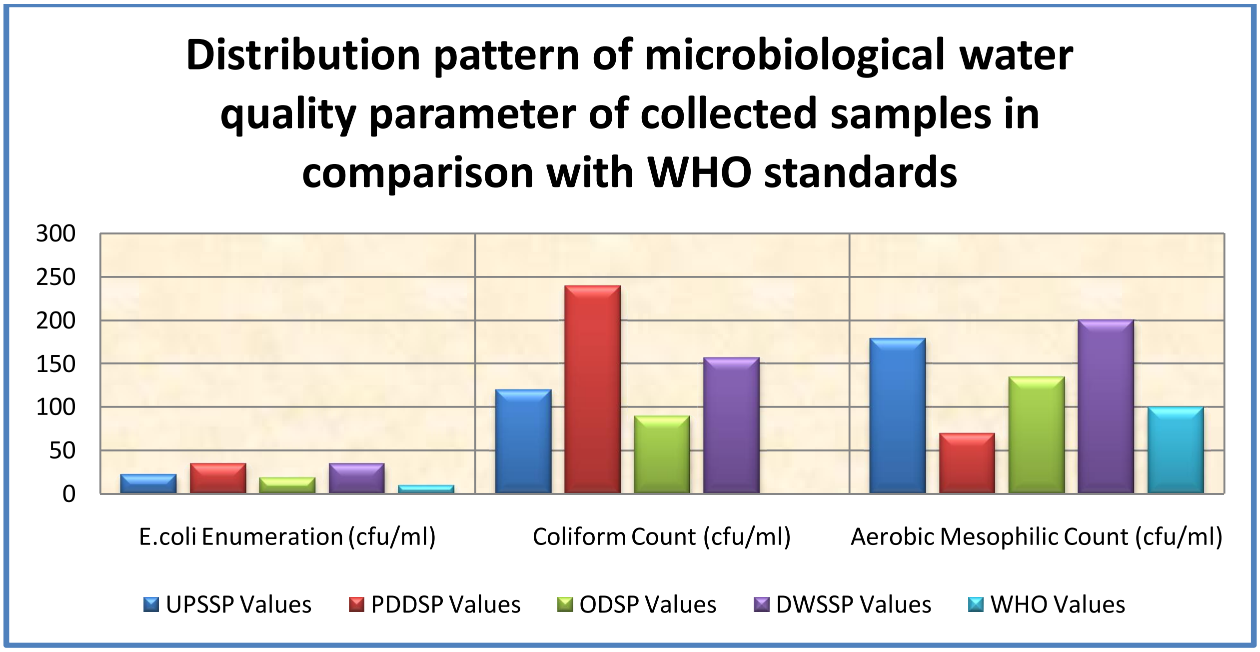
The chart above shows the distribution pattern of turbidity in the various sampling point. The first four columns represents the four sampling point while the last represents the WHO standard value for turbidity. The chart shows that apart from PDDSP (Pipe and Drain Discharge Sampling point) which shows value lower than WHO, the other three sampling point shows values higher than WHO standard.



Source: Author's laboratory Result from table 6.1 (2014).

Fig 6.3: Distribution pattern of Electrical conductivity in the four sampling points in comparison with WHO standard.

In the chart previous page the first four columns represents the four sampling point while the last represents the WHO standard value for electrical conductivity. It shows that apart from PDDSP (Pipe and Drain Discharge Sampling point) which shows value higher than the WHO standard value, the other three sampling point shows value lower than WHO standard.



Source: Author's laboratory Result from table 6.1 (2014).

Fig 6.4: Distribution pattern of microbiological water quality parameter of collected samples in comparison with WHO standard.

Each column in the chart above represents a microbiological water quality parameter, while the first four bars in each column represents the various sampling point values and the last bar representing the WHO standard value. The chart clearly shows that all the microbiological water quality parameter in the four analysed water samples exceed the WHO standard threshold for these parameters. Its presence in water indicates contamination by raw sewage especially human and animal excreta which are observed indiscriminately along the river course.

6.2. Test of Hypothesis

6.2.1. Analysis of variance (ANOVA) for Hypothesis 1.

The ANOVA result in table 6.6 below was conducted for hypothesis 1 which states ñH_0: ñThere is no significant difference between the concentration level of the physicochemical and microbiological water quality parameters of the river water sample in the study area and the WHO standardò. The ANOVA was carried out with the laboratory result in table 6.1. The data comprises the WHO water quality standard and physicochemical water quality of parameters analyzed in different sampling points of the study area.

Table 6.2: ANOVA of WHO water quality standard and Physicochemical Water Quality of Parameters in the Study Area

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	248940.456	4	62235.114	102.665	.001(a)
	Residual	6061.944	10	606.194		
	Total	255002.400	14			

(Source: Authorôs SPSS ANOVA, 2014)

The p value of 0.001 is less than critical value of 0.05. Consequently, P = 0.001 shows a statistical significance. Therefore the result shows a significant difference between WHO Water quality standard and the Physicochemical water quality of parameter in the study area (p = 0.001).

Decision: Hence, considering the P value of 0.001 which is less than critical value of 0.05, the hypothesis 1 which states ñH_O: there is no significant difference between WHO water quality standard and Physicochemical water quality of parameters in the study areaò is rejected and the alternate is accepted which states ñH1: there is a significant difference between WHO Water quality standard and the Physicochemical water quality of parameter in the study area (p = 0.001).

6.2.2 Analysis of Variance (ANOVA) for Hypothesis 2

The ANOVA result in table 6.7 was obtained for hypothesis 2 which states ñH_0: ñThere is no significant difference in the concentration level of river water samples amongst the four sample point. (Upstream Sampling Point (UPSSP), Pipes and Drain Discharge Sampling Point (PDDSP), Open Dump Sampling Point (ODSP) and Downstream Sampling Point (DWSSP)òThe ANOVA was carried out using laboratory result in table 6.1.

Table 6.3 ANOVA of the quality of water in river amongst the 4 sampled point in the Study Area

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	38780.071	3	12926.690	441.704	.001(a)
	Residual	380.452	13	29.266		
	Total	39160.523	16			

(Source: Authorōs SPSS ANOVA, 2014)

The p value of 0.001 is less than critical value of 0.05 consequently shows a statistical significance. Therefore the result shows a significant difference in the quality of water in the river amongst the four sampled points in the Study Area(p=0.0100).

Decision: Hence, considering the P value of 0.001 which is less than critical value of 0.05, the hypothesis which states; there is no significant difference in the quality of water in river amongst the four sampled point in the Study Areaò is rejected and the alternate is accepted which states ñH1: there is significant difference in the quality of water in river amongst the four sampled point in the Study Area.

6.3 Discussion of Findings

The findings and discussion below achieves the objectives and answers the research question that guided the study. Observed in this study are various point sources of pollution to the river water such as dumpsites cited indiscriminately along the river banks, the drainage from the abattoir, from homes, washing, bathing etc. and non-point sources such as leachates from the open dumps, runoffs from flood water, and farm lands along the river banks. These sources have been observed and identified as the major cause of deviation, increase and variance in the concentration level of selected physicochemical and biological water quality parameters from WHO standard and amongst the four sampling points in the study area.

The study emphasized that there is a statistical variation from the WHO water quality standard and that of the river water quality parameters tested such as turbidity, BOD, COD, DO, TSS,TDS, total coliform, Electrical conductivity etc. ($P = 0.001$). Some parameters are within the WHO standard while some deviated critically. There was a quantum increase in the concentration levels of pH, BOD, Nitrate, TSS, phosphate but did not exceed the WHO standard in all the sample point. The high concentration of total hardness at PDSSP may be linked with the increased discharge of domestic waste water, anthropogenic activities (swimming, bathing, and washing) along the river banks. The progression of water electrical conductivity level from 96.80εS/cm at DWSSP to 928.40εS/cm at PDDSP (an increase of about 80%) reflects the status of inorganic pollution and is a measure of TDS in the water (422εS/cm at PDSSP). This concentration far exceeds WHO maximum permissible limit and poses a great threat to the health of the local population that uses the water as a source of water.

The presence of E.*coli,* Coliform count and Aerobic mesophylic count with high concentrations recorded above WHO standard at all the sample point is a good indication of indiscriminate steady contribution of waste dump, abattoir waste, raw sewage from homes in increasing the pollution load of the river water. The river water is therefore contaminated as evidenced with the presence of dangerous intestinal pathogens of both humans and animals excreta which can cause various diseases of public health importance and associated risks either through usage, primary or secondary contact by the local communities except otherwise treated (chlorination etc) before use. Common health problems that may arise from the presence of the pathogens include diarrhea, typhoid fever, infective hepatitis and some gastro-intestinal infections. This gives a clear indication of the general sanitary condition of the water since this group includes bacteria of faecal origin. These results is consistent with the findings from other studies which observed that waste dumps in proximity to a river water, raw sewage directly channeled from abattoir, homes and other anthropogenic activities such as indiscriminate defaecation, washing, bathing and dumping of refuse along the river banks has a significant effect (P = 0.001) on a river physical, chemical and most importantly biological effects on water quality (Ubani*et al* 2014; Obeta and Ochege 2014; Nkwocha*et al* 2011; Vincent *et al* 2012). The fact remains that contaminants generated within sampling points during decomposition of biodegradable components of the waste enter into the water body increasing its concentration of organic and inorganic constituents of the river water thereby affecting its quality and ecological health even though some still remain within established limits.

6.3.1 Critical pollutants

The critical pollutants at some of the sample points are Turbidity, Total hardness, Chemical oxygen demand, Total dissolved solids, Electrical conductivity, e.coli, Coliform count, Aerobicmesophylic count. Table 6.8 summarizes the information on these critical pollutants.

Table 6.4: The Critical Pollutants

S/N	Parameters	No of sample points where returned values exceed WHO	Highest Value Returned	WHO Limits	% Increase above WHO
1	Turbidity	3	9.20	5.0	84
2	Total Hardness	1	180	100	80
3	Chemical Oxygen Demand	2	56	40	40
4	Total Dissolved Solids	1	422	250	68.8
5	Electrical Conductivity	1	928	500	85.6
6	E.*coli*	4	35	10	250
7	Coliform count	4	239	0	23900
8	Aerobic Mesophylic count	3	200	100	100

The percentage increase for these parameters are high especially the coliform count and these will likely constitute health risk to potential users.

6.3.2 Discussion on Parameters

It was observed that there is a slight objectionable colour in all the four sampling points as the water was observed to be cloudy. There is also a slight objectionable odour and taste in the four sampling points (UPSSP, DWSSP, PDDSP and OPDSP), and this could likely be attributed to offensive and foul smell from leachates in the open dump, pipes and drainges that drains raw sewage and abbatoir wastes indiscriminately into the river especially from sampling point (PDDSP). From table 6.1, the average values of pH at UPSSP, DWSSP, PDDSP and ODSP are 8.4, 7.5, 7.6 and 7.6 respectively. pH is a very important parameter in water chemistry because the effectiveness of most treatment projects depends on pH. Its pronounced effect of acidification includes gradual removal of fishes, aquatic organisms, floral compositions are altered and macrophytes disappear. The four sampling points fall within the threshold limit when compared with WHO, (2004) and this is in line with earlier study reported by Chima, (2009) and Ubani, (2014) on the same river.

Turbid water is unacceptable to consumers from taste and aesthetic view point and also causes decrease in photosynthesis process by obscuring deep penetration of light in water. The average tubidity values at UPSSP, DWSSP, PDDSP and ODSP are 9.2NTU, 8.7NTU, 0.7NTU and 9.2NTU respectively and this varies significantly (P= 0.00`). Ajibade, (2004) and Adefemi, (2007), reported elevated turbidity values in rivers in Nigeria and linked it to run off effects as well as domestic discharges of wastes (urban wastes) into the rivers studied. Apart from PDDSP with average value of 0.7NTU the other sampling points recorded average value higher than the WHO threshold limit value of 5.0NTU and this can be attributed to run-offs from open dumps, drainages and heaps of refuse indiscriminately dumped along river course and decaying of plants and animal materials not excluding human activities which disqualifies its use as a source for domestic purposes. High turbid waters are associated with microbial contamination (DWAF, 1998).

The average values for total hardness for UPSSP, DWSSP, PDDSP and ODSP are 62 mg/l, 66mg/l, 180mg/l and 62mg/l respectively. This result obtained though within the set limit of 100mg/l for WHO indicates pollution especially at the PDDSP with the highest average value above WHO limit and this could be traceable to waste water from homes channeled through pipes into the river and also from drains containig abbatoir waste water and consequently from indiscriminate anthropogenic activities along the river banks such as swimming, bathing and washing as observed and reported by Nkwocha, (2014). High levels of hard water ions such as Ca^{2+} and Mg^{2+} can cause scaly deposits in plumbing, appliances and boilers and can combine chemically with soap molecules which results to decreased cleansing action. The average values recorded for Biological Oxygen Demand (BOD) at UPSSP, DWSSP, PDDSP and ODSP are 1.6mg/l, 4.8mg/l, 3.2mg/l and 4.8mg/l respectively. BOD shows directly the amount of degradable organic matter by microbial metabolism. More and More, (1976) categorized BOD water values as 1-2mg/l for clean water, 2-3mg/l for fairly clean water, 4-5mg/l for fairly polluted water and 10mg/l for bad and polluted water. This shows that UPSSP and PDDSP are fairly clean while DWSSP and ODSP are fairly polluted and this also accounts for the slight objectionable taste. Also observed is the nearness of the sampling point to open dump which is a factor that promotes the loading of the water bodies with organic matter.

The values obtained are lower than the WHO standard of (10mg/l) and are comparable to the study reported by Akubugwo and Duru, (2011).

Dissolved oxygen is a very important factor in the chemistry and microbiology of water as fish and other aquatic animals depend on oxygen for life, likewise organic waste contributed by domestic wastes or of plants and animal are oxidized by bacteria and micro organisms with the help of dissolved oxygen. Oxygen values are actually low where orgainic matter accumulates because aerobic decomposers require and consume oxygen. The average values for UPSSP, DWSSP, PDDSP and ODSP are 4.8mg/l, 4.8mg/l, 3.2mg/l and 9.6mg/l respectively. These low values when compared with WHO threshold limit of 10mg/l indicates pollution especially at PDDSP (3.2mg/l) and the major possible causes would likely include contamination from leachates from opendumps sites, abattoir, organic matter, human waste and dumping of refuse, and ofcourse, washing, bathing, farming along the river banks. This is in line with the study by Vincent, (2012).

The average values for Nitrate recorded at UPSSP, DWSSP, ODSP and PDDSP are 26.85mg/l, 26.90mg/l, 24.76mg/l and 26.50mg/l respectively. Nitrogen which usually exists in water bodies as nitrate is a key ingredient in fertilizers. Excess amount of bioavailable nitrogen in marine systems lead to eutrophication and algae blooms. The values obtained from laboartory analysis are lower than the WHO set limit of 35mg/l. The presence of nitrate is most likely as a result of wastes being disposed off from indiscriminate dumpsites along the river course and animal waste from the abbatoir and also from non-point run-offs from farms, leachates from the dumps. High concentration of nitrates has a harmful effect of causing methemoglobinemia or blue baby syndrome and have been sited as arisk factor in developing gastric intestinal cancer. Chapman, (1996). Coliform count and E. *coli* is a common and standard measure of the bacteriological quality of water, its presence indicates contamination of water by excreta. The average value of E.*coli*measured in CFU/ml of the river water samples in UPSSP, DWSSP, PDSSP and ODSP are 23cfu/ml, 35cfu/ml, 35cfu/ml and 19cfu/ml respectively while the values for the coliform count for the samples as in above are 120cfu/ml, 159cfu/ml, 239cfu/ml and 90cfu/ml respectively. From table 6.1 and in comparison with WHO permissible limit, it is observed that the values obtained are higher than the WHO standard. These high concentration especially in PDSSP is a good indication of the contribution of the abattoir wastes, open dumps, raw sewage being discharged indiscriminately along the river course as observed. It is obvious that the river water is contaminated with dangerous intestinal pathogens from these point and other non-point sources and this poses a threat and health concern to users if untreated.

A small amount of Phosphorus is an essential nutrient for all aquatic plants and algae but in high levels it can be considered as pollutant as it leads to proliferation of microscopic algae. The concentration levels of Phosphates at UPSSP, DWSSP, PDDSP and ODSP are 1.54mg/l, 3.14mg/l, 1.40mg/l and 0.93mg/l respectively. These values were found to be below the permissible limit of 10mg/l by WHO. Total Dissolved Solids (TDS) recorded average values of 44.0mg/l, 45.0mg/l, 422mg/l and 44mg/l at UPSSP, DWSSP, PDDSP and ODSP respectively. The presence of TDS and high concentration at PDDSP is an indication of intensive anthropogenic activities that drains both domestic waste water from homes, abbatoir and urban run-offs containing suspended materials. (Chapman, 1996). Though the concentration at PDSSP poses a threat to local population that uses it, the other sampling points are within WHO set limit of 250mg/l for water quality. Total Suspended Solids (TSS) which includes anything drifting or floating in the water from sediment, silt and sand to plankton and algae and organic particles from decomposing materials. The average concentration recorded for TSS in the four sampling points- UPSSP, DWSSP, PDDSP and ODSP are 0.15mg/l, 0.02mg/l, 0.01mg/l and 0.08mg/l respectively and are all below the permissible limit of 30mg/l for WHO standard.

The temperature, of the river water samples were all below the permissible limit of 30^{o}C when compared with WHO, (2004) standard. The temperature value recorded ambient temperature value of 23^{o}C which poses no threat to the homeostatic balance of the ruver. The concentration of the Chemical Oxygen Demand (COD) from UPSSP, DWSSP, PDDSP and ODSP are 40mg/l, 56mg/l, 20mg/l and 56mg/l respectively. High concentration of COD in surface water is an indication that the wastes discharged into the river is highly polluted with oxidizable organic and inorganic pollutants. The concentration at UPSSP and PDSSP (40mg/l and 20mg/l) are within the WHO permissible limit of 40mg/l, while DWSSP and ODSP (56mg/l and 56mg/l) recorded values higher than the WHO permissible limit. This is likely due to the rate of dilution of the pollutants at the sampling points and could be compared with the study by Magaji, (2012). The concentration values of Electrical Conductivity for UPSSP, DWSSP, PDDSP and ODSP are 96.80 εS/cm, 99εS/cm, 928.40εS/cm and 96.80εS/cm respectively varying significantly (p=0.000) and are found to be correlated to TDS. PDDSP had a value significantly greater than than the other three sampling point and far above the WHO set limit of 500εS/cm and has clearly been influenced by the abbatoir effluent, run-offs and flood water from drains and also pipes that drains domestic waste water at the point of discharge to the river.

CHAPTER SEVEN

SUMMARY, CONCLUSION AND RECOMMENDATION

7.1 Summary and Conclusion

River water pollution is still a serious problem that needs to be addressed because of the importance of streams as a source for domestic uses and various purposes to so many rapidly growing communities and individuals in Nigeria.

This study has tried to investigate the effect of urban waste on the water quality of Mmiriocha River. Findings from the results obtained show that the urban waste discharged or dumped indiscriminately along the course of the river has significant effects on the river water quality, although the average concentration values of most physicochemical parameters analyzed fell below WHO standards for drinking water. This improperly disposed urban waste within the river is a major threat to the quality of the river and could be attributed to rapid population growth, poor planning and inadequate sanitation facilities for waste management within the study area. The findings from this research has also shown that the sources of these pollutants into these water bodies are through drainages, abattoir waste, and farming along the banks, runoffs from the municipal dump sites, indiscriminate defecation and refuse disposal which had contributed to elevated levels of the contaminant. The discharge of organic waste including human and animal excreta, either directly or indirectly through runoffs, into the water systems has resulted in high coliform count, e.coli, BOD levels and consequently, low levels of dissolved oxygen in the waters. The low level of dissolved oxygen recorded for the entire study period is an indication that the river water in the study area may not support life sufficiently.

The most important finding is the high concentration of organic wastes and microbiological parameters (E.*coli*, coliform count Aerobic mesophylic count) above WHO standard which is a clear indication of contamination by human and animal excreta and this was as a result of untreated abattoir and raw sewage indiscriminately discharged in the river water which makes it most unfit for domestic consumption. These pathogens can cause diseases such as typhoid, gastroenteritis, hepatitis etc. Even though the people in the study area do not depend solely on this river water as their source of water supply, the spate of water shortages could turn the tide. The case in point demonstrates that proper sitting of waste disposal units is an important part of environmental hygiene and needs to be integrated into total environmental planning in the country. Moreover, unsanitary disposal of waste, not only provides harborage for disease vectors, causes emission of odor and environmental nuisance, but also defaces urban habitations and particularly affects ecological integrity of surface water.

The problem of Mmiriocha river water quality arising from its proximity to the waste dump, abattoir and heavily populated residential area and poor waste management may be more widespread than this study was able to recognize due to certain limitations of the study. More extensive surveys are needed to monitor the quality of the river water.

7.2 Recommendation

In order to meet the Millennium Development Goal of clean and quality water supply in Nigeria, and due to paucity of potable water in Enugu, which makes inhabitants depend heavily from surface water resources for domestic, agricultural and other uses, the problem of surface water pollution must be addressed. In view of the findings of this work, failure to appreciate that water is a finite resource and an economic and environmental good for sustainability development and in addition to the fact that an abattoir and a waste dump is located very close to the river in the study area, and that indiscriminately discharge of untreated sewage from residents may continue unabated, the following recommendations are hereby made:

- Appropriate policy, legal, regulatory and institutional framework towards surface water protection and effective waste management should be strictly enforced and upheld. An example is the development of an ecological land use planning that will regulate and control coastal development.

- Rapid population growth and urbanization should be accompanied by an increase in the delivery of essential urban facilities and services such as water supply, sewage and sanitation, and collection and disposal of wastes.
- Efforts should be made to commence activities towards the relocation of the abattoir and the open dump to an area far away from the river in the study area and an effective management and evacuation of wastes generated to improve dumpsite conditions.

- An organized aggressive public awareness, environmental education and enlightenment programmes on water conservation and management for effective sanitation and public health hygiene and also the possible effect of indiscriminate dumping of wastes within stream environments and of drinking untreated water should be embarked upon through participatory workshops, extension services, radio and television programmes etc. by concerned relevant agencies. This will improve the attitude of people towards maintaining and achieving a healthy neighborhood quality.

- There should be a corresponding participation and positive collaboration of communities, the public agency (ESWAMA) and the private sector on waste management and sanitation matters, and not creating the impression that sanitation is government business alone.

- The appropriate regulatory body should ban or prohibit disposal of wastes and other anthropogenic activities within stream environments and a monitoring team set to over see this. The throw-away culture will have to be strongly discouraged and encourage reuse and also an effective disposal mechanism of household waste in Abakpa be introduced that would enhance sustainable development. The outcome will be a safer and cleaner environment, where streams do not serve as receptacles for wastes.
- Efforts should be geared towards the use of scientific techniques to develop appropriate technologies for dealing with solid waste management such as

encouraging the emergences and development of industrial ecology where wastes from one activity are input of raw materials for another activity. For example, engineered sanitary landfill sites should be designed and operated in accordance with WHO standards.

It is in the opinion of this research work that the attainment of effective waste and surface water management and sustainable development will remain an illusion in developing countries in general and Nigeria in particular if the current rate of urban population growth and increasing environmental decay are not matched with proportionate economic growth and environmentally friendly development practices.

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