BACTERIAL CONTAMINATION OF SOME FRUITS SOLD AROUND SELECTED WASTEDUMPS IN OWERRI METROPOLIS, NIGERIA

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CERTIFICATION

We certify that this work titled **"BACTERIAL CONTAMINATION OF SOME FRUITS SOLD AROUND SELECTED WASTEDUMPS IN OWERRI METROPOLIS, NIGERIA"** was carried out by **Afor, Ifeoma Anna (20184140738)** of the Department of Environmental Management, Federal University of Technology, Owerri.

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DEDICATION

I dedicate this Thesis to my beloved parents Mr. Hyginus and Mrs. Patience Afor, you are indeed the best parents ever.

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ABSTRACT

Analysis of bacterial contamination of fruits sold near waste dumps in Owerri Metropolis were carried out, the various contamination levels were determined on fruits such as; orange (*Citru X sinensis*), water melon (*Citrullu slanatus*), apple (*Maluspumila*), garden egg (*Solanumme longena*), groundnut (*Arachis hypogeaa*), pawpaw (*Carica papaya*) and carbbage. Soil and fruit samples were collected at the market wastedumps and its surrounding in Owerri Metropolis. The soil was collected with a soil augar and was collected at 0cm to 15cm depth. Soil and fruit samples used as control were collected where there was no wastedump. A total of sixty fruit samples and thirty soil samples were collected. Microscopic, physical examination and biochemical tests were carried out; five bacterial species were isolated in the soil and fruit samples: Isolate A; *Bacillus Subtills*, Isolate B; *E. coli*; Isolate C; *Samonella* spp, Isolate D; *Staphlacocus* spp and Isolate E: *Klebsiellaspp.* Spread plate method was used in the analysis. The results indicate that the bacterial loads in the soil samples were twice of the fruit samples at each sampling point. The soil sample control had no bacterial growth, the fruit samples used as control gave total of 344 Cfu/g. The total mean of bacterial loads in the soil samples were 45,725,000Cfu and that of fruit samples were 10473.3Cfu. The correlation result gave +1 while the t-test was 1.375(Cal), which shows that the different between the two samples (Fruits and soil) were insignificant. The study recommends that Government should stop people from dumping refuse on open market streets, rather trucks should be provided to carrying refuse from various locations and take them to approved dumpsite. People selling fruits should be encouraged to display the fruits on a table and not on the ground where it can be contaminated.

Keywords: fruits sold, bacterial contamination, waste dumps, Owerri Metropolis.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Modernization and progress has had its share of disadvantages and one of the major aspect is pollution it is causing to the earth, be it land, air or water. With increase in the number of people in the world and the rising demand for food and other necessities, there has been an increase in the amount of waste being generated daily by each household (Ebere, 2016).

This waste is finally disposed into municipal waste collection centers from where it is collected by the area municipalities to be further thrown into the landfills and dumpsites. However, either due to resource crunch or inadequate infrastructure, all of the waste does not get collected and transported to the final dumpsite. At this stage, if the management of waste is not done properly, it causes serious environmental impact and serves as breeding ground for pathogens or bacterial (Azizullah Yosufi 2019).

Waste that is not properly managed, most especially excreta and other liquid and solid waste from household, market center and community are seriously affecting the environment and lead to the spread of infectious diseases. Unattended waste lying around attracts flies, rats, and other creatures that in turn spread disease and release a bad odour. This led to unhygienic conditions and thereby to a rise in the health problems. Microorganisms can spread through air, water, land and into the environment, especially on exposed food items.

Disposing of waste through open dumping with open burning is the way waste is taken care of in most developing countries. This practice has led to creation of dumpsites posing significant risks to neighbouring communities and the environment. Open dumping practices are still being practiced, as the dominant method, in both low-income and upper middle-income countries. The

practice tends to be eliminated in the developed world, although there are still reports of illegal dumpsites (European Comparative and International Environmental Law, 2017).

Recent reports indicate that roughly 3.5 - 4 billion people are served by dumpsites where 40% of the total waste generated is disposed of (Swidbert *et al.*, 2022).

Open dumping usually takes place close to the urban centers and in some cases

Open dumping usually takes place close to urban centers, but in some cases residential areas are find expanded around the dumpsites. Of almost all of the world's 50 biggest dumpsites, 5 are located near or even within urban areas and close to natural resources. Forty two out of the 50 dumpsites have settlements in a distance of less than 2 km, 44 dumpsites are close (less than 10 km) to natural resources and 38 dumpsites are close to water sources such as rivers, lakes, oceans, posing a threat to marine and coastal pollution. Obviously, although unquantified, the contribution of dumpsites to marine litter is substantial (Swidbert *et al.*, 2022).

Fruits sold in the open markets play an important socioeconomic role in fulfilling the food and nutritional need of urban consumers at affordable prices in the lowest income groups and are considered to be very convenient and cheap (Aybuike Sezgin, 2016). Fruits sold in the markets in Owerri also provide food security for low-income urban population and the livelihood of a significant proportion of the population in the city. These fruits sold in the markets are described as a wide range of ready-to-eat foods or fruits and are consumed in the market or at home without further washing or are washed casually (Kwadwu *et al.*, 2023). These fruits are usually sold by vendors and hawkers in the markets or in other similar public places. While fruits vendors or sellers are appreciated for their convenience, they are also important in contributing to the nutritional status of the population. Contrary to these potential benefits, it is also recognized that these fruits vendors are often poor, uneducated, and lack knowledge in safe food handling, environment, sanitation and hygiene. Fruits are displayed on the ground in most cases and the

water used to wash them is not potable water. Consequently, fruits sold on public roads are perceived as a significant major public health risk.

1.2 Statement of the Research Problem

Improper dumping of garbage leads to the accumulation of waste at fruit vending sites. This leads to an increase in the pest population and also an increased risk of fruit contamination. Food-borne microbial disease is a major health problem associated with fruits or foods sold in unclean environment (Khan Redzwan, 2016). In addition, the resistance of food-borne microorganisms to multi-drug has made the food security situation more vulnerable in public health (Narayan *et al.,* 2023). “Diarrheal diseases are cases of intoxication most common in fruits in Nigeria and in some cases can lead to death. Diseases are caused either by the toxin from the microbes or by the reaction of the human body to the microbes. The traditional processing methods used in the preparation, improper storage temperature and, and poor personal hygiene of food or fruits handlers are some of the main causes of street fruit contamination (Oduro-Yeboah *et al.,* 2020). In addition, fruits sold in these markets are not effectively protected against flies and dust (Gadafi *et al.,*2020). In Owerri, fruits are mainly displayed in most cases on the ground or on small height platforms without covering in various markets streets, roadside and some vendors hawk it around. A study is needed to determine the concentration of bacterial in fruits sold around selected waste dumpsites in the Metropolis of Owerri.

1.3 Aim and Objectives of the Study

The aim of this study is to ascertain the levels of bacterial contamination on fruits sold in open market near waste dumps in Owerri Metropolis.

This was achieved through the following objectives, to

i. Ascertain the various bacterial isolates in the fruits, such as orange (*Citrus sinensis*), water melon (*Citrullus lanatus*), apple (*Malus pumila*), garden egg (*Solanum melongena*), groundnut (*Arachis hypogeaa*), pawpaw (*Carica papaya*) and carbage (*Brassica oleracea)*

ii. Determine the bacterial load in the soil and the selected fruits in the Study area

iii. Compare the levels of bacterial loads in the contaminated soil with the control.

1.4 Significance of the Study

Waste is said to be hazardous if it is infectious, meaning containing viable microorganisms or their toxins which are known or suspected to cause diseases in animals or humans. Waste disposal poses threats to both man, animals and the environment. Poisonous plants, insects, animal and indigenous pathogens are biologic hazardous agents that might spread into the environment through wind and water, human pest etc. Through the spread of bacterial from the wastedumps into the environment through carrier including humans and other pests, fruit items can be contaminated. Hence, the need to study the contamination of bacterial on fruit items sold around selected wastedumps in Owerri Metropolis, in Imo State.

1.5 Scope of the Study

The study was done in selected sale outlets near wastedumps in Owerri Metropolis which include Ekeonuwa Market, MCC Road, Emmanuel College, Wetheral, Douglass Road, Aba – Owerri Road, Egbu Road, Relief Market, Maria – Assumpta Area, Nekede Road and Okigwe Road.

Laboratory analysis was carried out to determine the level of contamination in each sample.

The pathogen (bacterial) isolated were A; *Bacillus Subtills*, Isolate B; *E. coli*; Isolate C; *Samonella* spp, Isolate D; *Staphlacocus* spp and Isolate E: *Klebsiella* spp.

CHAPTER TWO

LITERATURE REVIEW

2.1 Pathogenic Bacteria

Bacterial are microscopic, single-celled organisms belonging to Kingdom Monera that possess a prokaryotic type of cell structure, their cells are non-compartmentalized, and their DNA (usually circular or cocci) can be found throughout the cytoplasm rather than within a membrane-bound nucleus. They reproduce by fission or by forming spores. They are found everywhere. They can live in all kinds of environment, they can be found; in soil, acidic hot springs, radioactive waste, seawater, deep in the Earth's crust, in stratosphere, and even in the bodies of other organisms (Microbiology Society, 2021).

2.1.1 Classification of Bacteria

Bacteria may be classified based on their shape: spherical (cocci), rod-like (bacilli), spiral (spirochetes), or comma-shaped (vibrios). Other ways of classifying them are based on whether or not they are: gram positive or gram negative, aerobic or anaerobic, autotrophic or heterotrophic, etc. (Microbiology Society, 2021).

Identification

Typically, identification is done by growing the organism in a wide range of cultures which can take up to 48 hours. The growth is then identified visually or genomically identified. The cultured organism is then subjected to various assays to observe reactions to help further identify species and strain (Ricardo, 2019).

2.1.2 Mechanisms of Damage

Pathogenic bacteria disrupt or interfere with the function of host's tissues, resulting in symptoms of disease. Bacteria have the ability to directly damage host cells.

They can also cause damage indirectly by inducing an immune response that damages host cells unintentionally (Rick *et al.*, 2016).

2.1.3 Direct damage on host

Once pathogens attach themselves to the host cells, they cause direct damage as they use the host cell as nutrients and produce byproducts. For example, *Streptococcus mutans*, a component of dental plaque, metabolizes dietary sugar and produces acid as a bye-product. The acid decalcifies the surface of the tooth to cause tooth decay (Nash, Anthony, Dalziel, Robert, Fitzgerald and Ross 2015). However, the toxins produced by bacteria cause most of the direct damage to host cells (Scholarly Community Encyclopedia, 2023).

2.1.4 Toxin production

Production of toxic *endotoxins* is the lipid portions of lipopoly saccharides that are part of the outer membrane of the cell wall of gram negative bacteria. Endotoxins are released when the bacteria are lysesd, so after antibiotic treatment, symptoms may initially worsen as the bacteria die and they release their endotoxins. *Exotoxins* are secreted into the surrounding environment or released when the bacteria die and the cell wall breaks down (Scholarly Community Encyclopedia, 2023).

2.1.5 Indirect damage on host

An excessive or inappropriate immune response triggered by an infection can damage host cells. (Medical Encyclopedia, 2023).

Nutrients

Iron is necessary for people, as is the development of most microscopic organisms. To obtain free iron, a few microorganisms discharge proteins called siderophores, which remove the iron from iron-transport proteins by restricting to the iron much more firmly. When the iron-siderophore

complex is framed, it is taken up by siderophore receptors on the bacterial surface and afterward that iron is brought into the bacterium (Briana *et al.,* 2017).

Treatment

According to Ricardo, (2019) bacterial infections can be cure with antibiotics, which are bacteriocidal species if they kill bacteria or hinder the growth if they simply prevent bacterial growth. There are many kinds of antibiotics and each class hinders a process that is different in the pathogen from that found in the host. For example, the antibiotics chloramphenicol and tetracyclin hinders the bacterial ribosome but not the structurally different eukaryotic ribosome, so they exhibit selective toxicity, (Tobias *et al.,* 2023). Antibiotics are used both in human disease as curative measures and in intensive farming to promote animal growth. Both uses may be reason for the rapid development of antibiotic resistance in bacterial populations. Phage therapy can also be used to treat certain bacterial infections (Fernando *et al.,* 2019).

Prevention

Infections can be prevented by antiseptic measures such as sterilizing the skin before piercing it with the needle of a syringe or any other sharp object and by proper care of indwelling catheters. Surgical and dental instruments should also be sterilized to prevent contamination by bacteria. Disinfectants such as bleach are used to destroy bacteria or other pathogens on surfaces to prevent contamination and further reduce the risk of infection. Bacteria in food are destroyed by cooking to temperatures above 73 °C (163 °F) (Fernando *et al.,* 2019).

2.2 Bacterial Usually Found in Municipal Solid Waste

Chetan *et al.* (2017) confirms that the most common pathogen that are generally found in solid waste are bacteria and fungi. These micro-organisms use the components of the waste as the substrate for their multiplication that is growth. They grow and multiply on the wastes by using the

various components that make up the solid waste. Furthermore, a large variety of pathogenic microorganisms have been reported to be present in these organic wastes (Chetan *et al.* (2017).

The below table shows the result of a research carry out by Chetan *et al.* (2017), on Isolation and Characterization of Bacteria from Solid Waste.

2.2.1 Sources of Bacterial in Municipal Waste Dump Site

Gauthami *et al.* (2021), said that certain components of MSW entering landfills can contain enteric pathogenic microorganisms such as bacteria, viruses, and parasites which are capable of causing disease in humans and animals (bacterial pathogens are the most common pathogens in waste). Food waste, pet excrement (i.e. dog and cat feces), human excrement in absorbent products (e.g. disposable baby napkins for children and adults, feminine hygiene products), and bio-solids generated at wastewater treatment plants are all potential sources of pathogenic, bacteria in dumpsites (Gauthami *et al.,* 2021). Previous studies on MSW have focused on types of indicator bacteria (total coliforms, faecal coliforms and faecal streptococci) or enter viruses in faeces (Amir *et al.,* 2019). The attempted to estimate pathogen loading from various sources, but available data were limited to contributions for certain sources to MSW and loading of various pathogens. Municipal or city waste landfills do not appear to pose a significant public health threat, especially since the required lining of new and expanded MSW landfills in the United States in recent decades. However, old unlined landfill sites could be point sources, so the risk of pathogen contamination could be site specific and dependent on disposal practices (Amir, *et al.,* 2019). The purpose of this study was to identify trends and quantify the potential contribution of pathogens from several components in MSW in landfills as an aid to the assessment of potential public health risks. The research to determine the risk from pathogen sources and releases through MSW can help local and national leaders in making reasonable decisions to bring about more sustainable waste management practices for their communities. Pathogenic micro-organisms may originate

from numerous sources in MSW and both enteric bacterial pathogens and viruses have been detected in MSW.

Solid waste materials that contain or become contaminated with untreated human excretion or animal excretions are potential sources of harmful bacterial. Fecal-contaminated wastes are of the greatest concern because they may contain pathogenic micro-organisms that can survive or adapt for significant periods of time in the environment. Contamination of water or food supplies by enteric micro-organisms found in faeces can cause large-scale of out-breaks of disease (Gauthami *et al.*, 2021).

2.3 Roles of Bacterial in the Environment

2.3.1 Waste Management

Microbes play an important role in waste that should not be overlooked. According to recent research, bacteria and other microbes are often cause illnesses, but they play an important role in the waste recycling process. They are responsible for the biological degradation of organic materials and nutrient recycling in the natural environment. In addition to this fundamental role, microbes are also essential in the fermentation process of waste recycling, biodegradation of oil in the marine ecosystems, helpful in the treatment of wastewaters and in the production of alternative energy.

2.3.2 Natural Biodegradation

Microorganisms recycle nutrients in the environment, by decomposing organic materials. Organic materials, such as animal carcasses and tree trunks, decay by the action of decomposing microbes, which are also responsible for getting rid of industrial and household waste. Through a process called biodegradation, microbes use nutrients and chemical substances found in the environment for their own survival. The nutrients from the breakdown of these products are free in the environment to feed plants or algae, which in turn feed all animal

2.3.3 Fermentation

People have used bacteria, yeasts and other microbes to produce many foods and beverages since several thousands of years ago or in ancient times. Bread is the product of a microbial fermentation process to produce carbon dioxide, which are spread in the dough making the bread rise. Microbes are also fundamental in the production of beer and wine, converting sugars into alcohol. Microbial fermentation is also a step during the chemical process of waste recycling. *Aspergillums carbonarius* is a microorganism used in the biodegradation of chromium shavings, which are part of tannery waste.

2.3.4 Energy Production

When biodegrading brewery waste and other organic materials, micro-bacters can produce methane gas, the major part of natural gas. As of February 2011, scientists at Cornell University, NY, also researched the use of microbial communities to produce liquid bio-fuels, reports Science Daily. Anaerobic microorganisms, which live in oxygen-insufficient environments, can also convert a mixture of manure and energy crops, such as sugarcane and maize, into electricity".

2.4 Effect of Bacterial on Human

Pathogenic microorganisms are microbes that can cause disease (Marcin, 2019). Robert, (2017) carried out a study on human pathogenic microscopic organisms. Even though most microscopic organisms are innocuous or frequently helpful, some are pathogenic, with some number of species estimated as less than 100, believed to cause sicknesses in humans. By contrast, thousand (s) of bacterial groups exist in the human alimentary canal.

Robert in 2017 further found out that, one of the bacterial infections with the highest sickness trouble is tuberculosis, the symptom is observe on the individual when he or she is affect by Mycobacterium tuberculosis microbes, which have slaughtered around 2 million individuals every year, for the most part in sub-Saharan Africa.

Pathogenic trouble is tuberculosis, the symptom is observe on the individual when he or she is affected by mycobacterium tuberculosis microbes, which have slaughtered around 2 million individuals every year, for the most part in sub-saharan Africa .Pathogenic microscopic organisms contribute to other diseases world over significantly, like pneumonia, which can be brought about by microorganisms like Streptococcus and Pseudomonas, and food-borne sicknesses, which is caused by microbes like Shigella, Campylobacter, and Salmonella. Pathogenic microscopic organisms likewise cause diseases like tetanus, typhoid fever, diphtheria, syphilis, and uncleanliness. Pathogenic bacterial are additionally the reason for high newborn child death rates in non-industrial nations (Robert, 2017).

Every species has explicit impact and causes side effects in individuals who are contaminated. A few, if not a great many people who are infected by pathogenic microbes do not have indications. But people with weak immune system are more vulnerable to pathogenic bacterial diseases on specific tissue (Micheal *et al.,* 2019).

Bacterial microorganisms usually cause contamination on some particular tissues of the body. Others are *Bacterial vaginosis* is brought about by microbacter that changes the vaginal microbiota, this change is achieve by an overgrowth of the microbial that grows out the Lactobacilli species that keep up sound vaginal microbial populaces.

Another non-bacterial vaginal disease include: yeast contamination (candidiasis), *Trichomonasv aginalis* (trichomoniasis) (Micheal *et al.,* 2019).

2.5 Concept of Municipal Waste

Municipal solid waste (MSW) consists of various solid wastes from towns and cities from different types of household activities. It may include waste that can decompose biologically, electrical and electronic waste, and composite waste such as clothing, hazardous waste (paints,

spray, and chemicals), and medical waste Morf *et al.* (2013). The composition of municipal solid waste varies greatly from municipality to municipality of from cities to cities, (Kumar *et al.,* 2016) and does not consist of the same types of waste all the time. In municipalities which have a well-developed waste recycling system, the waste stream mainly consists of intractable wastes such as plastic film and non-recyclablepackaging materials. At the start of the 20th century, the majority of domestic waste (53%) in the UK consisted of coal ash from open fires (Wikipedia, 2023). In developed areas, where there is no significant recycling activity, the municipal solid waste is predominantly includes food wastes, market wastes, yard wastes, plastic containers and product packaging materials, and other miscellaneous solid wastes from residential, commercial, institutional and industrial sources (United States Environmental Protection Agency, 2021). Most definitions of municipal solid waste do not include industrial, agricultural wastes,medical waste, radioactive waste or sewage. Waste collection is performed by the municipality within a specific area. The term *residual waste* relates to waste left from household sources containing materials that have not been separated out or sent for processing (Wikipedia, 2023). Waste can be classified in several ways but the following list represents a typical classification:

Biodegradable Waste: Food and kitchen waste, green waste, paper (most can be recycled although some difficult to compost plant material may be exclude) Christchurch city council, (2016).

Recyclable Materials: Paper, cardboard, glass, bottles, jars, tincans, aluminum cans, alumifoil, metals, certain plastics, fabrics, clothes, tires, batteries,

Inert Waste: Construction And Demolition Waste, dirt, rocks, debris.

Electrical and Electrons (WEEE): Electrical appliance, light bulbs, washing machine, TVs, computers, screens clocks, watches, etc.

Composite Wastes: Waste clothing, Tetra Packs, waste plastics such as toys

Hazardous Waste: Including most paints, chemicals, tires, batteries, light bulbs, electrical appliances, fluorescent lamps, aerosol spray cans, and fertilizers

Toxic Waste: Including pesticides, herbicides, and fungicides.

Biomedical Waste: Expired pharmaceutical drugs, etc.

2.6 Waste management hierarchy

According to Edmerls, (2017), the waste hierarchy refers to the "5Rs" refuse, reduce, reuse repair and recycle, which classifies waste management strategies according to their desirability in terms of waste minimization. The waste hierarchy is the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of end waste. The waste hierarchy is represented as a pentagon because the basic premise is that policies should promote measures to prevent the generation of waste. The next step or preferred action is to refuse to use inorganic materials, seek alternative uses for the waste that has been generated i.e. by re-use. The next is to repair when they are broken and then recycling which includes composting. Following this step is material recovery and waste-to-energy. The final action is disposal, in landfills or through incineration without energy recovery. This last step is the final resort for waste which has not been prevented, diverted or recovered (Awuchi *et al.,* 2023). The waste hierarchy represents the progression of a product or material through the sequential stages of the pentagon of waste management. The hierarchy represents the latter parts of the life-cycle for each product.

Life-Cycle of a Product

The life-cycle begins with design, and then proceeds through manufacture, distribution, and primary use and then follows through the waste hierarchy's stages of refuse, reduce, reuse repair and recycle. Each stage in the life-cycle offers opportunities for policy intervention, to rethink the need for the product, to redesign to minimize waste potential, to extend its use. Product life-

Ifeoluwa, (2019) cycle analysis is a way to optimize the use of the world's limited resources by avoiding the unnecessary generation of waste.

2.6.1 Solid Waste Management in Owerri Municipality

A study recently carried out on Solid Waste Management in Owerri Municipality and its Immediate surroundings, of the types of waste created showed that the major component of waste was biodegradable (62%) while non-biodegradation waste accounted for 31.6% of generated in the municipal Navarro *et al.* (2019), the figures of biodegradable and non-biodegradable wastes as 54 percent and 46 percent respectively. Oil Resources and Allied Investment Limited (2008). Owerri is administrative city and people living in Owerri are mostly civil or public servants (43.8% and students 25%). What people do so as to earn a living (economic) and social status of the people residing in the city could be the main reason for the huge amount of biodegradable waste generated, Asomani *et al*, (2008).

Waste management methods practiced in Owerri Metropolis are as follow: open dumping (46%) which is the least acceptable method superseded the others while sanitary landfill (15.1%) and burning (13.5%) ranked 2nd and 3rd respectively. Also, Olafusi (2004) and Iman *et al.* (2007), “most cities of Nigeria and other developing countries, the greater percentages of generated are dumped on the surface of the ground along major roads, streets and open spaces”. The finding was 10473.3CCed by the information obtained from field trips and direct observations which revealed the existence of more than 250 dumpsites of different sizes within the municipality and its environs, Navarro *et al.* (2019). It was also discovered that the quality of wastes generated daily has over–whelmed the existing man-power and equipment resulting to their constant break down. The reason for inadequate equipment and lack of technical-Know-how may be ascribe to lack of funds, corruption, poor maintenance culture and lack of executive will whereby investment in waste management is regarded as a waste of resources since it is regarded as a non- profitable venture. Other waste management methods used were either purported or practiced at a minimal

level and could not contribute meaningfully to effective solid waste management. Giving credence to these findings people directly involved in waste handling confirmed that there is no concrete solid waste management system, describing the method practiced as simply refuse displacement which involves the transfer of wastes from one location to another.

Resource Efficiency

Resource efficiency reflects the understanding that global economic growth and development cannot be sustained at current production and consumption patterns. Globally, humanity extracts more resources to produce goods than the planet can mreplenish (United Nation Department of Economic and Social Affairs (USEPA, 2023). Resource efficiency is the reduction of the environmental impact from the manufacturing and consumption of these goods, from final raw material extraction to last use and disposal.

Polluter-Pays Principle

The polluter-pays principle mandates that the polluting party pays for the impact on the environment. With respect to waste management, this generally refers to the requirement for a **Waste Handling Practices**. Curbside collection is the most common method of disposal in most European countries, Canada, New Zealand, United States, and many other parts of the developed world in which waste is collected at regular intervals by specialized trucks. This is often associated with curb-side waste segregation. In rural areas waste may need to be taken to a transfer station. Waste collected is then transported to an appropriate disposal facility. In some areas, vacuum collection is used in which waste is transported from the home or commercial premises by vacuum along small bore tubes. Systems are in use in Europe and North America.

In some jurisdictions unsegregated waste is collected at the curb-side or from waste transfer stations and then sorted into recyclables and unusable waste. Such systems are capable of sorting large volumes of solid waste, salvaging recyclables, and turning the rest into bio-gas and soil

conditioner. In San Francisco, the local government established its *Mandatory Recycling and Composting Ordinance* in support of its goal of "Zero waste by 2020", requiring everyone in the city to keep recyclables and compostables out of the landfill. The three streams are collected with the curbside "Fantastic 3" bin system – blue for recyclables, green for compostables, and black for landfill-bound materials – provided to residents and businesses and serviced by San Francisco's sole refuse hauler, Recology. The City's "Pay-As-You-Throw" system charges customers by the volume of landfill-bound materials, which provides a financial incentive to separate recyclables and compostables from other discards. The City's Department of the Environment's Zero Waste Program has led the City to achieve 80% diversion, the highest diversion rate in North America. Other businesses such as Waste Industries use a variety of colors to distinguish between trash and recycling cans.

Financial Models

In most developed countries, domestic waste disposal is funded from a national or local tax which may be related to income, or property values. Commercial and industrial waste disposal is typically charged for as a commercial service, often as an integrated charge which includes disposal costs. This practice may encourage disposal contractors to opt for the cheapest disposal option such as landfill rather than the environmentally best solution such as re-use and recycling.

In some areas such as Taipei, the city government charges its households and industries for the volume of rubbish they produce. Waste is collected by the city council only if it is put in government issued rubbish bags. This policy has successfully reduced the amount of waste the city produces and increased the recycling rate (Jack, 2023).

Morocco has also seen benefits from implementing a $300 million sanitary landfill system. While it might appear to be a costly investment, the country's government predicts that it has saved them another $440 million in damages, or consequences of failing to dispose of waste properly.

2.7 Disposal Methods

2.7.1 Landfill

A landfill is a site for the disposal of waste materials by burial. Landfill is the oldest form of waste treatment, although the burial of the waste is modern; historically, refuse was simply left in piles or thrown into pits. Historically, landfills have been the most common method of organized waste disposal and remain so in many places around the world.

2.7.2 Incineration

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. This method is useful for disposal of both municipal solid waste and solid residue from waste water treatment. This process reduces the volumes of solid waste by 80 to 95 percent. ("How the world should cope with its growing piles of rubbish"). Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam and ash.

Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants.

Incineration is common in countries such as Japan where land is scarcer, as the facilities generally do not require as much area as landfills. Waste-to-energy (WtE) or energy-from-waste (EfW) are broad terms for facilities that burn waste in a furnace or boiler to generate heat, steam or electricity. Combustion in an incinerator is not always perfect and there have been concerns about pollutants in gaseous emissions from incinerator stacks. Particular concern has focused on some

very persistent organic compounds such as dioxins, furans, and PAHs, which may be created and which may have serious environmental consequences.

2.7.3 Recycling

Recycling is a recovery technique that entails collecting and reusing waste materials such as empty soda cans. The materials used in making the pieces can be reprocessed into new items. Recycling materials can be collected separately from trash using special bins and delivery vehicles, a process known as kerb side collection. Prior to collection, the owner of the waste is expected in certain societies to separate the waste into different bins (e.g., for paper, plastics, and metals). In other communities, all recyclable items are collected in a single container, and processing is done at a central facility later.

"Single-stream recycling" is the term for the latter process. "The most common consumer products recycled include aluminum such as beverage cans, copper such as wire, steel from food and aerosol cans, old steel furnishings or equipment, rubber tyres, polyethylene and PET bottles, glass bottles and jars, paper board cartons, newspapers, magazines and light paper, and corrugated fiberboard boxes.

PVC (Polyvinyl chloride) and LDPE (Low-Density-Polyethylene), are also recyclable. These items are usually composed of a single type of material, making them relatively easy to recycle into new products. The recycling of complex products (such as computers and electronic equipment) is more difficult, due to the additional dismantling and separation that have to be done.

The type of material taken for recycling varies by city and country. Each city and country has different recycling programs in-place that can handle the various types of recyclable materials. However, certain variation in acceptance is reflected in the resale value of the material once it is reprocessed. In July 2017, the Chinese government announced an import ban of 24 categories of

recyclables and solid waste, including plastic, textiles and mixed paper, placing tremendous impact on developed countries globally, which exported directly or indirectly to China (Walker, 2018).

2.7.4 Re-use

Biological Reprocessing

Plant material, food scraps, and paper products are examples of recoverable organic materials that can be recovered by composting and digestion processes to decompose the organic matter. In The organic waste is then recycled as mulch or compost for use in agriculture or landscaping. Furthermore, waste gas from the process (such as methane) can be captured and used to generate electricity and heat (CHP/cogeneration) to increase performance.

The aim of biological processing in waste management is to monitor and speed up the natural process of organic matter decomposition.

Energy Recovery

Energy recuperation from waste is the transformation of non-recyclable squander materials into usable warm, power, or fuel through an assortment of forms, counting combustion, gasification, pyrolyzation, anaerobic absorption, and landfill gas recuperation (USEPA, 2023). This process is often called waste-to-energy. Energy recovery from waste is part of the non-hazardous waste management hierarchy. Using energy recovery to convert non-recyclable waste materials into electricity and heat, generates a renewable energy source and can reduce carbon emissions by offsetting the need for energy from fossil sources as well as reduce methane generation from landfills This prepare is frequently called waste-to-energy. Energy recuperation from waste is portion of the non-hazardous waste management hierarchy. Utilizing energy recuperation to change over non-recyclable waste materials into electricity and heat, creates a renewable energy source and can reduce carbon outflows by offsetting the required energy from fossil sources as well as reduce methane era from landfills (USEPA, 2023).

Waste products may have their energy content directly harnessed by using them as a direct combustion fuel, or indirectly by converting them into another form of fuel. Thermal treatment includes anything from using waste as a source of fuel for cooking or heating to using gas as a fuel for boilers to produce steam and electricity in a turbine.

Pyrolysis and gasification are two types of thermal treatment that involve heating waste materials to high temperatures with little oxygen available. Under high pressure, the procedure is normally carried out in a sealed chamber. Solid waste is pyrolyzed to produce solid, liquid, and gaseous materials. The liquid and gas can be burned to generate electricity or transformed into other chemicals (chemical refinery).

The solid residue (char) can be converted into activated carbon and other things.

Gasification and new technologies and Organic materials are converted directly into a synthetic gas (syngas) consisting of carbon monoxide and hydrogen using plasma arc gasification. After that, the gas is burned to generate electricity and steam. Supercritical water decomposition at high temperatures and pressures is an alternative to pyrolysis (hydrothermal monophasic oxidation).

Pyrolysis is regularly utilized to change over numerous sorts of household and mechanical buildups into a recovered fuel. Diverse sorts of waste input: such as plant waste, nourishment squander, tires, set within the pyrolysis prepare possibly yield an alternative to fossil powers (Waste Hierarchy, 2014).

Pyrolysis is a process of thermo-chemical decomposition of natural materials by heat within the absence of stoichiometric amounts of oxygen; the decay produces different hydrocarbon gasses (Czajczyńska *et al.,* 2017). Amid pyrolysis, the atoms of question vibrate at tall frequencies to a degree that atoms begin breaking down. The rate of pyrolysis increments with temperature.

In mechanical applications, temperatures are over 430 °C (800 °F). Moderate pyrolysis produces gasses and strong charcoal (Reference book Britannica). Pyrolysis hold guarantee for transformation of waste biomass into valuable liquid fuel. Pyrolysis of waste wood and plastics can possibly deliver fuel.

The solids cleared out from pyrolysis contain metals, glass, sand and pyrolysis coke which does not change over to gas. Compared to the method of cremation, certain sorts of pyrolysis forms discharge less destructive by-products that contain soluble base metals, sulfur, and chlorine. In any case, pyrolysis of some waste yields gasses which affect the environment such as HCl and SO_2 (Prabir Basu: Biomass Gasification, Pyrolysis and Torre faction).

Resource recovery is the orderly redirection of waste, which was expecting for disposal, for a specific utilize (Chen, *et al.,* 2014). Is the handling of recyclables to extricate or recuperate materials and resources, or change over to energy?

These exercises are performed at a resource recovery office (USEPA, 2023). Resource recovery is not as it were environmental friendly, but it is additionally cost-effective (Government of Montana, 2023). It decreases the sum of waste for disposal, Economic – Improving financial productivity through the use of resource utilize, saves space in landfills, and moderates common resources (Government of Montana, 2023).

Asset recuperation (as against the waste management) employments LCA (life cycle examination) try to offer options to waste administration. For blended MSW (Civil Strong Squander) a number of wide research have shown that administration, source sorting and collection, taken after by recycling and reusing of the non-organic division and vitality and compost/fertilizer creation of the natural fabric through anaerobic absorption to be the favored way.

As a case of how asset reusing can be advantageous, numerous things tossed away contain metals that can be reused to make a benefit, such as the components in circuit sheets. Wood chippings in

beds and other bundling materials can be recycled to valuable items for cultivation. The reused chips can cover ways, walkways, or field surfaces.

Application of rational and consistent waste management practices can yield a range of benefits including:

Treatment and disposal and creating markets for recycles can lead to efficient practices in the production and consumption of products and materials resulting in valuable materials being recovered for reuse and the potential for new jobs and new business opportunities (Wikipedia, 2023).

Social – By lessening unfavorable impacts on wellbeing by legitimate waste management hones, this brings about results that engaged civic communities. Superior social points of interest can lead to new sources of jobs and possibly lifting communities out of poverty particularly in a few of the poorer nations and cities.

Environmental – Reducing or disposing of unfavorable impacts on the environment through reducing, recycling and reusing, and minimizing asset extraction can result in progressed discuss and water quality and offer assistance within the diminishment of nursery gas emanations.

Inter-generational Value – Taking after a successful waste management hone can give consequence as a stronger economy, a more pleasant and more comprehensive society and a cleaner environment (United Nations Environmental Programme, 2023).

Sustainability

The management of waste may be an important component in a business' capacity to preserve ISO14001 accreditation. The standard energizes companies to make strides their natural efficiencies each year by eliminating waste through asset recuperation hones. One way to do this can be by receiving asset recuperation hones like reusing materials such as glass, nourishment

scraps, paper and cardboard, plastic bottles and metal. Reused materials can regularly be sold to the development industry. Numerous inorganic waste streams can be utilized to deliver materials for development. Concrete and bricks can be reused as fake rock. This theme was on the motivation of the Universal WASCON conference in Spain in June 2015 and on the universal Conference on Green Urbanism, held in Italy (UNEP, 2023).

Avoidance and Reduction

A critical strategy of waste management is the avoidance of waste from being produced, also known as waste reduction. Strategies of shirking incorporate reuse of second-hand items, repairing broken things rather than buying new ones, manufacturing products to be refillable or reusable (such as cotton rather than plastic shopping sacks), discouraging customers from utilizing disposable product (such as expendable cutlery), expelling any food/liquid remains from cans and packaging, and creating items that utilize less material to attain the same reason (for case, light weighting of cans drinks) (Schneider *et al.*, 2012).

2.8 Challenges in Developing Countries

Regions with developing economies frequently encounter depleted waste collection services and insufficiently managed and uncontrolled dumpsites, with administration complicating the issue (Marcela *et al.*, 2021). Waste administration in these nations and cities is a continuous challenging due to failed educational system, inveterate under-resourcing and fast urbanization (UNEP, 2023). These challenges, along with the lack of understanding of different factors that contribute to the hierarchy of waste management, affect the treatment of waste (Marcela *et al.*, 2021).

Technologies

Traditionally, the waste management industry has been a late adopter of new technologies such as RFID (Radio Frequency Identification) tags, GPS and integrated software packages which enable better quality data to be collected without the use of estimation or manual data entry (Ojo, 2018).

2.8.1 Bacterial Usually Found in Municipal Solid Waste

Amalraj, (2006) confirm that the most common pathogen that are generally found in solid waste are bacteria and fungi. These micro-organisms use the components of the waste as the substrate for their multiplication that is growth. They grow and multiply on the wastes by using the various components that make up the solid waste. Furthermore, a large variety of pathogenic microorganisms have been reported to be present in these organic wastes (Amalraj, 2006).

The below table shows the result of a research carry out by Chetan *et al.* (2017), on Isolation and Characterization of Bacteria from Solid Waste

Table 2.1: Types of Bacteria with frequencies of isolation on the waste dumps

Organism	**Frequencies**
Pseudomanas spp	27.50%
Bacillus pasteurii	22.25%
Staphylococcus aureus	19.5%
Coryne bacterium	1%
Aeromonas species	17%
Micrococcus roseus	10%
Corynebacterium xerosis	0.5%
Eschresia	3.50%
Corynebacteriums	0.21
Alcaligenesfacilis	0.22

In Nigeria recently, some researches carried out some work on bacterial contamination in soil around open dumpsites. According to Hugbo and Okonkwo (2019), *Staphylococcus aureus*

constituted the most widely and frequently isolated potential pathogen. *Proteus mirabilis, Escherichia coli,* and *Klebsiella spp.* Also, William and Hakam, 2016 record that *Bacillus sp.,* and *Clostridium sporogenes* more frequently, while *Proteus spp*. had the smallest appearing frequency of bacterial isolate. The isolation of *Bacillus sp., Pseudomonas sp., Staphylococcus sp.,* from the soil samples was in accordance with the work of Obire *et al.* (2002).

2.9 Environmental and Social Issues Due to SW Mismanagement

2.9.1 MSW Open Dumping

In countries that are still developing, the management of SW is worsened by unsustainable practices that improve the environmental contamination and the spread of diseases. In particular, the open dumping in uncontrolled sites, open burning of waste fractions and the mismanagement of the leachate produced in final disposal sites, are the main issues detectable (Modak *et al.,* 2015). The situation is worsened in slum areas with additional problems of high-density population, traffic, air and water pollution. Uncontrolled disposal on open spaces near water bodies are great issues that needs attention globally in these contexts, which corresponds to public health issues (Manaf *et al.,* 2009).

Concerning open air final disposal, the main environmental impacts detectable are:

i. Visual impacts,
ii. Air contamination, odors and green-house gasses (GHG) emission,
iii. Vectors of diseases,
iv. Surface water and groundwater pollution (Peiyve *et al.,* 2021).

These issues are noticeable worldwide. In Banjul (Gambia) the dump site is located in an over populated areas, visible to the residents or people living in the area (Peiyve *et al.,* 2021).

It has a negative visible impact on people living in the area and tourists visiting the country. In particular, the smoke from burning debris is the biggest challenge, which covers some of the

residential areas, affecting also the life quality of the population. Indeed, the citizens are affected by the smoke from burning debris and the smell of decomposing waste. The nuisances are worst during the rainy period as the area becomes infested with flies and insects. Run off from the dump site with contaminants dissolved inflow into water bodies, while the leachate contaminates the soil and groundwater. Moreover, environmental contamination is due to the high level of fecal and total coliform that polluted the wells located near the site. The households that live around the dump site use well water for various purposes, although with high level of coliforms attributed to the proximity to the dump site (Seng *et al.,* 2018).

In Cambodia, in the capital city Phnom Penh, where the MSW management (MSWM) system lacks regulation, households commonly burned, buried, or dumped about 361,000 tons of MSW in 2008, and 635,000 tons in 2015 (Seng *et al.,* 2018). Also, in Thailand, more than 60% of the municipal SW final disposal was on open dumpsite. In 2004 there were 425 disposal sites, of which 330 was open dumps, the majority of disposal sites received about 25 tons of waste daily, while only the landfills of Bangkok received about 4500 tons daily (Chiemchaisri *et al.,* 2007). In the West Bank Palestinian territory, in 2005 was estimated that the MSW generated was around 2728 tons per day, while in 2001 there were 133 MSW dumpsites, open burning was practiced at 116 sites and burial at 13 sites; 64.9% of the population was aware of the environmental challenges and impacts associated with open dumpsites, and 41.6% thought that they were suffering because of the final disposal sites close to them (Al Khatib, 2015). In the capital city of Nigeria- Abuja, more than 250,000 tons of waste was generated every year in 2010. There were four major disposal dumpsites under its management, closed in 2005 due to odours, air pollution and burning of wastes at the dumpsite. Moreover, percolation of leachate from the buried waste flowed to the surface, especially during rainy seasons (Aderoju, *et al.,* 2018). In Maputo, administrative center of Mozambique, with about 1,200,000 people living in and where about 0.5 kg of waste per inhabitants are generate daily, the MSW is transported to the legal dumpsite of the

city, in operation over 40 years ago. The area is of about 17 ha, with heights that achieved 15 m; open fires and auto ignition of the waste are common challenge, exacerbated by the more than 500 waste pickers collecting recyclables waste at the dumpsite (Muchangos *et al.*, 2015). Therefore, SWM challenges are common worldwide, with environmental burdens and hazard for the population.

According Torretta *et al.* (2017), the landfill leachate generates in open dump sites contains concentration of organic carbons, ammonia, chloride, heavy metals, also as well as high concentrations of fluoride, chloride, ammonium–nitrogen, biological oxygen demand (BOD) and chemical oxygen demand (COD) as Karak, Bhattacharyya, Das, Paul and Bezbaruah researched. For instance, the MSW dumped at Mathkal dump site (Kolkata, India), is causing the degradation of water quality in and around dumpsite area: Cd and Ni are detectable in leachate, in groundwater contamination; the metals Pb, Cd, Cr and Ni are characterized as toxic for drinking water, and the concentration of these components increases near an unsanitary landfill and may lead to serious toxic risks. It has been reported that concentration of Cr, Cd, and Mn were higher in the groundwater due to leachate, affecting the life of the population and the quality of the environment (Babu *et al.*, 2010).

According to Parameswari *et al*. (2015) leaching of heavy metals in the water imposes serious health risks to humans. Heavy metal concentration of the soil samples at various depths ranges from 3.78 mg kg^{-1} to 0.59 mg kg^{-1} at a depth of 2.5 to 5.5 m, with concentration higher in the top soil up to a depth of 5.5 m (sandy clay layer). Therefore, the concentrations of heavy metals decreased with increasing soil depth, demonstrating the influence of the dumping activities". In Nonthaburi dumpsite, Thailand, the concentration of heavy metals was detected in boreholes and runoff. Within the runoff and the groundwater, the concentrations of chrome, cadmium, lead, nickel and mercury, are always ten times above the limits introduced by the World Health Organization (WHO) for drinking water (Prechthai *et al.*, 2008). In Tiruchirappalli district, India,

the MSW generation is about 400–600 tons per day and it is served by an open dumping site located 12 km from the city. The leachate shows that the range of COD range to 29,880–45,120 mg L^{-1} and the BOD_5 / COD ratio was less than 0.1. Based on the average concentration, the quantity of lead and cadmium were 5 and 11 times higher the soil contamination limits.

Another environmental issue due to organic waste open dump is the Gas Waste Produce due to waste anaerobic degradation. Methane gas is a by-product of landfilling MSW; since MSW is mainly disposed off in open dump sites, the generated methane is released directly into the surrounding air km. Experimental studies indicate that the anaerobic biodegradation of MSW organic waste generates about 200 Nm^3 of methane per dry tons of biomass (Themelis and Ulloa, 2007). Methane is one of the most important gas that improve the GWP, 25 times higher than CO_2 (Boucher *et al.*, 2009). Therefore, open dumps and uncontrolled landfills are direct source of GHG.

As a comparison, GHG emissions from waste landfilling were estimated per type of final disposal site: open dump, conventional landfills with energy recovery, and landfills receiving low-organic-carbon waste. The results showed that about 1000 kg CO_2-eq. t^{-1} are generated from an open dump, 300 kg CO_2-eq. t^{-1} from a conventional landfilling of mixed waste and 70 kg CO_2-eq. t^{-1} for low-organic-carbon waste landfills. If compared with the emissions due to provision of energy and materials to the landfill, estimated to 16 kg CO_2-eq. t^{-1}, it can be stated that open dump cause a GWP at least 50 times higher than the total MSWM system (Manfredi *et al.*, 2009). In Beijing City, where more than 60% of the waste is disposed of in sanitary landfills, an environmental impacts assessment showed that CH_4 emission is the most dominant contributor to GWP, with the annual amount of 55,000 tons; the landfills contribute the most to the impact potentials mainly due to methane emissions (Zhao *et al.*, 2015). In India, most of the SW is disposed of by landfill in open dump sites, generating large quantities of CH_4. At national level, it was estimated that the

methane emission from MSW disposal varies from 263,020 t in year 1980 to 502,460 t in year 1999 (Kumars *et al.,* 2004), increasing rapidly during the years.

Therefore, the mitigation of pollution and GHG emission can be obtained through the recovery and conversion of organic component to energy or compost. The main role is played by policy interventions, which should act through the incorporation of the waste management hierarchy considering direct and indirect impacts that would reduce the global carbon footprint (Ramachandra *et al.,* 2018).

2.9.2 Solid Waste Management in Owerri Municipality

Generally, wastes are materials or substances that are considered useless by the manufacturers or headline and therefore disposed off. Waste take three different forms; solid, liquid and gaseous (Uwakwe, 2013). The World Health Organization (WHO, 1994) defines solid waste as an unwanted and discarded material resulting from domestic, community, industrial, commercial and agricultural activities with little or no liquid content to flow freely. While waste management involves the following processes: collecting, transporting, processing or disposing, managing and monitoring of waste materials. The term usually relates to substances produced by human activities and the process is generally done to reduce the effect of waste on health, the environment or aesthetics according to, Adogu *et al.* (2015).

Waste creation is a continuous process and occurs in all places where there is life. As an important part of metabolism, living organisms produce different kinds of waste products which are released into the environment. Apart from this, other activities of man such as agriculture, food processing, wood work, building and construction and others also release different forms of wastes into the environment. In time past, the wastes produced were mainly organic and sufficiently decompose by saprophytic microbes and therefore posed no harm to environmental health and human health. The present time of technological advancement and industrialization has introduced different

forms of equipment and facilities into government established offices, residential homes, learning centers, industries and commercial centers. The application of these gadgets has tremendously improved production and living standard of the people and consequently the economy of many countries. However, the introduction and use of these machines brings about the generation of more wastes, some of which cannot be decompose by biological processes and are hazardous. Also, the amount and quality of organic wastes produced have become so much and cannot be cleanse microbes in the natural environment alone, resulting to the huge quantity of refuse found along the streets, roads, gutters, markets places and even in rivers in most cities of developing countries. Furthermore, urbanization brings about increased in population in urban cities. As soon researches have commented on the alarming rate of urban population growth, (Imam *et al.,* 2007) and they report that while Nigeria's population increased by about 2.8% per annum, the rate of urban growth is as high as 5.5%.

A study recently carried out on Solid Waste Management in Owerri Municipality and its Immediate surroundings, of the types of waste created showed that the major component of waste was biodegradable (62%) while non-biodegradation waste accounted for 31.6% of generated in the municipal Uwakwe, (2013), the figures of biodegradable and non-biodegradable wastes as 54 percent and 46 percent respectively. Oil Resources and Allied Investment Limited (2008). Owerri is administrative city and people living in Owerri are mostly civil or public servants (43.8% and students 25%). What people do so as to earn a living (economic) and social status of the people residing in the city could be the main reason for the huge amount of biodegradable waste generated, Asomani *et al*, (2008).

Improper solid waste management poses a great danger to the health conditions of the people, and the environment. These results are consistent with the work carried out by Stephen and Harpham (1992); Songsore and Macgranahan (1993) who attributed the prevalence of diseases, morbidity and mortality in Most African cities to poor sanitation and improper waste disposal practices. The

reports of environment Canada (2002), Olotuah and Fadairo (2005) and USAID (2008) revealed that flood, climate change and environmental carriers were partly due to the impact of inadequate solid waste management systems in developing countries. From the results obtained, most people claimed being aware (88.4%) of the health and environmental impacts of improper solid waste disposal, yet wastes are dumped indiscriminately in and around the city. The unsanitary health conditions could therefore not only be to linked inadequate supply of equipment and man-power or lack of awareness but to people's poor attitude to waste disposal and environmental hygiene, and lack of legislation which depicts in the manner people throw out wastes from moving vehicles, litter homes, institutions, markets and business premises with wastes, misuse public lavatories and defecate on roadsides even in broad day light Uwakwe, (2013). It is a common practice now especially around the municipality for landlords not to install toilet facilities in their houses, leaving their tenants with the options of either using nearby bushes or polythene bags which are thrown out along with other wastes, while wastes water is channeled to the roads. The objective of environmental sanitation is to create and maintain conditions that will promote health and prevent diseases Lucas and Gilles, 1990. Diseases associated with unsanitary health conditions include cholera, dysentery, diarrhea, gastroenteritis, malaria, typhoid fever and various other air- and water–related diseases USAID, 2008, Waste Info Sheet, 2009). This disease if mishandled can lead to morbidity and death. Consequently, with decayed environment and loss of man-power, the people are unable to maximize benefits of developing the environment and exploiting the available resources to service the essential needs of the populace. This in turn affects the economic development of the city and achievement of sustainable development.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location

The study was carryout in Owerri Metropolis which consists of three areas; Owerri Municipal, Owerri North and Owerri West. Owerri has an estimated population of approximately 1,401,873 as of 2016 and is approximately 100 square kilometres (40 square miles) in area. Owerri is bounder by Otamiri River to the east and the Nworie River to the south, (Alex, Acholonu 2008). The coordinates of Owerri are latitude **5.476310ºN** and Longitude **7.025853ºE** (Fig. 3.1).

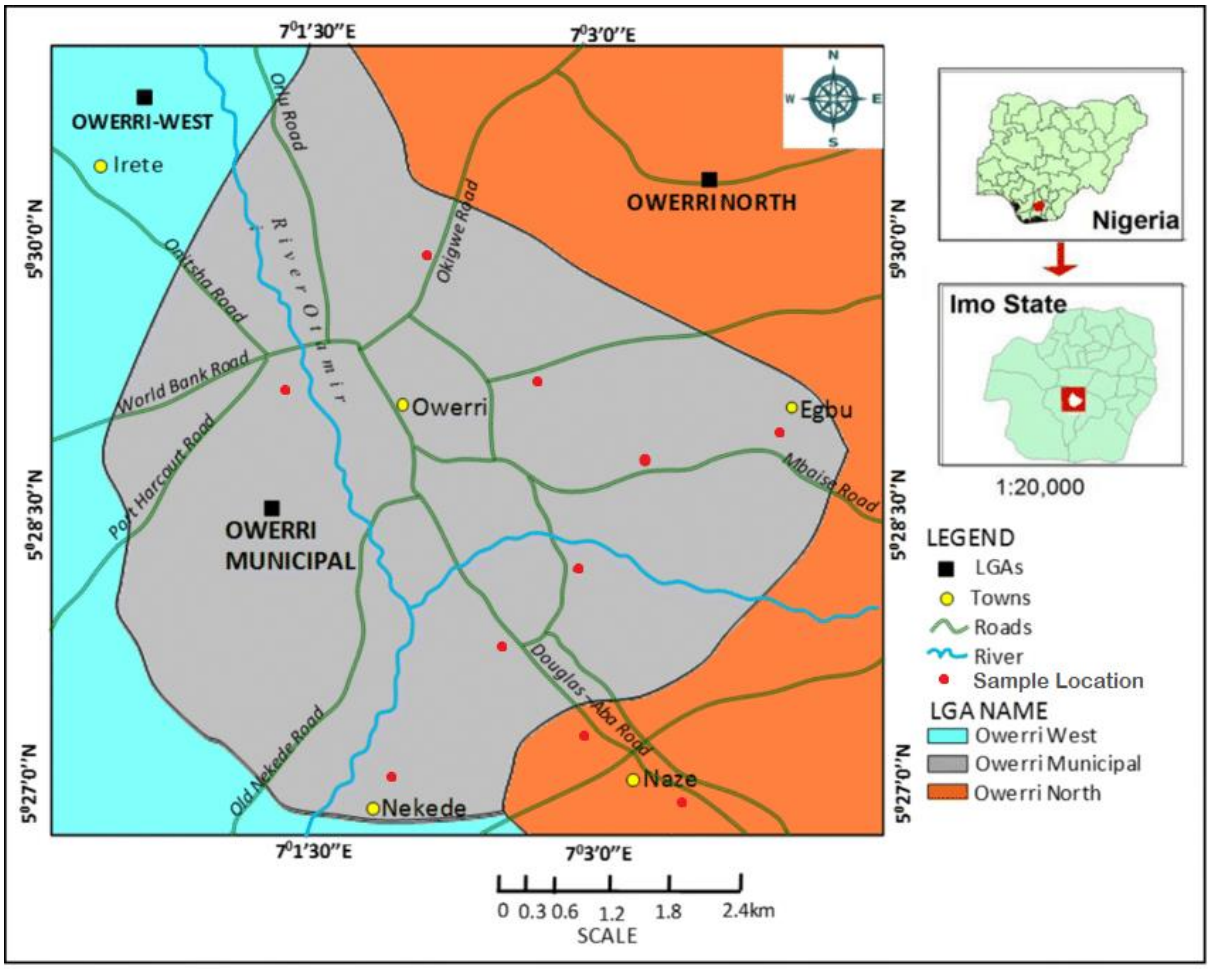

Figure 3.1: Map of the study area

Source: Researcher (2022)

3.1.2 Climate

Owerri has a humid tropical climate according to the Kopped-Geiger system. Rain falls most of the month of the year with a brief dry season, the city experiences harmattan and is significantly less pronounced than in other cities in Nigeria. The average temperature is 26.4^{o}C (em.wikipedia.org/wiki/Imo-state).

Owerri Climate Summary

Owerri has a Tropical wet and dry or savanna climate (Classification: Aw). The average temperature is 26.4^{o}C (em.wikipedia.org/wiki/Imo-state) and it is -1.22% lower than Nigeria's averages. Owerri typically receives about 229.07 millimeters (9.02 inches) of precipitation and has 262.95 rainy days (72.04% of the time) annually

Soil Type

In recent research investigated by Maduike *et al.* (2020) indicate that the soil in Owerri Metropolis is predominantly sandy clay and silt ranging from 2-10% and 9-25%; respectively.

Land Use

According to recent research, the land use system in Owerri Metropolis during the pre-colonial period was communal. The land was deemed not owned by individuals but by communities and families in trust for all the family members but after the pre-colonial period law was implemented to eliminate the pre colonial land use to facilitate private ownership of land

3.1.3 Sample Location

The Wastedump was located in the following locations: Wetheral, Emmanual College, Mbaise Road, Relief Market, Egbu Road, MCC Road, Aba Road, Ekeounwa Market, Nekede Road and Okigwu (Control). Soil samples collected at each wastedump was collected in three points and label as S1W, S2E, S3M, S4R, S4ER, S6MC, S7AR, S9EK, S10N and S8C. The fruits was collected in 3 replica and labeled A and B see Table 3.1; F1W: Fruit sample collected at Wetheral,

F2E: Fruit sample collected at Emmanuel College, F3M: Fruit sample taken at Mbaise Road, F4R: Fruit sample taken at Relief Market, F5ER: Fruits sample taken at Egbu Road, F6MC fruit sample taken at MCC Road, F7AR fruit sample taken at Aba Road, F9bEK fruit sample taken at Ekeonuwa Mkt, F10N fruit sample taken at Nekede Road.

Table 3.1: Sampling locations, soil sample, code and the fruit items collected and type of waste on each dump

Location of Dumpsites	Soil sample	Fruits Sample (a) Morning	Fruit Sample (b) Afternoon	Type of waste
Wetheral	S1W	F1aW	F1b W	Domestic and market waste
Emmanuel College	S2E	F2aE	F2b E	Domestic and market waste
Mbaise Road	S3M	F3a M	F3b M	Domestic and market waste
Relief Market	S4R	F4a R	F4bR	Domestic and market waste
Egbu	S5ER	F5aER	F5bMR	Domestic and market Waste
MCC	S6MC	F6a MC	F6bMC	Domestic and market Waste
Aba Road	S7AR	F7a AR	F7bAR	Domestic and market waste
Ekeonuwa Market	S9EK	F9aEK	F9bEK	Domestic and market waste
Nekede Road	S10N	F10aN	F10bN	Domestic and market waste
Okigwu (Control)	S8C	F8a C	F8bC	No dumpsite

Distance from the Wastedump

The distance from the waste dump varies from each sampling point to the other. On the average, the distance from the waste dump to the point of the fruit sample were collected was 2 meters to 5 meters.

3.1.4 Sample Collection

The samples were collected using systematic random sampling. Composite soil samples were obtained at 0- 15cm depth, using the soil auger from each sampling points distributed along the surface of the open dumps and a few meters away from the wastedump. Soil sample were collected (few centimeters away from each dumpsite) and also two fruit samples of three reprical were collected at each sampling point. Each of the samples was put into a plastic bag and labelled

3.1.5 Sample Preparation

3.1.6 Bacteriological Analysis for Fruit Samples

Enumeration of Total viable bacteria

Stock suspension of various sample matrixes were prepared by weighing out 10g of the sample using a pre weighed sterile container. A 90mL Sterile distilled water was added to the sample and the mixture shaken vigorously for 60 seconds and allowed to settle for 10 minutes

A 10-fold serial dilution was then carried out using sterile distilled water as the diluents. 1mL of each dilution from 10^3 to 10^8 were aseptically incubated in triplicate.

Nutrient agar with the above composition was the media used for incubation

Two undiluted plates were used as control.

The culture were incubated at room temperature for 48 hours. At the end of incubation period, the plates were counted using colony counter to determine number of l colony.

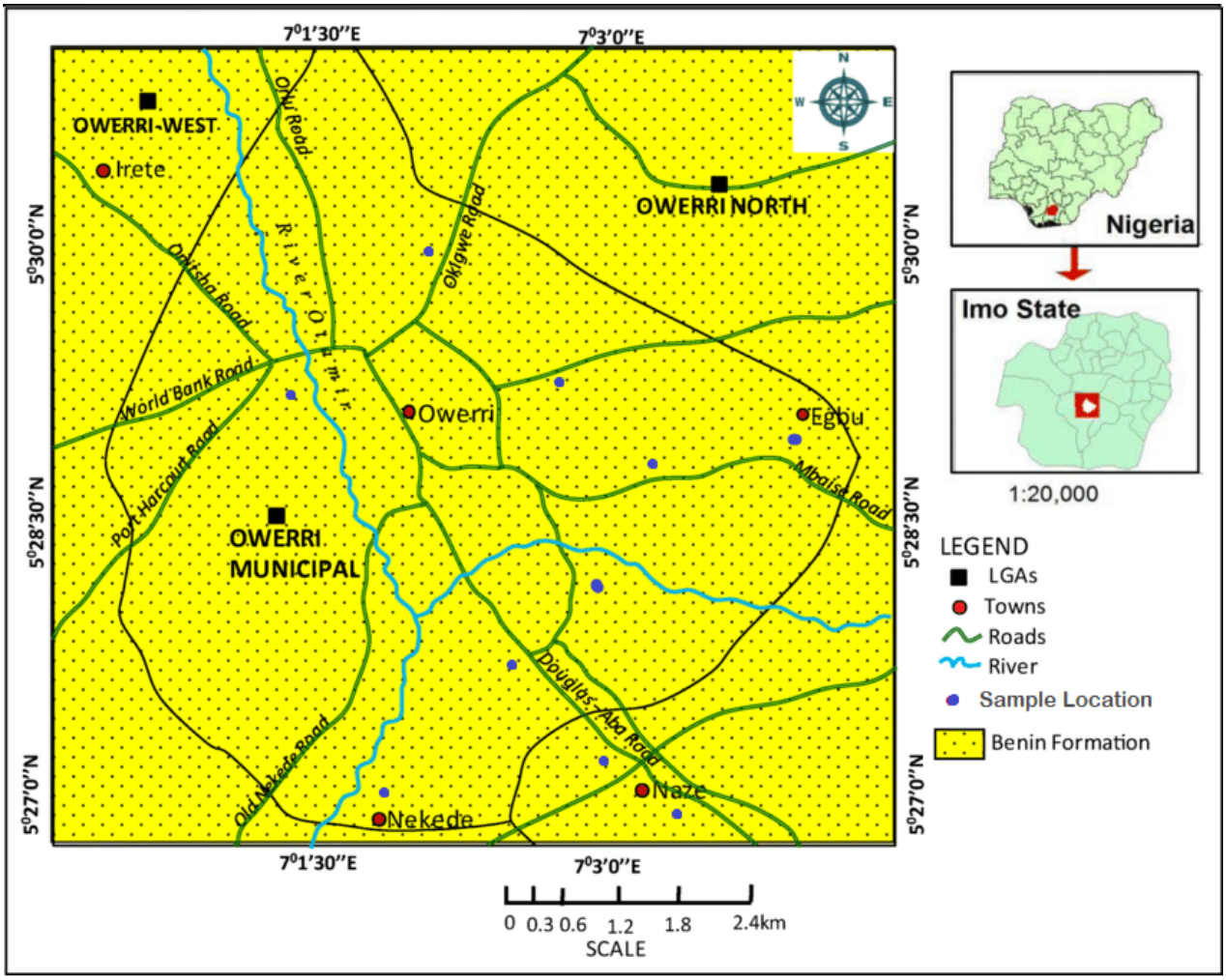

Figure 3.2: Sample collection points in Owerri Metropolis

Source: GIS Map (2022)

The Fruit Samples

The fruit samples were thoroughly washed and the waste wash put to serial dilution to ascertain the microbial load for microbial (bacterial) count. Spread plate method was used where 30-300 Cfu/ml was acceptable. Bacterial identification was also carried out to know the different genera of isolated bacteria. This was achieved by carrying out different biochemical methods and gram staining to state those that are gram positive and gram negative using standard methods as stipulated by Acharya, (2022) and Fahad and Al-Dhabaan, (2019).

The Soil Samples

Media prepared included nutrient agar for the study and their preparations were done according to the manufacturer's specifications. The diluents used were distilled water. The media and diluents prepared were sterilized at 121^{o}C for 15 minutes with an autoclave.

Serial Dilution, Microbial Isolation and Enumeration of Soil Bacteria

Using sterile pipette, ten-fold serial dilution was employed; 9m/s of distilled water were dispensed into (5) test tubes. Thereafter, 1 ml of each of the homogenized soil samples after filtration was serially diluted.

3.2 Isolation and Identification of Associated Microorganism

Bcterial isolates were identified based on their morphologies and reactions to biochemical test as described by Fahad & Al-Dhabaan, (2019), to determine their genera. The tests carried out included, Gram staining, Mobility test, coagulase, oxidase, indole, citrate utilization, Nitrate reduction test, sugar fermentation test and starch hydrolysis test.

3.2.1 Gram Staining

It was done by preparing a thin smear of the pure bacterial isolates with sterile wire loop on clean free slides containing a drop of sterile water. The smear fixed by using the reverse side of the

slides over flame after which they were stained crystal violet for seconds. This was washed off with sterile water.

Consequently, Lugol's iodine was added for seconds and washed off with water. The stain was thereafter decolorized with alcohol for 30 seconds and washed off immediately

The smears were counter-stained on a rack. Two drops of immersion oil were placed on the stained smears and observed under the microscope using x 100 objectives.

3.2.2 Motility Test

Stab culture technique as described by Acharya, (2022) was adopted. It involves the stab-inoculation of the test isolates into semi-solid media with the aid of a sterile straight wire on the centre of the tubes about half the depth of the media.

The stab cultures were incubated at 37^{o}C for 24 hours. Motility was observed by the migration of the bacteria from the stab lines into the media causing turbidity and thereby rendering the media opaque, while non-motile organisms gave growth confined to the path of inoculation.

3.2.3 Catalase Test

Catalase is an enzyme that acts on hydrogen peroxide (H_2O_2) to liberate oxygen and water. This test differentiates Staphylococcus species (which are catalase positive) from Streptococcus species (which are catalase negative).

Using the slide method two drops of hydrogen peroxide were put on a clean grease- free slide labeled A and B at two points. Using a sterile glass rod, the test organism was transferred to drop A while drop B remained as 'control'. The preparation was observed, effervescence indicates a positive reaction.

3.2.4 Coagulate Test

This test differentiates *Staphylococcus aureus* (coagulase positive) from other Staphylococci that are coagulase negative.

This is described by Sushmita, (2022). The isolates were picked with sterile inoculating wire loop and emulsified in a drop of distilled water on each clean grease-free slide. The test organisms were emulsified in each of the drops- labeled A and B and also a drop of plasma was added to A while B served as 'control'. Clumping of the cells of the test organisms within 10 seconds indicated a positive result.

3.2.5 Oxidase Test

This was carried out as described by Clifford, (2021). Two drops of 10% oxidase reagent were made on a piece of filter paper. The isolates were picked by means of glass rods and smeared on the filter papers. A positive reaction turned the papers dark purple.

3.2.6 Indole Test

This was carried out as illustrated by Adebukunola *et al.* (2018). The test was used to determine the stability of an isolate to breakdown the amino acid, tryptophan with the enzyme tryptophanase. Isolates were inoculated on peptone water and incubated for two days at 37^{o}C, after which, 0.5ml of Kovac's reagent was added and shaken gently. Appearance of red coloration indicated positive test.

3.2.7 Citrate Utilization Test

This test is employed to identify some members of the family Entero bacteriaceae. It was based on the ability of the isolates to utilize citrate as sole source of carbon and ammonia as their sole source of nitrogen. Agar slants of Simon's citrate were prepared as described by Sagar, (2022),

which had green colour. Utilization of citrate by the test organisms turned the colour to royal blue indicating positive result.

3.2.8 Methyl Red-Voges Proskauer Test

These tests were carried out using M.R.V.P medium as described by Microbiologynote.com (2022). The MR-VP medium was used for methyl-red test and Voges Proskauer test.

a. Methyl Red Test

To a-two-day old MR- VP culture medium incubated at 37^{o}C, 0.4% methyl red indicator was added. Organisms that produced acid in the medium, which contained dextrose and phosphate gave red colour (MR positive) while a yellow colour indicated a red negative reaction.

b. **Voges Prosskauer test**

To a two- day old MR-VP culture medium incubated at 37^{o}C, 10% KOH was added gently down the tube side so as to form an interface. The tubes were allowed to stand for an hour, organism that produced a neural end product, from glucose or dextrose fermentation gave a yellow colour at the interface (VP positive). A negative result was observed when no colour formation occurred at interface.

3.2.9 Urease Test

The urea agar was dispensed into screw-capped test tubes and sterilized by autoclaving. After sterilization, the medium was allowed to set in a standing positive. Slants of sterilized medium were inoculated by stabbing using straight wire. These are indicative of urease activity.

Sugar Fermentation and Gas Production Test

This test can be used for all the sugar, the isolates were tested for their ability to ferment sugar. One percent peptone water and bromocresol purple indicator was prepared and 9ms were dispensed into test tube and Durham tube was inverted over each test tube. It was than autoclaved

at 121^{o} for 15 minute at 1kgcm^{2} pressure. It was allowed to cool and 1ml of 10% sterile glucose, sterilized by filtration was added to each of the test tubes containing the medium.

Thereafter, the isolates were inoculated into the medium and incubated at 37^{o} for 24hours. Gas production in the Durham tubes and colour change of the medium from light yellow to pink indicated a positive gas and acid production respectively. Where no gas was seen in the Durham tubes and no colour noticed in the medium, the test was negative.

3.3 Physico-Chemical Analysis of Soil Samples

One gram of each pre-weighed soil sample was dissolved in 20ml of the prepared acid mixture. To increase the solubility, the sample solution was heated on hot plate until the volume was reduced to 3ml. Then, the solution was cooled and filtered into 25ml volumetric flask using Whatman 42 filter paper. The filtrate was diluted up to the mark of distilled water (Ejiogu *et al*., 2019).

3.3.1 Experimental Procedures

3.3.2 Nitrate

Nitrate was determined by cadmium reduction method using HI 83200 multi parameter at a wavelength of 525nm. Ten milliliters of the sample were poured into two separate sample cell bottles. One was used as blank to zero the photometer and sachet of nitrate reagent powder pillow was added to the second sample cell bottle and was swirled into the cell compartment and timed for 4 minutes 30 seconds. At the end of countdown, the READ button was pressed to display the results in mg/l of nitrate and nitrate-nitrogen.

3.3.3 Phosphate

Phosphate was determined by Amino acid method using HI 83200 multi parameter at a wavelength of 525nm. Ten milliliters of the sample were poured into two separate sample cell bottles. One was used as blank to zero the photometer and ten drop of HL 93717A-0 molybdate

reagent, then the content of one packet of HI93717B-0 phosphate HR reagent B were added to the curette. It was shaken gently to dissolve and was inserted into the cell compartment and timed for 5 minutes. At the of countdown, the READ button was pressed to display the results in mg/L of phosphate, phosphorus and phosphate (P_2O_5)

3.3.4 Sulphate

Sulphate was determined by turbid metric method using HI 83200 multi-parameter at a wavelength of 466nm. Ten milliliters of the sample were poured into two separate sample cell bottles. One was used as blank to zero the photometer and one sachet of sulphate reagent powder pillow was added to the second sample cell bottle and swirled into mix. It was then inserted into the cell compartment and timed 5 minutes. At the end of the countdown, the READ button was pressed to display the result in mg/l of sulphate.

3.4 Statistical Technique

Statistical methods involved in carrying out a study include planning, designing. Collecting data, analysis, drawing meaningful interpretation and reporting of the research findings. The statistical analysis gives meaning the meaning less numbers, thereby breathing life into a lifeless data. The results and statistical tests are used (Ali *et al.,* 2016).

The following were the statistical Technique used;

Mean: In mathematics and statistics, the arithmetic mean, arithmetic average, or just the mean or average is the sum of a collection of numbers divided by the count of numbers in the collection. the collection is of a set of results from an experiment, an observational study, or a survey. Wikipedia.

Standard Deviation: Standard deviation is a statistic that measures the dispersion of a dataset relative to its mean and calculated as the square root of the variance. The standard deviation is

calculation as square root of variance by determining each data point's deviation relative to the mean (Jefreda Brown, 2023).

t-test: According to Wikipedia, a t-test is a type of statistical analysis used to compare the averages of two groups and determine whether the differences between them are more likely to arise from random chance. It is any statistical hypothesis test in which the test statistical follows a student t- distribution under the null hypothesis.

Correlation: It is a mutual relationship or connection between two or more things.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Results

Table 4.1 shows the raw result bacterial count on fruit samples for all study locations its values range from 0 to 34500 CFu/g. Table 4.2 Display the load of bacterial in the soil samples for all study locations and it values range from 0 to 365000000CFu/g. Table 4.3 shows the mean and the standard deviation in the cumulative of bacterial loads in the fruit samples a and b for all the location which range from 0 to 34500CFu/g. Fable 4.4 reveals the mean and the standard deviation of bacterial load in soil samples for all the study locations and the value range from 0 to 35000000Cfu/g. Table 4. 5 Compare the mean and standard deviation between the fruit sample 'a' and the soil samples for all locations value range from 0 to 365000000Cfu/g. Table 4.6 shows correlation between fruit sample (a) and soil samples its values range from -0.52456 to + 1. Table 4.7 Comparison of computation of mean and standard DEVIATION of fb and soi sample for all locations and value range from 0 to 365000000Cfu/g. Table 4.8 shows the Correlation result of Fruit Samples a and Soil Samples its values range from 0 to -0.04323. Table 4.9 shows the tests carried out to isolate the bacterial species in the soil and the fruit samples. **Figure 4.1:** Shows the percentage of each of the bacterial specie isolated in all the samples collected in all the locations. Table 4.10 shows the bacterial isolate from the sample around the wastedumps in all location**.** Comparing the percentage of bacterial count in the fruit samples with the bacterial count in the soil samples.

Table 4.1: Results of Bacterial Count in Fruit Samples

Location	F1a	F1a	F1a	F2b	F2b	Fb2	Unity
Wetheral Road	1920	1940	1920	7420	7420	7430	CFu/g
Emmanuel College	1920	3250	3240	28200	28100	28200	CFu/g
Maria Assumta	1920	4240	4250	0	0	0	CFu/g
Relief Road	4420	4430	4430	4050	4060	4050	CFu/g
Egbu Road	3460	3450	3460	32800	32800	32800	CFu/g
Mcc Road	3410	3400	3400	3370	3350	3360	CFu/g
Aba Road	21800	21700	21800	0	0	0	CFu/g
Control	315	315	314	316	317	319	CFu/g
Douglas Road	3150	3120	3160	28700	28800	28700	CFu/g
Nekede Road	34300	34500	34500	344	344	344	CFu/g

Table 4.2: Cumulative Bacterial Load in the soil samples

Location	S1	S2	S3	Unity
Wetheral Road	5780000	5770000	5990000	Cfu/g
Emmanuel College	392000000	392000000	392000000	Cfu/g
Maria Assumta	7930000	7930000	7910000	Cfu/g
Relief Road	8420000	8400000	8440000	Cfu/g
Egbu Road	7970000	7970000	7960000	Cfu/g
Mcc Road	9660000	9670000	9640000	Cfu/g
Aba Road	8140000	8190000	8200000	Cfu/g
Control	0	0	0	Cfu/g
Douglas Road	6930000	6900000	6930000	Cfu/g
Nekede Road	365000000	361000000	365000000	Cfu/g

Table 4.3: Mean and Standard Deviation of Fruit Samples a and b

Points	F1a	F1a	F1a	Mean	S.D	Unity	F1b2	F1b2	F1b2	Mean	S.D
Wetheral Road	1920	1940	1920	1920	1	Cfu/g	7420	7420	7430	7420	6
Emmanuel College	1920	3250	3240	3250	6	Cfu/g	28200	28100	28200	28200	6
Maria Assumta	1920	4240	4250	4240	6	Cfu/g	0	0	0	0	0
Relief Road	4420	4430	4430	4420	6	Cfu/g	4050	4060	4050	4050	6
Egbu Road	3460	3450	3460	3450	6	Cfu/g	32800	32800	32800	32800	0
Mcc Road	3410	3400	3400	3410	6	Cfu/g	3370	3350	3360	3370	10
Aba Road	21800	21700	21800	21800	0	Cfu/g	0	0	0	0	0
Control	315	315	314	315	0.5	Cfu/g	316	317	319	417	0.6
Douglas Road	3150	3120	3160	3150	2	Cfu/g	28700	28800	28700	28700	6
Nekede Road	34300	34500	34500	34100	0.2	Cfu/g	344	344	344	344	0

Table 4.4: Mean and Standard Deviation of Bacterial Loads in the Soil Samples

Location	S1	S2	S3	MEAN	S.D	Unity
Wetheral Road	5780000	5770000	5990000	5850000	124000	Cfu/g
Emmanuel College	392000000	392000000	392000000	392000000	392000000	Cfu/g
Maria Assumta	7930000	7930000	7910000	7910000	15200	Cfu/g
Relief Road	8420000	8400000	8440000	8440000	20000	Cfu/g
Egbu Road	7970000	7970000	7960000	7970000	570	Cfu/g
Mcc Road	9660000	9670000	9640000	9660000	20800	Cfu/g
Aba Road	8140000	8190000	8200000	8180000	521000	Cfu/g
Control	0	0	0	0	0	Cfu/g
Douglas Road	6930000	6900000	6930000	6920000	17300	Cfu/g
Nekede Road	365000000	365000000	365000000	363000000	334000000	Cfu/g

Table 4.5: Comparison of Mean and standard Deviation of Fruit Sample (a) and Soil Samples

Locations	F1a	F1a	F1a	Mean	S.D	Unity	S1	S2	S3	MEAN	S.D
Wetheral Road	1920	1940	1920	1920	1	Cfu/g	5780000	5770000	5990000	5850000	124000
Emmanuel College	1920	3250	3240	3250	6	Cfu/g	392000000	392000000	392000000	392000000	392000000
Maria Assumta	1920	4240	4250	4240	6	Cfu/g	7930000	7930000	7910000	7910000	15200
Relief Road	4420	4430	4430	4420	6	Cfu/g	8420000	8400000	8440000	8440000	20000
Egbu Road	3460	3450	3460	3450	6	Cfu/g	7970000	7970000	7960000	7970000	570
Mcc Road	3410	3400	3400	3410	6	Cfu/g	9660000	9670000	9640000	9660000	20800
Aba Road	21800	21700	21800	21800	0	Cfu/g	8140000	8190000	8200000	8180000	521000
Control	315	315	314	315	0.5	Cfu/g	0	0	0	0	0
Douglas Road	3150	3120	3160	3150	2	Cfu/g	6930000	6900000	6930000	6920000	17300
Nekede Road	34300	34500	34500	34100	0.2	Cfu/g	365000000	361000000	365000000	363000000	334000

Table 4.6: Correlation Between Fruit Sample (a) and Soil samples

	VARIABLE	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
VARIABLE	1										
1	0.563744	1									
2	0.538	0.997473	1								
3	0.538649	0.997502	0.999996	1							
4	0.537739	0.997504	0.999961	0.99998	1						
5	-0.52456	-0.53479	-0.50859	-0.50912	-0.50951	1					
6	0.05834	0.4665	0.492211	0.490796	0.488514	-0.02192	1				
7	0.054418	0.462179	0.487981	0.486571	0.484305	-0.01887	0.99998	1			
8	0.056352	0.464494	0.490239	0.488826	0.486551	-0.02074	0.999996	0.999994	1		
9	0.055418	0.463331	0.489104	0.487692	0.485422	-0.01976	0.99999	0.999999	0.999999	1	
10	0.344973	0.842897	0.835216	0.836312	0.839282	-0.64994	0.185996	0.183417	0.184889	0.184119	1

Table 4.7: Comparison of computation of mean and standard deviation of fa and soil

Points	F1b2	F1b2	F1b2	Mean	S.D	Unity	S1	S2	S3	MEAN	S.D
Wetheral Road	7420	7420	7430	7420	6	Cfu/g	5780000	5770000	5990000	5850000	124000
Emmanuel College	28200	28100	28200	28200	6	Cfu/g	392000000	392000000	392000000	392000000	392000000
Maria Assumta	0	0	0	0	0	Cfu/g	7930000	7930000	7910000	7910000	15200
Relief Road	4050	4060	4050	4050	6	Cfu/g	8420000	8400000	8440000	8440000	20000
Egbu Road	32800	32800	32800	32800	0	Cfu/g	7970000	7970000	7960000	7970000	570
Mcc Road	3370	3350	3360	3370	10	Cfu/g	9660000	9670000	9640000	9660000	20800
Aba Road	0	0	0	0	0	Cfu/g	8140000	8190000	8200000	8180000	521000
Control	316	317	319	417	0.6	Cfu/g	0	0	0	0	0
Douglas Road	28700	28800	28700	28700	6	Cfu/g	6930000	6900000	6930000	6920000	17300
Nekede Road	344	344	344	344	0	Cfu/g	365000000	361000000	365000000	363000000	334000

Table 4.8: Correlation of Fruit Samples A and Soil Samples

	Variables	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
Variables	1										
1	-0.13491	1									
2	-0.13307	0.999994	1								
3	-0.13502	1	0.999994	1							
4	-0.13431	0.999997	0.999991	0.999998	1						
5	-0.29091	0.175546	0.175295	0.175439	0.175021	1					
6	0.05834	0.166843	0.164861	0.166827	0.166519	-0.04446	1				
7	0.054418	0.169775	0.167782	0.169759	0.169453	-0.04209	0.99998	1			
8	0.058148	0.16679	0.164808	0.166774	0.166466	-0.04439	1	0.99998	1		
9	0.056317	0.168299	0.166311	0.168283	0.167976	-0.04323	0.999995	0.999995	0.999995	1	
10	-0.40579	0.455408	0.452818	0.455398	0.455427	0.239292	0.696712	0.701185	0.696715	0.698947	1

Table 4.9 shows the tests carried out to isolate the bacterial species in the soil and the fruit samples

Table 4.9: Identification of Isolates

SN	Identification Test	Isolate A	Isolate B	Isolate C	Isolate D	Isolate E
	Catalase test	+ve	+ve	+ve	+ve	+ve
	Citrate test	+ve	-ve	-ve	-ve	+ve
	Flagella test	Flagellated	Flagellated	Non flagellated	Non Flagellated	Non Flagellated
	Getatine hydrolysis	+ve	+ve	-ve	+ve	+ve
	Grain Staining	+ve	-ve	-ve	+ve	-ve
	Indole Test	-ve	+ve	-ve	-ve	-ve
	Motility	+ve	-ve	+ve	-ve	-ve
	Methy red test	+ve	+ve	+ve	+ve	-ve
	Nitrate reduction	+ve	+ve	+ve	+ve	+ve
	Oxidase test	-ve	-ve	-ve	-ve	-ve
	Pigmentation	-ve	-ve	-ve	+ve	-ve
	Shape	Rod	Rod	Rod	Cocci	Rod
	Spore formation	-ve	-ve	-ve	-ve	-ve
	Urease	-ve	-ve	-ve	+ve	+ve
	VP (voges Proskaues) test	+ve	+ve	-ve	+ve	+ve
	Glucose Fermentation	+ve	+ve	-ve	+ve	+ve
	Lactose Fermentation	-ve	+ve	-ve	+ve	+ve
	Maltose Fermentation	+ve	+ve	+ve	+ve	+ve
	Xylose Fermentation	+ve	+ve	+ve	-ve	+ve
	Starch Hydrolysis	+ve	-ve	+ve	+ve	-ve
	Bacteria Species	***Bacillus subtilis***	***E. coli***	***Samonellaspp***	***Staphylococcus areus***	***Klebsiella spp***

Identification key use from Berger's Manual of Determinative bacteriology

Table 4.10: Bacterial isolate from the samples around the wastedumps

Variable	A Fruit Item	B Soil	C Control
Bacillus subtilis	+	+	_
E. coli	+	+	+
Samonella spp.	+	+	+
Staphylococcus spp.	+	+	_
Klebsiella spp.	+	+	_

Key: + = Positive – = Negative

Identification key use from Berger's Manual of Determinative bacteriology

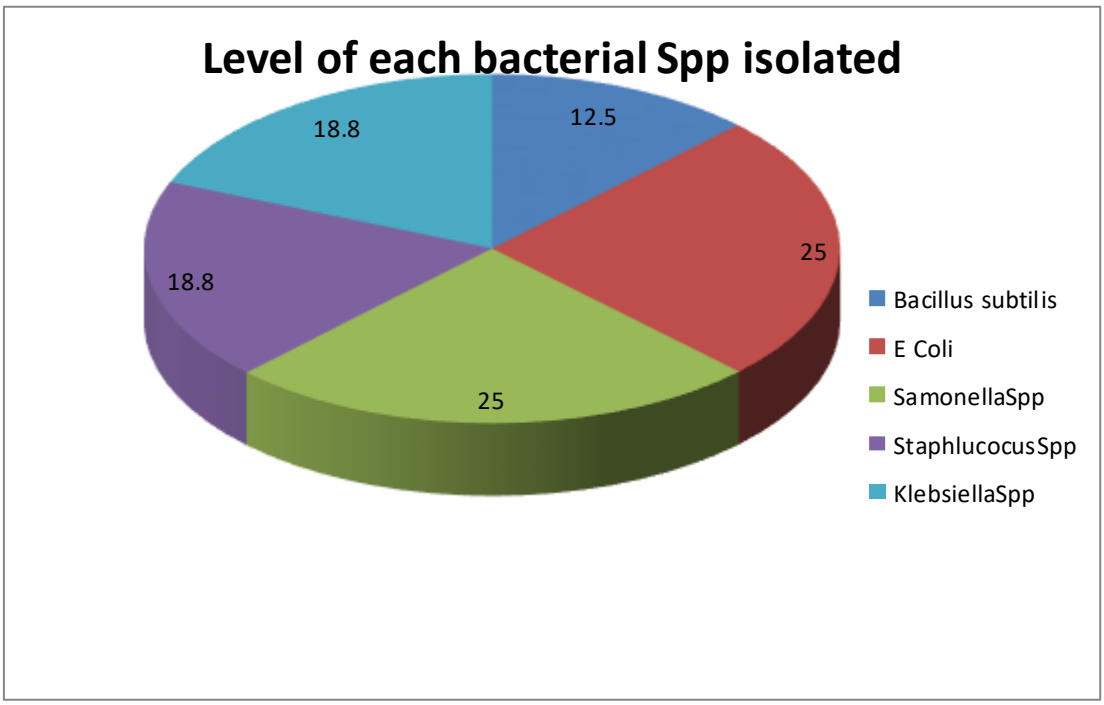

Figure 4.1: The percentage of each of the bacterial specie isolated in all the samples collected

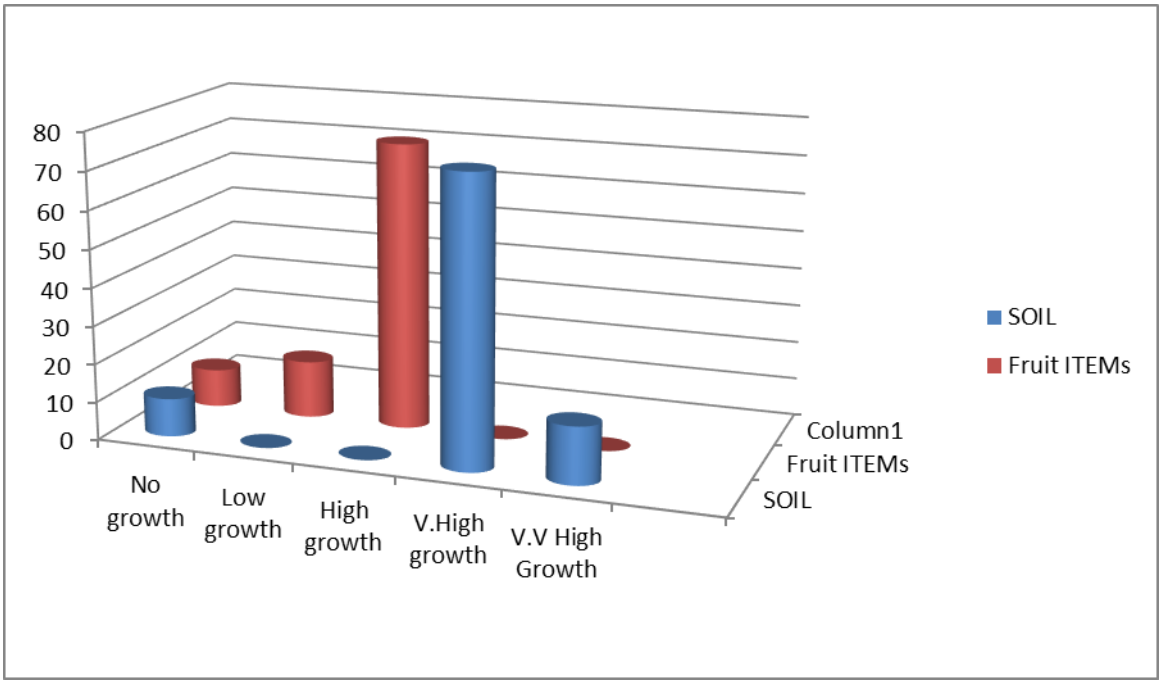

Figure 4.2: Compare the percentage of bacterial count in the fruit samples with the bacterial count in the soil samples

4.2 Discussion

Table 4.1 shows that six of the fruit items sampled had no bacterial growth and nine of which had low bacterial growth. The fruit samples with no and low growth was because they were displayed on a platform and was little bit farther from the dumps and were 10% and 15% respectively. Forty-five of the fruit items sampled had high bacteria count; they displayed on the ground or on a platform with no coverage and most times were very close to a dumps which was 75% of the whole fruit samples analyzed. This agreed with Charles (2020) assertion that Pathogenic micro-organisms originate from numerous sources in MSW and both enteric bacterial pathogens and viruses have been detected in MSW". The low load of bacterial buttress the fact that no place in the market street of Owerri Metropolis is free of wastedumps. This is supported by the findings of Oluwadara *et al.* (2018) who reported that in most cities of Nigeria and other developing countries, the greater percentages of waste generated are dumped on the surface of the ground along major roads, street and open spaces. But sample has no growth and this was because they were placed on a platform, and partially covered. The remaining fifteen samples that had high loads of bacterial in them, they are displayed on the ground, near the wastedumps.

Table 4.2 shows that three of the soil samples had no loads of bacterial due to the fact that there was no wastedumps close to the point where the samples were collected, and the three sample was the control. It reveal that there were a lot of bacterial in the soil samples collected around the wastedumps in Owerri Metropolis and they were contaminated because of the present of wastedumps. This supports by a report by Edugreen, (2019). "If at this stage the management and disposal of waste is not properly done, it could cause serious environmental impact. Only the control which was gotten from where there was no open wastedumps were free of contaminations.

Table 4.10, shows that, *Bacillus subtilis, E. coli, Samonella* spp, *Staphylococcus* spp and *Klebsiella* spp are the bacteria species present in the samples.

Column A all the five bacterial isolated was present in the fruit items.

Column B has the five microbes isolated present in it; the soil has the highest Coliform count which confirms that the bacterial spread to the fruit items sold around the wastedump from the dumps

Column C has only two microbes present in it, and the samples were collected where there were no wastedump. This result in column C further confirms that it was the present of waste dumps in the other sampling points that contaminated the soil and which spread to the fruit items sold around the wastedump in Owerri Metropolis.

This agrees with the findings of the following researcher who worked on soil Hugbo *et al,* (2019) these above species of bacterial, although in different frequency and one or two variation in the species isolated.

Figure 4.1 above shows the percentage of each bacterial species isolated in the samples collected around the wastedumps. *E. coli* and *Samonella* spp. are more abundant in the samples they were, *Staphylococcus* spp (25%), *Klebsiella* spp. (18.8%) and *Bacillus subtilis* (12.5%).

Correlation was used to determine the relationship between the bacterial loads in the soil samples and in the fruit samples. From the analysis, correlation of +1 was obtained. Which shows that the loads of bacterial in the fruit samples increase as the loads of bacterial in the soil increased. This implies that improper solid waste management is the major source of bacterial contamination of fruits sold around waste dump in Owerri Metropolis. This result is consistent with the work carried out by Umunakwe *et al.* (2019) who attributed the prevalence of diseases, morbidity and mortality in Most African cities to poor sanitation and improper waste disposal practices. This is supported by Uwakwe (2003) finding that improper solid waste management poses a great danger to the health conditions of the people, and the environment.

Apart from the microbes identified in the study area, there is probability that the wastedumps will attract rodent and other pest to the area. These agree with Albert *et al*. (2021) report that improper refuse dumping leads to an increased pest population and resulted in an increased risk of food contamination. Food borne illnesses of microbial origin are a major health problem associated with street foods".

The bacterial species isolated can get the fruit through various means;

Table 4.11: The bacterial species

Bacterial species	**Mode of transmission**
Bacillus subtilis	Biosurfactant
E.coli	Handling
Samonella spp	Handling
Staphylococcus spp	Biofilm
Klebsiella spp	Handling, washing and biofilmi

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Bacterial Contamination of fruits sold around wastedumps in Owerri Metropolis, is a research work carried out in ten different points (places) in Owerri Metropolis. The fruit samples were sixty and the soil samples were thirty. The samples were taken to the laboratory for analysis to determine the level of bacterial Contamination in them. It was observed that the samples were contaminated except the three soil samples use for control. These were the varieties of bacterial found in them or isolated A; *Cillus subtills*, Isolate B; *E. coli*; Isolate C; *Samonella* spp, Isolate D; *Staphlacocus* spp and Isolate E: *Klebsiella spp.* The levels of contamination in the fruit and in the soil, samples were compared, it showed that the bacteria load in soil were higher than that in the fruit samples. Statistical analysis was carried out which gave a correlation of +1 and t- test of 1.375 (Cal) less than the t-test (tab) which indicates that the different between the mean of the soil and fruits samples were insignificant. From the findings it was concluded that there is no place in Owerri Metropolis that is free from contamination. Also, from the study some recommendations were made.

5.2 Conclusion

In Owerri Metropolis there are no proper waste disposal sites, so people use open dumpsim to dispose off their waste. And these open dumps are mostly located on the market and residential streets. On the street you will see sellers displaying the food items, the traders mostly those selling fruits display these fruits on the ground not minding the wastedumps close to the place. Little wonder the fruit samples were found to contain loads of bacterial in them. The total mean of bacterial loads in the soil samples was 45,725,000 and the total mean of bacterial load in fruit samples were 10473.3. The correlation result gave +1 and the t- test was 1.375(cal) lesser than the

t- test (tab) which shows that the bacterial loads in the soil may spread to the fruits sold near the waste dumps in Owerri Metropolis.

From fruits Isolates A, B, C, D and E were Isolated, From Soil Samples, Isolates A, B, C, D and E were Isolated and from the control samples with low microbial loads but isolates B and D were Isolated. Base on the results of microscopic physical examination and biochemical test and in accordance with Bergers manual of Determinative Bacterology.

The Isolates were identified as follows:

Isolate A: *Bacillus subtilis*, Isolate B: *E. coli*, Isolate C: *Samonella* spp., Isolate D: *Staphlucocus* spp. and Isolate E: *Klebsiella* spp. from where there is no open dumpsite. Though, it was very difficult to found a place without waste dump in Owerri Metropolis and low bacterial growth was found on the fruit samples analyzed, which shows that there is no place in Owerri Metropolis that is free of waste dump.

5.3 Recommendations

Base on the findings of this study, the following recommendations are made

The government should provide sanitary dumpsite in the Owerri Metropolis and encourage people to use it.

People doing one business or the other in the market should be educated on the danger in defecating or urinating on an open ground or in the waste dump in the market.

Government should stop people from dumping refuse on open market streets by providing trucks that will be carrying refuse from various store and take them to the proper dumpsite provided by the government while a token will be paid by the store owner. This is also a way of generating income for the state and creating employment for the citizens.

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