EVALUATION OF HEAVY METALS, SOME ORGANIC AND MICROBIAL CONTAMINANTS IN THE EFFLUENTS FROM SOME FOOD INDUSTRIES IN ANAMBRA STATE, NIGERIA

BY

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CERTIFICATION

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DEDICATION

This research is dedicated to the Almighty God for His Grace upon my life. Indeed, He is always faithful.

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ABSTRACT

This study was carried out to evaluate the concentrations of heavy metals and other contaminants in the effluents from some food industries in Anambra State. Effluents from Life Breweries, Onitsha; KP beverages, Ogidi; Obisco beverages, Ogidi; Golden Vegetable Oil, Onitsha and Resource Improvement and Manufacturing Company (RIMCO Nnewi) in Anambra State were sampled for a period of eight months – four months rainy season and four months dry season – for comparison; and analyzed for levels of heavy metals pollution using Atomic Absorption Spectrophotometer (AAS). Physico-chemical parameters, microbiological and organic pollutants loads of the effluents were also determined using standard analytical methods. Results obtained were compared with the Federal Ministry of Environment Industrial Effluent Limit (FMEnv) to determine the level of conformity of these industries with this standard. Result of the mean concentrations of the heavy metals were generally above the allowable industrial effluent limit. It was discovered that the total mean level of the heavy metals were higher in the dry season than in the rainy season in almost all the food industries studied. The mean concentrations of mercury in the dry season were in the decreasing order of 3.783 ± 0.860mg/l (Savana) > 3.182 ± 0.497mg/l (Obisco) > 2.865 ± 0.497mg/l (Golden) > 2.724 ± 0.497mg/l (KP) > 2.655 ± 0.497mg/l (Life) > 0.878 ± 0.497mg/l (RIMCO) respectively compared to the rainy season levels of 1.985 ± 0.860mg/l (Savana) > 1.935 ± 0.497mg/l (Golden) > 1.874 ± 0.497mg/l (Obisco) > 1.638 ± 0.497mg/l (Life) > 1.564 ± 0.497mg/l (RIMCO) > 1.252 ± 0.497mg/l (KP) respectively. Two sample paired t – test showed that there were no significant difference ($P > 0.05$) in the levels of Pb, Cr, As, Cd, and Zn in both seasons except for Hg and Fe which were significantly higher ($P < 0.05$) in the dry season than in the rainy season in all the effluent samples. Analysis of Variance (ANOVA) showed that there were no significant difference ($P > 0.05$) in the mean concentrations of Hg, Fe, Pb, Cr, Cd, and Zn among the effluent samples except arsenic levels which showed significant difference ($P < 0.05$) among the different effluents studied. Apart from pH and hardness levels (which failed to meet the FMEnv effluent limit), other physico-chemical parameters of the effluents were either within or below the allowable industrial effluent limit. Again, two sample paired t-test showed that pH, TS, TDS and TSS were highly significant ($P < 0.05$) between rainy and dry seasons. Though pH and TSS were higher in the dry season than in the rainy season, TS and TDS were higher in the rainy season. Nevertheless, Analysis of Variance (ANOVA) indicated that there were significant difference ($P < 0.05$) in the mean concentrations of pH, TS and TDS among the different samples but TSS was not significant. Alkalinity, hardness, chloride and nitrate levels were not significant ($P > 0.05$) between rainy and dry season though there was significant difference ($P < 0.05$) in the levels of chloride and nitrates among the different industries studied. The most probable number (MPN/100ml) index of organisms were highest in the effluents from Golden oil in the dry season (35MPN/100ml) followed by Savana (33MPN/100ml) in the rainy season, though these were below the 500MPN/100ml recommended by FMENV, in industrial effluents. Organisms isolated were *Enterobacter aerogens, Bacillus cereus,* and *Escherichia coli*. Organic pollutants indentified in the effluents were mainly toluene compounds, 3, 5 – di – ter – butylphenol, hexa decanoic acid, Di – n – octylphthalate and 2 – methylnaphthalene among others. The pollution index values for mercury, zinc, lead, iron, arsenic, chromium and cadium showed significant degree of pollution by these heavy metals. Pollution potential of the effluents studied ranged in the order: Savana effluent > Life breweries effluent > Obisco effluent > Golden effluent > KP effluent > RIMCO effluent respectively.

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

List of Table Continued

List of Table Continued

LIST OF FIGURES

List of Figure Continued

LIST OF APPENDICES

LIST OF ABBREVIATION

NA	Not Available
BDL	Below Detection Limit
P_1	Point of Discharge of Effluent
P_2	15 Meters away from the Point of Discharge of Effluent
P_3	30 Meters away from the Point of Discharge of Effluent
SD	Standard Deviation
SE	Standard Error
RIMCO	Resource Improvement and Manufacturing Company
KP	King Size Pharmaceuticals
TS	Total Solid
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
MPN	Most Probable Number of Coliform Organisms
FMENV	Federal Ministry of Environment
GC – MS	Gas Chromatography Mass Spectoscopy
CV	Coefficient of Variation

CHAPTER ONE

1.0 INTRODUCTION

Industrial effluent discharges are world wide sources of potential pollution (Ajao, 1985). Acute toxicity tests give firsthand information on the effects of such discharges on organisms and the ecosystem as a whole and are valuable in creating awareness as to the potential harmful effects of such industrial discharges to the environment (Ajao, 1985). Industrialization develops the world and makes life better. Ironically, human lives are haunted by the huge volume of waste products of industries dumped in the environment. With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose of these waste waters safely and beneficially. Hillman, (1988) has drawn attention to the particular concern attached to heavy metals, and carcinogens, mainly organic chemicals.

Moreover, too many processing plants in one area will eventually overwhelm natural ecosystems nearby, frequently causing unwanted fertilization and eutrophication of coastal waters. Local impacts are particularly obvious because waste from processing industries are generally produced throughout the year giving no chance for the environment to recover. Impacts are likely to be detrimental when the same ecosystem receives wastes from cluster of processing industries (Bagge-Ravn, *et al.,* 2003). If wastes are organic in nature, they are subject to bacterial decay. As a result, the oxygen concentration in the water is reduced with an increase in Biological Oxygen Demand (BOD). This can starve aquatic life of the oxygen it needs and anaerobic decomposition of organic matter leads to the breakdown of proteins and other nitrogenous compounds, releasing hydrogen sulphide, ammonia and methane, all of which are potentially hazardous to the ecosystem and toxic to marine organisms in low concentration. Agbese, (1998) asserted that industrial pollution is gradually changing Nigeria's environment as many towns and villages have been polluted by toxic wastes. In these industries, there appear to be no organization programmes for disposal of effluents and industrial wastes. Many factories discharge their wastes directly into rivers, streams or into open gutters causing serious environmental problems. The pollutants generated from the industries are of great diversity structurally and include toxic metals, organic and inorganic solids and liquids (Okotere, 1982).

1.1 Background of Study

Each step in the food industry system-food production, processing, transportation, storage, distribution and marketing-has some impact on the environment and there is much concern about environmental pollution. Due to the highly diversified nature of the food industry, various food processing, handling, and packaging operations create wastes of different quality and quantity which, if not treated, could lead to increasing disposal and severe pollution problems. Additionally, they represent a loss of valuable biomass and nutrients if not recovered by appropriate methods of technologies for upgrading, bioconversion or reutilization (Kroyer, 1995).

The diverse food processing industries include a range of sectors such as the following: Alcoholic and non-alcoholic beverages, fruits and vegetables, diary products, meat and fish, grain mill and bakery products, sugar and confectionary products, fats and oils and frozen packaged, and convenience foods, among others.

The most common environmental concerns in the industry according to Osho *et al.*, (2010), are water consumption and waste water discharge, chemicals used in processing and cleaning, packaging reduction and disposal, and food scraps and refuse. Energy efficiency and greenhouse gas emissions are increasingly important as well (Tehobanoglous *et al*., 2003; Beychok, 1967). Food industry effluents are generally characterized by high contents of biodegradable pollutants; suspended substances constitute a large part of these pollutants, in addition to the high biological oxygen demand (BOD) and chemical oxygen demand (COD) concentrations of the effluents (Shahidul, *et al.,* 2010). Some effluents contain oils and grease, some toxic materials (e.g. cyanide).

Effluents from food and beverage factories contain degradable organic pollutants. Some effluents contain, while some lack nutritious materials suitable for microbial growth. Effluents of canned fruit and soda beverages, for example, contain high percentage of sugar, very low percentage of protein, and little nitrogen or phosphorous. Thus biological growth according to Ajao, (1985) in these effluents, therefore, is rather weak.

The constituents of food and agriculture wastewater are often complex to predict due to the differences in BOD and pH in effluents from vegetable, fruit and meat products and due to the nature of food processing and post harvesting. Processing of food from raw-material require large volumes of high grade water. Vegetable washing generates waters with high load of particulate matter and some dissolved organics and may also contain surfactants. Animal slaughter and processing produces very strong organic waste from body fluids, such as blood and gut contents. Thus, wastewater is frequently contaminated by significant levels of antibiotics and growth hormones from the animals and by a variety of pesticides used to control external parasites. Effluents generally have an adverse effect on water bodies such as lakes, rivers, oceans and ground water and this is caused by human activities (Abel, 1996; Nascimes *et al*., 2000). Pollutants in water include a wide spectrum of chemicals, pathogens and physical chemistry or sensory changes. Wastewaters can be contaminated by feed-stock materials, by-products, product material in soluble or particulate form, washing and cleaning agents, solvents and added value products such as plasticizers.

The specification for releasing various types of industrial effluents into the public sewer network or to surface water courses is not only determined by the concentration of biological oxygen demand (BOD) of organic and inorganic elements, which vary from country to country, but also requires the water to have several additional characteristics. The specifications for effluents discharge are that it:

i. Does not affect the safety or health of sewer network workers.

ii. Does not affect the sewer pipes

iii. Does not affect the treatment processes in water treatment plants. In addition to these, the required specification of industrial effluents released into public sewers include the following:

   a. BOD concentration should not exceed approximately 20mg/L.
   b. Suspended solids concentration should not exceed approximately 600mg/L.
   c. No release of grease, oils or nitrogen compounds (due to their impacts on the treatment process).
   d. No release of explosives or toxic materials (due to their potential impacts on the safety and health of the sewer network workers).
   e. Sulphate concentration should be less than 100mg/L, and the pH value should be between 6-10 (to protect the sewer pipes).

Wastewater contains offensive and potentially dangerous substances which cause pollution and contamination of receiving water bodies (Schudram and Shaw, 2000). One of the most important factors of water pollution is the microbial contamination, especially with pathogenic micro-organisms. Enteric pathogens are typically responsible for several waterborne sicknesses (Niewhick, 1998; Sabae, 2004).

Contamination of water is a serious environmental problem as it adversely affects human health and the biodiversity in the aquatic ecosystem. Dangers to public health from polluted water comes not only from direct use of the water, but also from consuming fish that have lived in polluted streams. Many poisonous substances are absorbed by fish, often in a concentrated form, hence eating of fish from polluted water may be even more hazardous than drinking water. Water transmitted diseases have been the cause of high mortality rates in rural areas. Some deaths have been linked to water polluted by non-treated wastes originating from domestic and industrial activities. Nigeria is a typical example of such a situation. To make matters worse, Benka-Coker and Ojior, (1995) and Nieto, (2000), noted that contaminated water is used for abattoir cleaning, which of course aid in the spread of disease-causing organisms. The above researchers associated human health with the possibility of accumulation of pathogenic enteric micro-organisms by aquatic organisms.

Only a few colony-forming units (cfu) are necessary for infection in predisposed subjects. The use of indicator bacteria such as faecal coliforms (fc) in water quality determination on fresh water source is widely known (You-Joe *et al.*, 2003). Currently, coliforms and *Esherichia coli*are of great importance among bacterial indicators used in water quality definition and health risk (Giannoulis *et al.,* 2005). However, operational evaluation of microbial load of wastewater (biologically) is often complicated because of variation in raw waste water composition, strength and flow rate owing to the changing and complex nature of the treatment processes (Akaninwor and Gwin, 2006). Pathogens are a serious concern for managers of wastewater because excessive amount of faecal bacteria in sewage and urban runoff, according to Fleisher *et al*., (1998) have been known to indicate risk of pathogen-induced illnesses in humans, thus, identification of these pathogenic agents in water resource is beneficial for controlling and preventing the infectious diseases.

Together with essential nutrients, plants and animals also take up small amounts of contaminant heavy metal compounds and can concentrate them. As certain heavy metals such as lead, cadmium and mercury have been recognized to be potentially toxic within specific limiting values, a considerable potential hazard exists for human nutrition. Some metals are naturally found in the body and are essential to human health. Iron, for example, prevents anemia, and zinc is a co-factor in over 100 enzymes (Schumacher *et al.*, 1993). They normally occur at low concentrations and are known as trace metals. In high doses, they may be toxic to the body or produce deficiencies in other trace metals, for example, high levels of zinc can result in a deficiency of copper, another metal required by the body.

Heavy or toxic metals according to Abdulla and Chmielnicka, (1990) are trace metals which in their standard state have a specific gravity (density) of more than about $5g/cm^3$ (Density at least 5 times that of water) and as such, are stable elements (they cannot be metabolized by the body). They are bio-accumulative (passed up the food chain to humans). Once liberated into the environment, through the air, drinking water, food or countless human-made chemicals and products, heavy metals enter and accumulate in the body tissues faster than the body's detoxification pathways can dispose of them, a gradual build up of these toxins will occur. Some of them such as copper, nickel, and iron, for example, are essential in very low concentrations for the survival of all forms of life and are described as essential trace elements (Abdulla and Chmielnicka, 1990). Only when they are present in greater quantities, can these, like the heavy metals, lead, chromium and mercury which are already toxic in very low concentrations, cause metabolic anomalies. High concentration exposure is not necessary to produce a state of toxicity in the body, as heavy metals accumulate in body tissues and overtime, can reach toxic concentration levels.

Heavy metal exposure is not an entirely modern phenomenon. Silva *et al.*, (1993) have cited the contamination of wine and grape drinks by lead-lined jugs and cooking pots as a contributing factor in the decline and fall of the Roman empire, and the Mad hatter character in Alice in Wonderland was likely modeled after nineteenth-century hat makers who used mercury to stiffen hat material and frequently became psychotic from mercury toxicity. Human exposure to heavy metals has risen dramatically in the last years, probably, as a result of an exponential increase in the use of heavy metals in industrial processes and products. Today, chronic exposure comes from mercury-amalgam dental fillings, lead in paints and tap water, chemical residues in processed foods, and “personal care” products (cosmetics, shampoo and other hair products, mouth wash, toothpaste, soap among others (Abdulla and Chmielnicka, 1990).

1.2 Research Problem

With the gradual increase in the establishment of food industries in the state, especially at Onitsha, Nnewi and Ogidi, chronic effects of industrial wastes pollution is likely to be inevitable. Ideally, physical location of industries should strike a balance between socioeconomic and environmental considerations. In developing countries such as Nigeria, this is determined by various criteria, some of which are environmentally unacceptable, thereby posing serious threat to public health. Significant in this respect is the establishment of industrial estates along side residential areas in most state capitals and large urban centres in Nigeria. Already, some of the food industries are at a loss on the most effective way of disposing their wastes. Meanwhile, serious cases of contamination within the immediate environment have been observed (Adebisi and Fayemiwo, 2010). The situation, will no doubt, worsen where no attempt is made to address the problem. This research was initiated in an attempt to assist in providing a solution to this problem by overall assessment of the pollutant load of effluents from these food processing industries.

1.3 Scope of Study

This research involves collection of waste water samples from the following food processing industries in Anambra State on monthly basis, ranging from June, 2010 to January, 2011; spanning a period of eight (8) months. The food industries are (a) Resource Improvement and Manufacturing Co. Ltd; Akwu Uru, Umudim Nnewi (RIMCO), (b) Life Breweries Nigeria Ltd, Onitsha, maker of Life Breweries and Savanna soft drinks, (c) King Size Pharmaceutical Company (KP) Ltd Ogidi, (d) Golden Vegetable Oil Onitsha, and (e) Obisco Distilling and Hot Drinks Ogidi. The samples were analysed quantitatively using Atomic Absorption Spectrophotometer (AAS) Py Unican 1900 and other physiochemical methods. Also, microbiological examination were performed to determine the level of microbial contamination. It is intended that the parameters so obtained will give an indication of the level of the pollutants in the wastes waster.

1.4 Aim and Objectives of Study

This work is aimed at evaluating the heavy metal loads and some organic and microbial contaminants from the effluents of some food processing industries in Anambra State, Nigeria.

The specific objectives of this study are as follows;

1. To determine physicochemical characteristics of the effluents in the two seasons.
2. To determine the microbiological loads of the effluents during the two seasons
3. To determine the pollution index of the effluents during the two seasons.
4. To determine the level of organic pollutants in the effluents.

1.5 Importance of Study

Since a large number of food industries use a lot of water in their operations, a considerable volume of wastewater emanates from them. As industrial effluents are as varied in nature as industries themselves, the problem of pollution gets further aggravated as no standard procedure for treatment can be recommended. For a variety of reasons, industrial effluents are generally discharged into water courses either untreated or inadequately treated. This according to WHO, (2002), has created a problem of surface and sub-soil water pollution.

This work, no doubt, will help in Post Environemtnal Monitoring of the area/surrounding where these industries are situated so that the dangers posed by these effluents can be handled most effectively and efficiently.

1.6 The Study Area

Located in the South-East Nigeria, Anambra State is bound by Delta State to the West, Imo State to the South, Enugu State to the East and Kogi State to the North (Fig. 1). The food industries investigated were life Breweries Ltd, located at 87/97 Port Harcourt Road, Onitsha, Onitsha North Local Government Area of Anambra State. This industry produces Life Breweries and Savana soft drinks and had their effluent channeled into a drainage system that empties into Niger River. Golden vegetable oil was the next, situated at Plot 51A Harbour Industrial Layout, off Atani Road, Onitsha. Produces Golden Vegetable Oil and had its effluent discharged into open gutter which also empties into Niger River. Obisco Industries is situated at Umuonyejekwe Layout, Otigba Crescent, Ogidi, producers of flavoured black gold whisky, Sir Peters dry gin and ponche. King Size Pharmaceutical (KP) company, located at kilometer 15 Enugu/Onitsha express road, Ogidi produces KP brandy, dark rum, shnapps, satchet and bottled water, drugs such as asprin, syrup and paracetamol. Both companies are in

Idemili North L.G.A and also channelled their wastewater into the nearest drainage that either empties into ‘odoodo’ or ‘ofiakauzu’stream. Resource Improvement and Manufacturing Company (RIMCO), Akwu Uru Industrial Estate, Umudim, Nnewi produces Life Vegetable Oil, soaps, plastic tanks and jerry cans, master feeds and lubricants (A – Z engine oil). This company channeled its wastewater into an open gutter that empties into Ele River (‘Mmiri Ele’) very close to it.

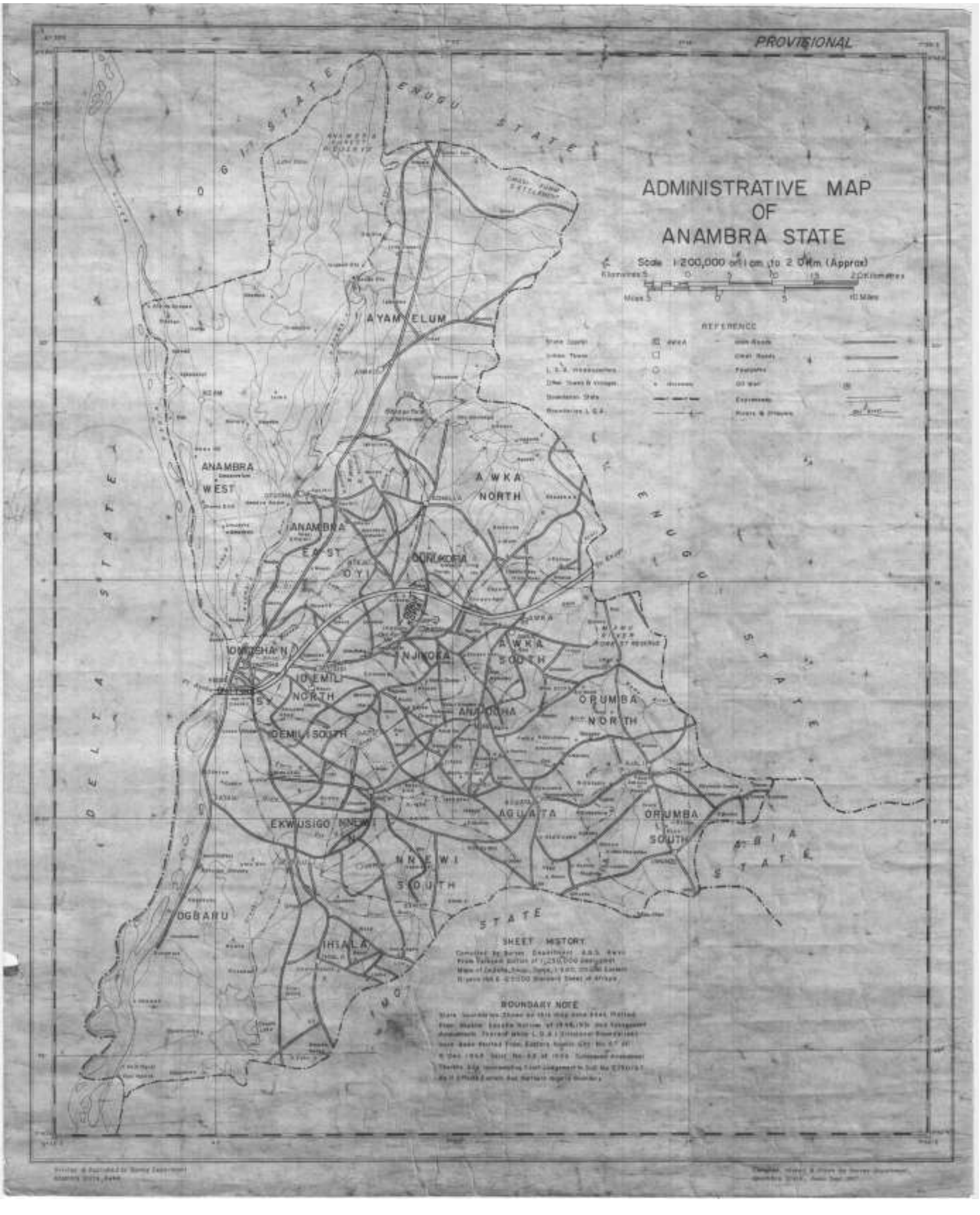


Fig. 1: Map of Anambra State

CHAPTER TWO

LITERATURE REVIEW

Industrial effluents containing toxic chemicals and heavy metals pollute several surface waters due to indiscriminate discharge of these wastes into rivers, streams, lakes, seas and on land. Mercury is one of the heavy metals, in a group that includes lead, cadmium, plutonium and others. Some marine algae may harbour heavy metals in concentration of up to one hundred times that of the water in which they are living, small fish eating the algae develop high concentrations of heavy metal in their flesh; larger fishes that eat the smaller fishes concentrate the metal still further, and so on up to fish eating birds or animals (Mertz, 1987). In today's industrial society, there is no escaping exposure to toxic chemicals and metals.

Most industrial effluents contain non-biodegradable toxic and hazardous wastes which bioaccumulate in living organisms when consumed. These wastes, according to Kaviraj and Guhathakurata, (2004) and Environmental Protection Agency, (1991), pose high health risks as well as threatening coastal and eustuarine fishes on which most rural populace, especially in the riverine areas, depend on for their livelihood.

Heavy metals cannot be degraded biochemically in nature. The stability of these materials therefore allows them to be transported to considerable distances by water; and as a result, their levels in the upper members of the food chain can reach values significantly high to cause health hazards, when such organisms are used as food by man. Some of these heavy metals are clearly inorganic form at the time of discharge and do undergo further biotransformation inside the organisms that consume them which render them extremely dangerous as reported by Montagomery, (1995) and Ezekwe, (2002). In general, therefore, selecting a treatment method for industrial effluents depends primarily on the following:

i. Identifying the various pollutants present in the effluent.
ii. Characterizing the effluent
iii. Regulating the sewers and separating the waste streams
iv. Selecting the treatment technology based on the different available physical, chemical or biological treatment capabilities.

The effects of heavy metal toxicity studies confirm that heavy metals can directly influence behaviour by impairing mental and neurological function, influencing neurotransmitter production and utilization, and altering numerous metabolic body processes. Systems in which toxic metal elements can induce impairment and dysfunction include the blood and cardiovascular, detoxification pathways (colon, liver, kidneys, skin), endocrine (hormonal), energy production pathways, enzymatic, gastrointestinal, immune, nervous (central and peripheral), reproductive and urinary (Groten and VanBladersen, 1994).

Much of the damage produced by toxic metals stems from the proliferation of oxidative free-radicals. A free-radical is an energetically unbalanced molecule, composed of an unpaired electron; it “steals” an electron from another molecule to restore its balance. Free radicals result naturally when cell molecules react with oxygen (oxidation), but, with a heavy toxic load or existing antioxidant deficiencies, uncontrolled free radical production occurs which if not checked, can cause tissue damage throughout the body; free-radical damage underlines all generative diseases. Antioxidants such as Vitamin A, C and E curtail free-radical activity.

Urbanization and industrialization develop countries economically, but lead to environmental pollution. The main effect of urbanization is increased run off which causes increased erosion thereby making the water muddy which is a type of pollution.

In addition to this, many new and sometimes toxic chemicals are added to the environment by various food processing plants.

Several human activities have indirect or devastating effects on water quality, aquatic environment and the human environment in general-such activities include accidental or unauthorized release of chemical substances, discharge of untreated wastewater or leaching of noxious liquids from solid waste disposal sites (Freeze and Cherry, 1999; Ojelabi and Fasunwan, 2001; Okonkwo *et al*., 2006). Many organic compounds occurring naturally and the synthetic ones are widely used as herbicides and pesticides, as well as in a variety of industrial processes. The negative effects on organisms vary with the particular type of compound, some are carcinogenic, toxic, directly to humans or other organisms, and make water unpalatable; and some accumulate in organisms. Industries producing pesticides, plastics, chlorine, caustic soda, pulp and paper introduce into the environment (soil & water) heavy metals such as mercury (Montagomery, 1995; Ezekwe, 2002). Analysis or the use of whole organisms according to Abdulrachman and Yahay, (2006), Okoye *et al.,* (2002) to evaluate the concentration of heavy metals in lower animals such as fish and crabs gave startling results. A lack of suitable processing variable limits the effective control of effluent quality (Agedengbe *et al.,* 2003). In recent years, the efficacy of industrial waste water evaluation has focused on new technology rather than conventional method such as ion-exchange, chemical precipitation and solvent extraction among others which are prohibitively expensive and inefficient, thus the need for the use of potential microorganisms in their treatment or in some cases, recycling is done as reported by Technologous *et al.,* (2003). The average daily amount of waste in the sewage produced by individual industry is customarily expressed by a related Biochemical Oxygen Demand (BOD) (Yang, 1996).

2.1 Impact of food processing effluents on the environment:

A wide variety of complex chemicals that can cause severe biotic damage at low concentrations and threaten the function of life include industrial additives, surfactants, pesticides, “wonder drugs”, pharmaceuticals among others. These pollutants appear in effluents from treatment plants, in drainage from agricultural land and settlements, and in leakages from septic tanks as well as land fills with their piles of corroding consumer products

In Nigeria, studies of wastewater effluents from six tanneries of Kano and Sokoto states have been carried out to characterize the composition of the effluents for possible environmental pollution risks (Lawal and Singh, 1981). Work has also been done on the chemical and biological analysis of effluents from Life Breweries, Onitsha; Anambra State of Nigeria, to monitor the level of its contamination of Niger River which serves as the receiver of these wastes (Igboeli, 1995).

The pollution of ground water and importance of ground water have been discussed by many workers including Okon *et al*., (1971); Mara *et al*., (1998), Leopold, (1977) and Ajiwe *et al*., (1986). Again, the global call for safe potable water has led to the analysis of ground and surface waters by some workers in Nigeria (Ajayi and Adeleye, 1977; Okoye, 1986). Industrial effluents, fertilizers from farm lands, diesel from pleasure boats, are possible pollutants of rivers and their environment (Raymond, 1992). Studies on the effects of human activities and industrial effluents on Nigerian biota have focused on various macro benthic invertebrates and fish (Ajao, 1985; Arimoro *et al.*, 2008 and Edokplayi, 1993). Acute toxicity tests of cassava and rubber effluents on the *oxtracoda stradesia prava kile*, 1935 (*crustacean ostracoda*) have been studied by Onyedineke *et al.,* (2000). According to the research, effluents resulting from the cassava mill plants are often directly or indirectly discharged into aquatic system without any prior treatment. Cassava wastewater contains unextracted starch, cellulose and carbohydrates, as reported by Abiona *et al.,* (2005). Cynogens and glycosides are easily hydrolysed into hydrogen cyanide which is toxic to aquatic animals and pose serious threat to the environment (Abiona *et al.,* (2000). The study also noted that effluents from rubber processing plants also find their way into the aquatic systems and contain both organic and inorganic matter that originate from the natural latex rubber and from chemicals used in processing such as ammonia, formic acid, sodium meta-bisulphite and sodium sulphite (Abiona *et al*., 2000; Kantachote *et al.,* 2005).

Array of chemicals and industrial materials leak from pipelines, storage tanks, and holding pond. Among these pollutants are classified as hazardous, meaning they are either inflammable, corrosive, explosive or toxic. As rain water percolates through the soil, it carries pollutants to the water table where they mix with the ground water and contaminate the supply. Because, ground water movements are usually slow, polluted water may go undetected for a long time (Odoemena, 1999).

Most often neglected is the damage done to property through corrosive attack resulting from the discharge of acids and occasionally of other industrial wastes into the fresh water resource. Corrosion of steel objects such as ships, damage to concrete structures in the stream and corrosion of piping, pumps, valves and other equipment in plants using contaminated water are quite common. There is evidence also that organic and inorganic chemicals in waste water used for irrigation can under certain circumstances accumulate in the plant and present potential toxic risks to consumers of agricultural products (Kaviraj and Guhathakurata, 2004). The principal health hazards associated with the chemical constituents of wastewaters, therefore, arise from the contamination of crops or ground waters. Hillman, (1998) has drawn attention to the particular concern attached to the cumulative poisons, principally heavy metals, and carcinogens, mainly organic chemicals. In view of the possible accumulation of certain toxic elements in plants (for example, cadmium, and selenium), the intake of toxic materials through eating the crops irrigated with contaminated wastewater must be carefully assessed. Many cities in the developing countries (like Nigeria) have been developed without adequate and proper planning, thus leading to indiscriminate actions including dumping of wastes in and around water bodies, washing and taking baths in rivers; and the use of rivers varies from one locality to another and so are the involvements, demands for its use accordingly, from fish farming to transportation, laundry and convenient points of waste discharge from both home and food processing industries, to recreation and do serve the domestic needs of the people for drinking water (Njoku and Onyeka, 2007).

Some non-metallic elements commonly used in industries are also potentially toxic to aquatic lives and to some extent to human beings: chlorine is widely used to kill bacteria in municipal water, sewage treatment plants and to destroy various micro organisms found in plumbing lines in water works stations. Chlorine can also kill or harm fish population (Chukwu, 2008; Marce *et al.,* 1993). Acids from industrial operations and acid mine drainages especially in coal and sulphide areas remain serious sources of surface and ground water pollution (Obodo, 2004; Odoemena *et al.*, 1999). Moreover, the runoff water from fertilized fields carries some of the fertilizers to rivers. In rivers and lakes, the fertilizer provides nutrients that increase the growth of algae. The algae use up the oxygen dissolved in the water, and the lack of oxygen causes the death of fish and other aquatic lives. Phosphates in laundry detergents have the same effect. Hence, the use of fertilizers as well as detergents results in eutrophication of water body. Pesticides used on crops get into rivers in this way too (Ajiwe and Okonkwo, 2007).

Problems from most of the above categories can be expected if untreated effluent is allowed to enter a river. The severity of the problem will, of course, depend on the volume of the effluent and the size of the receiving river or stream. There is the opinion that a flood-plain river can receive large amount of pollution because it is all washed out each rainy season, this may apply to some extent to inorganic pollutants such as some metals which require years to build up to toxic level (Sundaresan, 1977; Council of European Community, 1980). The situation is, however, quite different with biological pollutants. Here, we are dealing with infections and pathogenic agents which can produce their effects (in the spread of disease) within hours of entering the drinking water (UNEP, 2002). It therefore becomes imperative that effluent from food and other related industries are treated adequately so as to make them harmless at their point of discharge. Polluted water may contain pathogens and disease-producing organisms such as fungi, bacteria, viruses, protozoa, parasites and worms which are vectors that carry and spread diseases like salmonellosis, dysentery, diarrhea, typhoid fever, and other related diseases (Earth Watch, 1995; O'mel, 1985). Thus, contamination of water by effluents from food industries, is a serious environmental problem as it adversely affects the human health and the biodiversity in the aquatic ecosystem.

2.2 Heavy Metals

Heavy metals are contaminants that may occur as residues in food from the environment and industrial activities or from food processing. The term heavy metal refers to metallic chemical elements that have relatively high density (at least 5.0), are toxic or poisonous at low concentration values. They are natural components of the earth’s crust that cannot be degraded or destroyed, which would mainly include the transition metals, some metalloids, lanthanides and actinides. Examples as reported by Alloway, (1995) include copper, zinc, selenium, iron, lead, mercury, cadmium and silver among others. Heavy metals are also classified based on density, atomic weight, chemical toxicity in relation to living organisms. An alternative term to heavy metal is toxic metal of which no consensus of exact definition exists. Some of these metals such as cobolt, chromium, copper, manganese, molydenium and zinc are not left out of the list of heavy metals (Lee, 2007). Heavy metals may also be classified as “trace elements” because they occur in concentrations of less than 1% (frequently below 0.01% or 100mg/kg) in rocks of the earth’s crust (Marcorechio et. al., 2007). The trace elements or heavy metals often called micronutrients such as zinc, copper and manganese are useful to crops, while cobolt, manganese, copper and zinc are useful to live stock (Egeronu and Ibe, 2004). These metals that cannot be bio-degraded chemically in nature include cobolt, zinc, manganese, magnesium, copper, lead, nickel, cadmium and mercury (Earth Watch, 1995; Okoro, 1981; Jordao *et al*., 2004, Mombeshora *et al*., 1981).

Zinc is an essential component of about a hundred enzymes. This number is smaller in vertebrates. Zinc deficiency in man leads to dwarfism, reduced rates of blood clothing and wound healing, skin abnormalities and other problems (Alloway, 1995). The requirement, doses and tolerance levels of essential or trace elements are decided on the basis of effect on growth, health, fertility and other relevant criteria (Elinder and Jarup, 1996).

Breathing heavy metal particles, even at level well below those considered non-toxic, can have serious health effects. Virtually all aspects of animal and human immune system function are compromised by the inhalation of heavy metal particulates. In addition, heavy metals can increase allergic reactions, cause mutation, compete with "good" trace metals for biochemical bond sites, and act as antibiotic, killing both harmful and beneficial bacteria (Oskarsson, 1989). Heavy metals can also increase the acidity of the blood. The body draws calcium from the bones to help restore the proper blood pH. Further, toxic metals set up conditions that lead to inflammation in arteries and tissues, causing more calcium to be drawn to the area as a buffer. The calcium coats the inflamed areas in the blood vessels like a bandage, patching up one problem but creating another, namely, the hardening of the artery walls and progressive blockage of the arteries. Without replenishment of calcium, the constant removal of this important mineral from the bone result in osteoporosis (loss of bone density leading to brittle bones).

Current studies by Baroni, *et al.,* (2007), and Barros*, et al.*, (2007) indicate that even minute levels of toxic elements have negative health consequences, however, these vary from person to person. Nutrition status, metabolic rate, the integrity of detoxification pathways (Ability to detoxify toxic substances), and the mode and degree of heavy metal exposure, all affect how an individual responds. According to Nriagu *et al.,* (2007), children and the elderly whose immune systems are either underdeveloped or age-compromised, are more vulnerable to toxicity. These heavy metals produced by manufacturing industries have been the main cause of the alterations of the quality of the surface and underground water bodies. In places where these heavy chemicals and metals are produced, the concentration of these contaminants have been found to be very high on the soil, surface and underground water bodies. The inhabitants of these environments consequently become the endangered species. Cases of kidney failure, liver problems, blood infections, heart failures and extinction of aquatic organisms are common hazards (Myong, 2001; Nwaje and Iwegbue, 2007).

2.3 The toxic heavy Metals

2.3.1 Lead:

The Origin of Lead in Foodstuffs

Lead has been mined since ancient times and has been processed in many ways. For example, for water pipes, containers and, as acetate, even for sweetening wine ("lead sugar") (Silva *et al.,* 1993). World production amounts to millions of tons and is used in the manufacture of accumulators, solders, pigments, cables and anti-rust agents (red/lead/lead/oxide) (Bosshard and Zimmerli, 1994). The main sources of lead pollution in the environment are: Industrial products and their emissions, road traffic with leaded petrol, the smoke and dust emissions of coal and gas-fired stations, the laying of lead sheets by roofers as well as the use of paints and anti-rust agents (Schuman, 1993; Sada and Odomerho, 1988).

Problems for foodstuff were caused for a long time, and are still caused today on occasion, by the soldered seams of cans and the soldered closures of condensed milk cans, the metal caps of wine bottles and, still by lead pipes in drinking water systems. As regards to toxic effects, lead can trigger both acute and chronic symptoms of poisoning. According to report by Maduabuchi *et. al.,* (2006) acute intoxications only occur through the consumption of relatively large single doses of soluble lead while chronic intoxications can arise through the regular consumption of foodstuffs only slightly contaminated with lead.

Lead is a typical cumulative poison. As a result of their comparatively high affinity for proteins, the lead ions consumed, bond with haemoglobin (red blood pigment) and the plasma protein of the blood (Abdulla and Chmielnicka, 1990). This leads to inhibition of the synthesis of red blood cells and thus of the vital transport of oxygen. If the bonding capacity here is exceeded, lead passes into the bone-marrow, liver and kidneys, and according to Van Dokkum *et al.*, (1989), such an intoxication leads to the following:

i. Encephalopathies in the central nervous system (CNS)

ii. Disturbances in kidney and liver functions progressing as far as necrosis.

iii. Damage to the reproductive organs

iv. Anaemias and many metabolic deficiency symptoms.

Particularly dangerous to all forms of life are the organic lead compounds. They cause injuries to mental development such as reduction of intelligence, growth disturbances and spasticity. Children are particularly at risk from lead consumption, both before and after birth, as they absorb lead more rapidly than adults (Timothy *et al.*, 1989). Particularly affected are small children, with their habit of placing dirty fingers and objects of all kinds into their mouths or licking them (so-called mouth/hand activity) and, in this way, swallowing dust and soil particles containing heavy metals, from lead-based paints.

Present Contamination of Foodstuffs

In 1993, the Joint FAO/WHO Expert committee for Additives and Contaminants JECFA. (1989) reduced the value it had provisionally specified for adults in 1972, for tolerable lead consumption per week (PTW, Provisional Tolerable Weekly Intake), from 0.05mg/kg body weight to 0.02 mg (or 25µg). This is because research has revealed further harmful potentials in lead. The foodstuffs which contribute most to the consumption of lead are vegetables, fruits, drinking water, beverages and cereal product (Becker and Kumplaineni, 1991).

Fruits and vegetables mostly acquire their contamination through impurities in the air. The lead content in drinking water presents a problem in many countries. Thus, the present WHO guideline of 50µg/l is exceeded in Great Britain (JECFA, 1989). The World Health Organisation (WHO), stipulated respected minimum standard concentrations for these elements as numbers that will be present in the water bodies before they can be considered safe for use.

2.3.2 Cadmium

This exists in low concentrations in all soils. It is actively extracted from its ores for commercial purposes and is also emitted in industrial processes such as metal smelting and refining, coal and oil fired power stations, electroplating plant (Jones, (1989). It is spread by air and water (sewage sludge) far over sea and land, especially in the vicinity of heavy industrial plants. Cadmium is today regarded as the most serious contaminant of the modern age. It is absorbed by many plants and sea creatures and, because of its toxicity, presents a major problem for foodstuffs. Contamination through fertilizers becomes an increasing problem. For its toxicity, it is concentrated particularly in the kidneys, the liver, the blood-forming organs and the lungs. Cd intoxication most frequently results in kidney damage (necrotic protein precipitation) and metabolic anomalies caused by enzyme inhibitions (Richtwete, 1986). It was discovered by Galas-Gorchev, (1991), that the Itai-itai sickness in Japan (with bone damage) was a result of the regular consumption of highly contaminated rice. Cadmium is extremely toxic and consumption of water high in cadmium could cause adverse health effect to the end users.

Present Contamination of Foodstuffs:

Among the foodstuffs which present a problem are offal, crustaceans and shellfish. Here, values of several mg/kg are found (Darmond and Denton, 1990), however, vegetables are of greater importance for human cadmium contamination. According to a research by Gazza, (1990) and Groten *et al.,* (1990), rice and wheat contain 10-150µg/kg, meat, fish and fruit, between 1 and 50µg/kg but that of milk products is very low. The permissible cadmium contamination levels are based on the value last set by the FAO/WHO in 1989 of about 7µg/kg body weight, corresponding with a quantity of 0.4-0.5mg/person (70kg) per week. The typical quantities of cadmium consumed per person per day in the western industrialized societies are between 10 and 15µg, but these are considerably higher in some localities (JECFA, 1989).

Groten, *et al.,* (1990) argued that one problem of a special kind is the smoking of tobacco. According to them, 20 cigarettes a day, provide a cadmium input of 4µg.

2.3.3 Mercury

This passes into the environment through emissions from chemical plants (plants, paper, chlorine, plant pesticides) and power stations, mostly in effluents and sludges. The situation in sea water according to Goya, (1996) is of particular significance. Mercury becomes concentrated in shellfish, crustaceans and fish and thus, also passes, in the form of highly toxic mercury methylate, into the human food chain.

In 1965, the consumption of fish from regions of the sea contaminated by effluent led to the appearance of the so-called Minamata sickness in Japan and, in 1972, bread from cereals contaminated with fungicides containing mercury led to epidemic poisoning in Iraq (Emoyan *et al.,* 2006; Reeves and Vanderpool, 1997).

In its toxic effects, mercury in the form of its methyl compounds is specifically the most toxic of the heavy metals (Goya, 1996). When consumed orally, it first passes into the liver, the kidneys and the brain. Accumulation only takes place temporarily. A large part is excreted with the faeces. The salts of bivalent mercury, in the case of chronic consumption, first cause tiredness, loss of appetite and weight loss. In the end the kidneys fail. Muscular weakness and paralysis are typical (Chang, 1990).

The methyl mercury from animal foodstuffs also damages the central nervous system and the immune system.

Present contamination of foodstuffs

Vegetable foodstuffs are only very slightly contaminated with mercury, except when they are grown in the vicinity of emitting industrial plants. Among the animal foodstuffs, it is practically only sea food which exhibits relatively high contents of mercury (Oskarsson, 1992; Obodo, 2004). A special case are animals which are fattened on contaminated fish meal. The FAO/WHO Expert Committee (JECFA) (1989), has set a provisional maximum acceptable value for mercury consumption at 5µg per kg body weight per week. The average consumption of mercury varies in uncontaminated parts of the world between 20 and 80µg per day, but in contaminated regions, it is often temporarily higher (Elinder and Jarup, 1996). At these consumption, however, the values quoted above are only reached in exceptional cases. Up to 80% of the quantities of mercury consumed, originate by way of the food chain, either directly or indirectly from sea food.

The target organ of organic mercury (methyl mercury) in humans is the brain, where it disrupts the blood balance, upsetting the metabolism of the nervous system. The main toxic effects of inorganic mercury are that it tends to disrupt the functions of the kidney and liver. Compared with the inorganic mercury, methyl mercury can much more easily cross the placenta and affect the foetus (Eleanor, 1980; Igbegbe *et al*., 1992; Eboatu and Okonkwo, 1999).

2.3.4 Other heavy metals

Some heavy metals (the so-called trace elements) are essential in very small concentrations for the survival of all life forms, for example, copper, iron, zinc, chromium, molybdenum and others. Despite this fact, it is often forgotten that in some circumstances, in higher concentrations, these can also be quite toxic, for example when they are present in an organic compound (Eleanor, 1980).

Nickel has often been associated recently with allergies (contact with jewellery and jeans buttons containing nickel). There is no established knowledge of effects of this type when it is absorbed in the gastero-intestinal tract (Igbegbe *et al.,* 1992). Cocoa is one of the foodstuffs with higher than average natural nickel contents.

The copper content of tomato dishes prepared in copper pots and having a copper content of 0.1 – 0.2 mg/kg body weight has already been found to cause digestive disturbances in sensitive consumers (Oskarsson, 1989). This is inspite of the specified tolerable quantity or daily consumption of 0.5mg/kg.

Chromium, copper and zinc play major roles in modern industry and, in the vicinity of extraction or processing plants, the emissions arising are certainly capable of causing an undesirable contamination of agricultural products. Considerable quantities have been found in fruit and vegetables.

The presence of calcium and magnesium ions in water cause hardness. This hardness provides protection possibly by preventing dissolution of lead from water pipes as this can produce high blood pressure, one of the causes of heart attacks. Vanadium levels in the environment are rising as a consequence of the burning of vanadium-containing fossil fuels and its mining and processing in order to meet the growing needs for the metal in industry. Both acute and chronic effects of occupational exposure to vanadium compounds are manifested in the respiratory tract by irritation, including bronchitis and pneumonia. Beryllium is a powerful phosphate inhibitor and strontium is a competitor for calcium in the bone (Klabunde, 1980).

For the protection of human health, guidelines for the presence of heavy metals in water and contaminants have been set by different international organizations such as WHO, USEPA, EPA, and EUC, thus heavy metals have Maximum Contamination Level (MCL) which is enforceable standard set at numerical values with an adequate margin of safety to ensure no adverse effect on human health set by WHO, (1971).

2.4 Physico-chemical Parameters

2.4.1 pH

The pH value or hydrogen ion concentration is a measure of the acidity or alkalinity (basicity) of water or aqueous media. It is one of the most important determinations in water chemistry since many of the processes involved in water treatment are pH-dependent. Pure water is very slightly ionized into positive (H^+) ions and negative hydroxyl (OH^-) ions. A solution is said to be neutral when the numbers of hydroxyl ions and hydrogen ions are equal, each corresponding to an approximate concentration of 10^{-7} moles/l. The neutral point is temperature dependent and occurs at pH 7.0 at 25^oC. When the concentration of hydrogen ions exceeds that of the hydroxyl ions, i.e at pH values of less than 7.0, the solution or water has acidic characteristics. Conversely, when there is an excess of hydroxyl ions i.e. the pH value is greater than 7.0, the solution or water has basic characteristics and is sometimes described as being on the alkaline side of neutrality. The pH value of an unpolluted water is mainly determined by the inter-relationship between free carbon dioxide and the amounts of carbonate and bicarbonate present. Thus, the pH values of most natural waters are in the range of 4 to 9. Hard water which have percolated through limestone have high pH values. The pH of wastewater, however, is dependent on the by-products found in the wastes and on the manufacturing process undergone. Waters of low pH tend to be corrosive and if the pH value is very low, water can have a sour or acidic taste.

2.4.2 Odour/Taste

Odour just like taste is a subjective test which relies upon description rather than quantitative results. Odours tend to be closely related to tastes although there are certain non-volatile substances, such as sodium chloride which give rise to tastes without causing odour. Eddy (2005) reported that there are many potential causes of tastes and odours in water which include the following:

(i) Decaying vegetation, and algae may give rise to grassy or fishy odour. Algae may cause offensive odours as they die off while some living algae also cause taste and odour problems.

(ii) Moulds and some other organisms may give rise to earthy or mouldy odours and tastes in a water which may wrongly be attributed to algae growth. In stagnant waters and especially water in long lengths of pipeline left standing in warm surroundings, such as the plumbing system of a large building, the moulds have favourable conditions for growth and the first water drawn in the morning may have an unpleasant taste and odour of the kind mentioned above.

(iii) Iron and sulphur bacteria produce deposites which, on decompsotion release an offensive smell. The sulphur bacteria give rise to the sulphuretted hydrogen (rotten egg) smell.

(iv) Iron above certain amount will impact a bitter taste to a water.

(v) Industrial wastes constitute a prolific source of odour or taste problem in water. The odour or taste, however, depends on the nature of the substance within the waste. For potable water, it is usually to specify that the odour and taste should be objectionable.

2.4.3 Acidity

Acid water is one which has a pH value of less than 7.0. Acidity in water could be as a result of dissolved carbon dioxide which produces week carbonic acid. Organic acids produced by decomposing vegetation can also give rise to acidity in water. When the acidity is from natural origin such as these, the pH value of the water is usually above 3.7. Waters polluted by industrial effluent can contain free mineral acidity from strong acids and their salts, with pH values of below 3.7. The main requirement of acidity in water is that the water should be non-corrosive. The extent to which corrosion occurs, however, depends in most cases, largely upon the acidity or carbon dioxide content of the water and conversely, it can be controlled by the presence of calcium carbonate alkalinity with a sufficiently high pH. Certain treatment processes, notably, coagulation with aluminum sulphate reduce the pH value of the water making it more acidic. This happens mainly in water meant for domestic use. The final water leaving a treatment work should be non-corrosive with the pH value increased to correct for acidity when necessary. Where pH correction is not applied and an acidic water is allowed into the distribution system, corrosion problems can arise. This can result in attack of concrete pipes and the dissolution of heavy metals such as copper, zinc and lead.

2.4.4 Alkalinity

This is almost entirely due to the bi-carbonate, carbonate and hydroxide ions in water, usually in association with calcium, magnesium, sodium and potassium ions. Alkalinity of a water resource is its quantitative capacity to react with a strong acid to a designated pH. It is significant in many uses and treatment of natural and waste waters.

Since alkalinity of many surface waters is primarily a function of carbonate, bicarbonate and hydroxide constant, it is taken as an indication of the concentration of those constituents. Analysts often quote alkalinity in terms of $CaC0_3$ instead of carbonate or bicarbonate content. This is a convenient form of expression whereby the sum of the constituent salts is expressed in equivalent terms of calcium carbonate.

Alkalinity can exist in water resources below the neutral point of pH 7.0 because of the relationship between alkalinity, carbon dioxide and pH values. In the simplest form of the relationship, bicarbonate alkalinity is in equilibrium with carbon dioxide in water between pH values of 4.6 and 8.3. Above pH 8.3, free carbon dioxide ceases to exist and combines to give both carbonate and bicarbonate alkalinity. Between pH values of 9.4 and 10, the alkalinity is all due to caustic or hydroxide alkalinity (APHA, 1980). High level of alkalinity especially that of sodium carbonate can give rise to taste problem.

2.4.5 Total Solids/Residue

Total solids refer to solid matter suspended or dissolved in water or wastewater. Residue may affect water or effluent quality adversely in a number of ways. Waters with high residue generally are of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer. A limit of 500mg residue/litre is desirable for drinking water. Waters with very high dissolved solids (non-filterable residue) may be unsatisfactory for such purposes as bathing. Total solid is the term used for the material left in the vessel after evaporation of a sample and its subsequent drying in an oven at a defined temperature (T^oC).

- **Suspended Solid**

Suspended solids are particulate matter that floats in suspension in water. They have three main sources: Natural soil erosion, materials produced as a by-product of domestic and industrial activities and matter formed originally within a water body. Suspended matters are major carriers of many organic and inorganic pollutants including most toxic heavy metals, pathogens and nutrients. Suspended solid is also known as filterable solids because it can be filtered (WHO, 1993; European Community (EC), 1980).

- Dissolved Solids

This is also known as non-filterable solid because, it passes through the filter paper. They are dissolved substances in water. This parameter is a quantitative measurement of the dissolved salts in water. For a given water, the dissolved solids concentration can be directly related to the conductivity. Dissolved solids is obtained as the difference between total solids and suspended solid in a particular quantity of water sample.

2.4.6 Hardness

Originally, water hardness was understood to be a measure of the capacity of water to precipitate soap. Certain materials in water react with soap causing a precipitation which appear as a scum or curb on the water surface. Until enough soap has been dissolved to react with all these materials, no lather can be formed. A water which behaves like this is said to be hard. In conformity with current practice, total hardness is defined as sum of the calcium and magnesium concentrations both expressed as calcium carbonate in milligrame/litre. When hardness is numerically greater than the sum of carbonate and bicarbonate alkalinity, that amount of hardness equivalent to the total alkalinity is called “carbonate hardness”; the amount of hardness in excess of this is called non-carbonate hardness. When the hardness numerically is equal to or less than the sum of carbonate and bicarbonate alkalinity, all hardness is carbonate hardness and non-carbonate hardness is absent. A comparison of hardness levels may be given as in Table 1.

Table 1: Twort Hardness Classification

Range (mg/l)	Hardness Level Twort et al., 1986
0-50	Soft
50 – 100	Moderately soft
150-200	Slightly hard
Over 200	Hard
Over 300	Very hard

The problem caused by excessive hardness mainly is economical in terms of scale formation on boilers and hot water systems and the wastage of soap. Conversely, water softer than 30-50mg/l tend to be corrosive and liable to taking lead into solution which could lead to heart disease (U.K. Department, 1971). Where softening of water is used for domestic supply, it is recommended that a minimum hardness concentration of 60mg/l Ca (equivalent to 150mg/l $CaC0_3$) be used (NALCO, 1979).

2.4.7 Chloride

Chloride in the form of Cl^- ion is one of the inorganic anions in water and waste. In potable water, the salty taste produced by chloride concentration is variable and dependent on the chemical composition of water. Some waters containing 250mg chloride/litre may have a detectable salty taste if the cation is sodium. On the other hand, the typical salty taste may be absent in waters containing as much as 1,000mg/l when the predominant cation are calcium and magnesium. Chlorides are derived from natural mineral deposites, from agricultural or irrigation discharge or from sewage and industrial effluents. A high chloride content may harm metallic pipes and structures as well as growing plants (APHA, 1980).

2.5 Microbiological Monitoring

Disease in man can be caused by the presence of pathogenic organisms. From the health point of view, the most important characteristics of a good water is obviously an absence of pathogenic organisms, which are usually difficult to detect in water supply because of their small numbers. Even in a sewage effluent or polluted water, they may be present only infrequently or at irregular interval depending upon one or more carriers who excrete the pathogen.

The number of bacteria in the faeces of man and animals are quite numerous, and of these, the majority are *Escherichia coli,* which is a natural inhabitant of the intestines. Although *E. coli* has been considered harmless, certain strains have now been implicated in infantile diarrhoea (Okafor, 1985).

Test for *E . coli*

A high percentage of all bacteria found in faecal matter are *E . coli.* The presence of this bacterium in a water supply therefore indicates pollution by faecal microbes. Other Coliform organisms will usually be present as well but if *E. coli* are absent, then, the inference is that pollution primarily arises from the soil or vegetation since other members of the *E. coli* aerogenes group are predominantly found in soil. The presence of any Coliform bacterium must, however, be regarded as an advance warning that more serious pollution may follow, especially after rain.

The organisms which are used as indicators of contamination are:

Escherichia coli, Streptococcus faecalis, Clostridium perfringens (Welchi). Among these, the most commonly used indicators are *E. coli* and the Coliform group as a whole.

2.5.1 Routine Test for Bacteria Contamination of Water

The routine test to distinguish the kind of bacteria in water and to estimate the probable number of *E . coli* present are as follows:

The Plate Count

The standard plate count is not a central procedure in the examination of wastewater because it does not differentiate between the various types of organisms. It is principally done to know the number of colonies of bacteria which develop. The count also known as total colony count or total viable plate count is carried out on a non-selective medium e.g. nutrient agar. In this method, an aliquot of the water sample is spitted out on nutrient agar and incubated at 37°C. High count indicates high organic matter pollution. For most samples suspected to be highly contaminated, dilutions of up to 10^4 may be required during plating, but for samples of potable water, it should be enough to make a pour plate of an undiluted 1ml sample and 10^1 dilution. The colonies should, as in routine plate counting lie between 30 and 300 (Okafor, 1985).

Examination for Coliform organism and *E. coli*

Coliform bacteria are defined as all Gram-negative non-spore forming rods capable of fermenting lactose, with the production of acid and gas at 37°C in less than 48 hours. *E. coli,* which is a Coliform is regarded as a Gram-negative non-spore forming, short rods capable of fermenting lactose with acid and gas formation at both 37°C and 44°C in less than 48 hours; it also produces indole in peptone water containing tryptophane and can use sodium citrate as a sole carbon source. The test for Coliform and *E. coli* is also known as the presumptive and differential test respectively.

Detection

Two methods are used for the detection of Coliform organisms and *E . coli;* these are the multiple tube method and filtration or membrane filtration.

(i) Multiple Tube Method

The tests are conducted in three stages:

(a) The first stage is the presumptive test

Suitable volumes of water samples are inoculated into a number of tubes containing a suitable liquid medium such as MacConkey agar. Media are incubated at 37^{o}C for up to 48 hours. An estimate of the Coliform organisms present in the given volume can then be counted.

(b) Confirmatory Test

This test is for the presence of Coliform and *E. coli* in the presumptive positive tubes. Aliquotes of sample are sub-cultured from the positive tubes into fresh tubes of MacConkey agar, or brilliant green bile broth. One set of tubes is incubated at 37^{o}C for 48 hours for confirmation of the presence of Coliform; and the other set incubated at 44^{o}C for 24 hours to conform the presence of *E . coli.* The confirmatory test is positive if the tubes produce acid and gas at the end of the incubation period.

(c) Biochemical Test (further confirmation on completed test).

Completed tests are carried out if confirmatory test is positive. Contents of presumptive positive tubes are employed in further tests. Aliquots are inoculated on either eosin methylene blue agar, or MacConkey agar, and isolated typical coliform colonies with greenish metallic sheen or pink colonies with dark centres are picked off for identification by indole tests, methylred test, voges preskauer test, citrate utilization e.t.c.

Also a gram stained smear of the colonies on a slide is made. If the organism are gram-negative, non-spore forming bacilli fermenting lactose with the production of acid and gas at 37°C in less than 48 hours, they are members of the coliform group.

On the other hand, if gram-negative, non-spore forming bacilli capable of fermenting lactose with production of acid and gases at 37°C and 44°C in less than 48 hours and capable of producing indole with peptone water containing tryptoplane and can use sodium citrate as sole source of carbon are observed, they are *E. coli.*

(ii) The Membrane Filter Technique

This is an alternative method to the multiple tube technique. In this, a sample is drawn by vacuum through a membrane which retains all bacteria in the sample on it. The membrane is then saturated with or placed on a suitable culture medium and placed in an incubator so that each bacterium multiplying develops into a viable colony. The number of colonies is counted (as in the agar plate count, but using a magnifying glass), each separate colony being assumed to have originated from one bacterium, total coliform and faecal coliform can be distinguished. The method permits bacteriological testing in the field, provided that there is also available, a portable incubator, a supply of sterilized glass ware, distilled water, and (if any extensive testing is necessary) an autoclave for resterilizing glass ware. The method is however, unsuitable for highly turbid water because the pores of the membrane are rapidly blocked with the particulate matter of the water (Eddy, 2005; McFeters, 1974).

Test for Faecal Streptococci

Faecal streptococci are bacteria which principally occur in the faeces of man and animals. They are not as numerous as *E. coli* in all normal cases, hence the test for faecal streptococci may offer no advantage over the *E . coli* test, except in cases of doubt. (Koka, *et al.*, 2007; Okonkwo *et al.,* 2006). Since animals generally excrete much higher numbers of faecal streptococci than humans, the ratio of coliforms to faecal streptococci in a water can indicate whether the pollution is derived from human or animal sources. Koro and Bukar (2005), noted that the ratios of faecal coliforms to faecal streptococci greater than 4.0 are strongly indicative of predominantly human contamination with the associated danger of human disease transmission.

2.6 Wastewater Treatment and Disposal

Although industrialization is inevitable, various devastating ecological and human disasters which have continuously occurred over the last four decades implicate industries as major contributors to environmental degradation and pollution problems of various magnitude (Abdel-Shafy and Abdel-Basir, 1991; Asia and Ademoroti, 2001; Amoo *et al*., 2004), It has been reported that industrial effluent has a hazard effect on water quality, habitat quality and complex effects on flowing waters. (Ethan *et al*., 2003). Industrial wastes and emission contain toxic and hazardous substances, most of which are detrimental to human health (Rajaram and Ashutost, 2008; Ogunfowokan *et al.*, 2005, Jimena, *et al.,* 2008). These include heavy metals such as lead, cadmium and mercury, and toxic organic chemicals such as pesticides, dioxins, polyaromatic hydrocarbons (PAHs), petrochemical and phenolic compounds (Rao *et al*., 1998; Njoku *et al.,* 2009; Gbadebo *et al.,* 2010). Thus, if wastewater is not treated before discharge into the environment, it may lead to serious environmental degradation with its ugly effects on human health.

Because of the diversity of food processing industries, and the chemical processes involved in the operations, it is difficult to establish a standard and central method of treating all effluents. Methods of treatment is therefore based on the physical, chemical and biological composition of the wastes. Nevertheless, the general operation in the treatment units is based on the following features:

(i) Primary treatment:

This consists of physical separation of floating and suspended (settleable) solids from the effluents. Screens, grit chambers and settling tanks are employed for this purpose.

(ii) Secondary treatment:

This includes flocculation and precipitation of the remaining material in the water with the help of biological or chemical agents and their physical separation in secondary settling tanks. The by-products of the treatment processes are grits and sludges of different kinds of which grits can easily be disposed off by burial or burning. Sludge contains unstable volatile organic materials depending on the constituents and may be treated by the method of digestion in which gases are produced with high calorific values which can be successfully utilized for heating or power generation (Buswell, 1928).

2.6.1 Choice of Method of Treatment

As stated before, the choice of the method of treatment is determined by the conditions prevailing in each situation such as; the character of the waste, circumstances pertaining to the body of water being used for final disposal, state health department requirement, the cost of plant and its operation. Just as we have primary and secondary treatment, a detailed division is given below based on the treatment operation.

2.6.2 Physical Treatment

This includes those operations which do not involve chemical changes in the waste.

Clarification: This is the removal of coarse-dispersed solids which may be removed from water by sedimentation and filtration. When clarified by sedimentation, solid particles settle by gravity on the bottom of a settling tank in which water undergoing clarification is at rest or in slow horizontal or upward motion. Here, it is only particles which sink in water that can be removed from it by sedimentation. Sedimentation takes a long time, requires large capacity settling tank and cannot ensure complete removal of coarse- disposed impurities from water.

Filtration is a process of clarification of water by passing it through a porous material which retains coarse impurities on its surface and in pores. Filters used for water clarification are termed clarifying filters, also refers to as mechanical filters.

Another important aspect of mechanical treatment operation is skimming or floatation. This is used in the separation of grease and oil. It is a practice prevalent in oil producing and allied industries.

Certain substances in wastewater could easily be disposed of by heating, cooling, boiling and evaporation.

2.6. 3 Chemical Treatment:

This involves the addition of chemicals to the wastewater and is concerned with chemical changes or reactions in the constituents of the waste. Examples of chemical treatment processes are:

(a) Precipitation method

(b) Cation exchange processes

(c) Aeration

(d) Neutralization of acids and alkali.

2.6. 4 *Biological Treatment:*

This involves separation of *purtrecible* matter in suspension, and colloidal state. It includes:

(i) *Aerobic biological treatment:*

Bacteria are the primary degrader of organic wastes. They breakdown wastes to provide themselves with the necessary energy to reproduce. Aerobic bacteria utilize oxygen to carry out this work, i.e.

$$\text{organic wastes + oxygen} \xrightarrow{\text{bacteria}} \text{oxidized wastes + energy}$$

This energy is used to build new cells.

$$\text{Organic waste + Energy} \xrightarrow{\text{bacteria}} \text{New bacteria}$$

The process of bacteria oxidation leads to the mineralization of organic wastes (their conversion to inorganic forms) e.g.

$$\text{Organic carbon} + O_2 \xrightarrow{\text{bacteria}} CO_2$$

$$\text{Organic nitrogen} + O_2 \xrightarrow{\text{bacteria}} NO_3^-$$

$$\text{Organic Sulphur} + O_2 \xrightarrow{\text{bacteria}} SO_4^{2-}$$

Bacteria are used to oxidize wastes because they are self maintaining and self adjusting chemical factors that do the work at lower cost than man. Aerobic bacteria merely need an adequate supply of oxygen, this is provided in the form of mechanical aeration.

(ii) *Anaerobic Digestion*

This practice is applied mainly in the digestion of sludges, obtained as a result of some physical treatment of the wastes. Effluent sludges are best treated in the absence of oxygen by two spontaneously disappearing groups of anaerobic bacteria. The first group solubilizes the solids, principally to organic acids such as acetic acid, which are then converted by the second group to a mixture of carbon dioxide and methane. Methane is a useful fuel, and is thus potentially, valuable by-product of sewage treatment.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Sampling

Wastewater samples were collected from Resource Improvement and Manufacturing Company (RIMCO), Umudim, Nnewi; Life Breweries Ltd, Onitsha; Golden Oil Ltd Onitsha; King Size Pharmaceutical (KP) Ltd, Ogidi, and Obisco Beverage Company Ogidi, all in Anambra State. These were collected at one month interval starting from June 2010 to September 2010 (Rainy season) and October 2010 to January 2011 (Dry Season). A total of eight (8) sampling trips were made to each of the companies; 4 months dry season and 4 months rainy season for effective comparison.

Samples were collected at three different spots along the point of discharge of the effluents starting with point of discharge. (P_1) to 30 meters away from point of discharge (P_3).

The first sample was collected at the point of discharge of the effluent (P_1), then 15 meters away from the point of discharge (P_2) and finally 30 meters away from the point of discharge (P_3), making a total of three (3) sampling points per food industry per visit, except for Life breweries, Onitsha where Savana effluent had different pathway.

This pathway coalesced with that of Life Breweries effluent pathway at a point, thus samples were collected at the point of discharge (P_1) for both effluents. Collection of samples at 15 and 30 meters away from the point of discharge could not be continued for Savana effluent because of the mixing of its effluent with that of Life Breweries effluent but sampling continued with Life Breweries at the two points. Thus, there was no P_2 and P_3 for Savana effluent.

Collection of wastewater samples from the food industries lasted for eight (8) months, and at the end of each month, sixteen (16) samples were collected.

Each sample for physico-chemical analysis was collected using a 2 litre plastic container with a screw cap. The container was initially washed with detergent and rinsed with distilled water. At the point of collection, the container was rinsed three times with the sample before collection.

The pH of the effluents was taken on the field. Samples for biological monitoring were collected in sterilized one litre glass bottles with screw caps and care was taken not to allow air bubbles into the bottles during collection. The samples were immediately transported to the laboratory to ensure that the microbes are not suffered to death. Every sample collected was labeled correctly using masking tape.

Tests were carried out on fresh samples since samples for bacteriological examination should not be stored longer than 6 hrs. However, samples for physico-chemical analysis were stored in the refrigerator from where they were taken for analysis on daily basis.

The following examinations were carried out on the wastewater samples after collection:

(a) Physicochemical analysis

(b) Heavy metal determination

(c) Microbial analysis

(d) Determination of organic pollutants

3.2 Materials ad Reagents Used

3.2.1 Materials used for physico-chemical parameters

Portable pH meter (Hanna microprocessor)

Evaporating dishes - procelain dish of 100ml capacity, muffle furnace, analytical balance, funnel, drying oven, desiccator, water bath; burette pipette, conical flasks, millipore filter paper, stirring rods; colorimetric instrument-spectronic-21-spectrophotometer; volumetric flasks, beakers and spatula.

3.2.2 Reagents for Physico-chemical parameters

0.1M HCl, methyl orange indicator, phenolphthalein indicator, 0.01M EDTA, ammonia buffer solution (pH 10), Erichrome Black T (sodium salt of 1-(1-hydroxyl-2-naphthylazo)-5-nitro-2-naphthal-4-sulphonic acid, 0.014M $AgNO_3$ solution, distilled water, potassium chromate indicator, brucine reagent, concentrated sulphuric acid, 30% NaCl, nitric acid (concentrated), conditioning reagent (mixture of 7.5g NaCl, 3ml conc HCl, 10ml of 20% isopropylalcohol, 5ml glycerol and 30ml distilled water), stock sulphate solution, barium chloride ($BaCl_2$) crystals, standard sulphate solution, standard 0.02M NaCl solution.

3.2.3 Material for heavy metal determination

Atomic Absorption Spectrophotometer Model Pye Unican 1900.

3.2.4 Reagents for heavy metal determination

Air produced by compressor, acetylene gas (standard commercial grade), several stock and standard metal solutions.

3.2.5 Materials for Microbiological Analysis

Sterile tubes, sterile 20ml and 10ml bottles, sterile Durham’s tubes, sterile graduated 10ml, 1ml and 0.1ml pipettes.

3.2.6 Reagents for Microbiological Analysis

MacConkey Broth, Brilliant Green Bile Broth (BGBB), Eiosin Methylene Blue Agar [EMBA], nutrient agar, peptone water, reagents for IMVIC test and other biochemical test.

3.2.7 Materials for Organic Pollutant Determination

Hexane – analar reagent grade

GC-MS-QP 2010 PLUS SHIMADZU JAPAN

3.3 Physico-Chemical Analysis

3.3.1 pH Determination

Procedure:

The pH of the effluents were measured using a portable pH metre at the sampling point. This was done by rinsing the electrode with the sample. The metre was allowed to stabilize before taking the readings.

3.3.2 Total Solid (Residue)

This was done according to the method outlined by APHA, (1980).

Procedure

Clean dry evaporating dishes were ignited at 550°C for 1 hour in a muffle furnace. They were allowed to cool, weighed and stored in a desiccator, 100ml of each sample was measured and transferred into each of the pre-weighed dishes. The samples were evaporated to dryness on a water bath, allowed to cool and weighed.

Calculation:

$$(\text{mg/l})\ \text{Total solids} = \frac{\text{Ws} \times 10^6}{V_I}$$

Where V_I = Vol. of sample evaporated

W_S = Weight in gramme of residue obtained.

3.3.3 Total Suspended solids:

Procedure:

The Millipore filter paper was dried, weighed and fitted into a funnel. 100ml of the sample was filtered through it. The filter paper was removed and dried in the oven at 105^{o}C for 1 hour. It was later cooled in a desiccator.

mg/L Total Suspended solid =

$$\frac{(A - B) \times 1000}{\text{Sample volume (ml)}}$$

Where A = weight of filter paper + residue in mg.

B = weight of filter paper in mg.

3.3.4 Total Dissolved solids:

The total dissolved solids was easily obtained by simple calculation.

Total dissolved solids = Total solid – suspended solids.

3.3.5 Alkalinity Determination:

The double titration method as given by AOAC, (1980), NNPC Refinery Laboratory Analysis, (1979) and Annual Book of ASTM Standard for Water, (1978).

Procedure:

25ml of each sample was pipetted into a conical flask, three drops of phenolph-thalein indicator was added, there was no colour change.

Methyl orange indicator was added and was titrated to a light pink end point with 0.1M HCl.

Calculation:

(a) **Hydroxyl content (mg/l)**

$$= \frac{1000 \times V \times M \times 17}{V_I}$$

(b) **Bicarbonate content (mg/L)**

$$= \frac{1000 \times V \times M \times 30}{V_I}$$

(c) **Total Alkalinity (mg/L $CaCO_3$)**

$$= \frac{1000 \times V \times M \times 50}{V_I}$$

Where V = Vol. of acid used in titration

M = Molarity of HCl

V_I = Vol. of sample used.

3.3.6 Total hardness Determination

This was done using APHA, (1980) method of EDTA Titrimetric method.

Principle:

Ethylene diaminotetra acetic acid and its sodium salt (EDTA) form a chelated soluble complex when added to a solution of certain metal cation. If a small amount of a dye such as Eriochrome Black T is added to an aqueous solution containing Calcium and magnesium ions at pH of 10.0 ± 0.1, the solution becomes wine red.

If EDTA is added to a titrant, the calcium and magnesium will be complexed and the solution turns from wine red to blue, marking the end point of the titration.

Procedure:

25ml of the sample was pipetted into the conical flask and two drops of Erichrome Black T solution was added.

2ml of ammonia buffer was titrated with 0.01M EDTA solution. The colour changed from wine red to blue black when the end point was attained.

Calculation:

Total Hardness (mg/$CaCO_3$/L)

$$= \frac{V \times M \times 2.5 \times 1000 \times S}{\text{Vol. of sample used}}$$

Where V = Vol. of EDTA used in titration

M = Equivalent weight of Ca^{2+}

S = Strength of ETDA

$$2.5 = \frac{\text{Molecular mass of } CaCO_3}{\text{Atomic mass of } Ca^{2+}}$$

3.3.7 Chloride Determination

This was done using APHA (1980) method.

Principle:

In a neutral or slightly alkaline solution, potassium chromate can indicate the end point of the silver nitrate titration of chloride. Silver chloride is precipitated quantitatively before red silver chromate is formed.

Procedure:

25ml of the waste water sample was pipetted into a conical flask, 3 drops of K_2CrO_4 indicator was added, the mixture was titrated using $AgNO_3$ solution until the colour changed to a light red (precipitation) end point.

Calculation:

Chloride content (mg/l)

$$= \frac{V \times N \times E \times 1000}{\text{Vol. of sample used.}}$$

Where V = Vol. of $AgNO_3$ used in titration.

N = Normality of $AgNO_3$.

E = Equivalent weight of chloride.

3.3.8 Determination of Nitrate

Nitrate was determined using Brucine colorimetric method (APHA, 1980)

Procedure:

100ml each of the standards were transferred to a set of 250ml beakers. To these standards were added 2ml of 30% NaCl solution, 20ml of concentrated sulphuric acid and swirled. 0.2g of Brucine reagent was added to all the flasks which produced colour development. 10ml each of the samples and a blank were treated with the same reagents as the standards.

The absorbance of the standards and the samples were read with spectrophotometer at 410nm.

The readings of the standard were plotted against their concentration to obtain the calibration curve.

The total nitrate concentration for the samples were calculated from the calibration curve by interpolation.

3.3.9 Sulphate Determination

This was done using Turbidiometric method (APHA, 1980).

Principle:

Sulphate ion is precipitated in a hydrochloric acid medium with Barium chloride so as to form barium sulphate ($BaSO_4$) crystals of uniform size. Light absorbance of the $BaS0_4$ suspension is measured by a transmission photometer and the sulphate ion concentration is determined by comparison of the reading from a standard curve.

Procedure:

Formation of barium sulphate turbidity: 100ml each of the standard solution were poured into conical flask. To each standard was added 5.00ml conditioning reagent with stirring for one minute. While still stirring, a spatulaful of barium chloride crystal was added. Distilled water was used to standardize the spectrophotometer. This was poured into absorption cell of the spectrophotometer and after placing the cell at the compartment, the galvanometer was adjusted to zero absorbance. One of the cells was emptied and filled to the mark with treated standard solution, this was placed in the compartment and was allowed to stand for four (4) minutes. The absorbance was read at 420nm wavelength. 100ml of each sample in the twin cell was taken and treated the same way as the standard and the absorbance was also recorded.

Preparation of Calibration Curve

The absorbance of the standard solution was plotted against their concentrations to obtain the calibration curve.

This was used to obtain the concentration of sulphate in the samples.

Calculation:

$$\text{mgS0}_4/\text{l} \quad = \quad \frac{\text{mg SO}_4^{2-} \text{ x } 1000}{\text{ml samples}}$$

3.3.10 Acidity

Procedure:

100ml of the sample was pipetted into a 250ml flask and 3 drops of the phenolphthalein indicator added. It was then titrated with 0.02M NaOH from the burette until the first permanent pink colour appeared (APHA, 1980).

Calculation

Total Acidity (mg/l CO_3^-) =

$$\frac{\text{ml of NaOH x Molarity of NaOH x 50 x 1000}}{\text{ml of sample}}$$

Molarity of NaOH = 0.02M

3.4 Heavy Metal Determination

Determination of mercury, chromium, cadmium, zinc, lead (Pb), manganese (Mn), and copper (Cu) by Atomic Aborption Spectrophotometry (AAS), pye unican 1900.

Standard Metal Solution

A series of standard metal solution were prepared by diluting the following stock metal solution with water containing 1.5ml concentrated HNO_3/l.

Copper: 1.00g of copper metal was dissolved in 1.5ml of Nitric acid (HNO_3) and diluted to 1000ml with distilled water; 1.00ml = 1.00mg Cu.

Manganese: 3.076g manganous sulphate ($MnSO_4$-H_2O) was dissolved in 200ml distilled water; 1.5ml of concentrated HNO_3 was added and diluted to 1000ml with distilled water.

Lead: 1.598g of lead nitrate was dissolved in 200ml of distilled water and 1.5ml concentrated HNO_3 added and made up to 1000ml with distilled water. 1.00ml = 1.00mgPb

Cadmium: 1.00g cadmium metal was dissolved in a minimum vol of 1:1 HNO_3; 1.00ml = 1.00mgCd.

Nickel: 1.273 nickel oxide (NiO) was dissolved in a minimum vol of 10% v/v HCl and diluted to 100ml with water, 1.00ml = 1.00mgNi.

Zinc: 1.00g of Zinc metal was dissolved in 20ml 1:1 HCl and diluted to 1000ml with water, 1.00ml = 1.00mgZn

Procedure:

The hollow cathode lamp of desired metal was installed in the pye Unican SP 1900 and the wavelength was set. The AAS was turned on and the amount of current suggested by the manufacturer to the hollow cathode lamp was applied. The instrument was allowed to warm up until the energy source was stabilized. The burner head was installed, the air was turned on and the flow rate adjusted to the value specified and the flame was ignited. A standard was aspirated and atomized and the burner adjusted to obtain a maximum response.

Standardization:

At least 5 (five) concentrations of each stock standard metal solution was prepared by diluting aliquots of stock solution to 100ml. Each standard was aspirated in turn into the flame and the absorbance recorded. A calibration curve for each metal being determined was obtained by plotting on a linear graph paper the absorbance of standard versus their concentration in mg/l.

Analysis of Samples

The nebulizer was rinsed by aspirating distilled water containing 1.5ml concentrated HNO_3/l. The instrument was zeroed by aspirating blank. The samples were then atomized and the absorbances were recorded.

The concentration of each metal ion in mg/l was calculated by referring to the appropriate calibration curve.

3.5 Pollution Index (Pi) of the Heavy Metals

Pollution index (Pi) shows the relative pollution contributed by each heavy metal. A pollution index of more than 1.00 (Pi > 1.000) indicates that average heavy metal concentration are above the permissible levels, while values less than 1.00 shows no pollution.

Pollution index (Pi) is expressed as a function of the concentration of individual heavy metal against the baseline standard or tolerable limit. It is given as

$$Pi = \frac{1}{n} [M.sub1/(T.L).Sub.1] + [M.sub.2/(T.L).sub.2] + \ldots + [M.subn/T.L.)\ sub.n]$$

Lee *et al.,* (1998).

Where Pi = Pollution index

M.sub1; M. sub2 and M.subn = Average concentrations of polluting heavy metals

(T.L). Sub1; (T.L). sub 2 and (T.L). subn = Baseline standard or Tolerable limit of the polluting heavy metals.

3.6 Microbiological Analysis

Method

3.6.1 Presumptive Test: Measured amounts of 5ml single strength, 10ml double strength, MacConkey broth medium were sterilized in 20ml and 10ml bottles containing a Durham tube for indicating gas production. With sterile graduated Pipettes, the following amount of waste water were added. Into each of 5 bottles of 10ml double strength MacConkey broth were inoculated 10 ml of waste water. Into each of 5 bottles of 5ml single strength MacConkey broth were innoculated 1ml of waste water. Into each of 5 bottles of 5ml single strength MacConkey broth were inoculated 0.1ml of wastewater.

These were repeated for the respective wastewater samples. There after, the bottles were incubated at 37^{o}C in a water bath and examined after 24hours for the presence or absence of acid and gas production. Those that showed acid and sufficient gas to fill the concavity of the top of the Durham tubes were considered to be contaminated or presumptive positive as a result of the growth of Coliform bacilli. Any remaining negative bottles were reincubated for another 24hours for further checking, and if acid and gas develop, they too were regarded as being positive. Again, the negative bottles were subcultured unto fresh Nutrient Agar plates to check if there was other contaminants apart from Coliform bacilli.

3.6.2 Differential Coliform Test (EIJKMAN Test):

Here, Eijkman test is usually employed to ascertain whether the Coliform bacilli detected in the presumptive test were *Escherichia coli.* This test depended on the ability of E. coli to produce gas and turbidity when growing in Brilliant Green Bile Broth medium pre-warmed at 37^oC. Here, all bottles considered presumptive positive were sub-cultured into Brilliant Green Bile Broth medium pre-warmed at 37^oC. These were incubated at 44^oC in a water bath and examined after 24hours for the presence of gas production and turbidity and for colour change.

For confirmatory test, all bottles showing gas production and turbidity were sub-cultured unto Eiosin Methylene Blue Agar. Peptone water broth were also inoculated and incubated at 44^oC in a water bath and examined after 24 hours to check for indole production at 44^oC.

For completed test, colonies developing were gram stained and were further inoculated into Indole test medium, methyl red test medium, voges-proskaur test medium, Citrate medium. Also, slopes were made on nutrient agar. All these were examined and the result were recorded respectively.

3.6.3 Identification of the Isolates

The isolates were identified using the following methods-

3.6.3.1 *Macroscopic Examination*

This was the visual examination of the appearance of the organisms isolated on the eiosin methylene blue agar media and nutrient agar media respectively. Such examination included colony morphology, size, colour, texture, whether smooth or rough surface, flat or raised and other features.

3.6.3.2 *Gram Staining:*

Gram staining method was most commonly used in microbiology since it differentiates bacteria into two classes- the gram positive organisms that stained dark purple and gram negative organisms that stained pale to dark red. To identify the cell type, and features of the isolates, the gram stain was therefore performed on each isolate.

Method

With a sterile wire loop, the isolates were smeared on a clean grease-free slide and fixed with mild heat, the slides were stained with 0.5% crystal violet solution for 1 minute. They were washed with water and flooded with Lugols lodine for 1minute followed by washing with water again. Each sample slide was rinsed or decolourised with acetone-alcohol solution. These were then washed with water. The slides were counter stained with neutral red for 2 minutes and washed with water. The back of the slides were wiped clean and were placed in a draining rack for the smears to air dry. Each smear was examined microscopically using oil immersion, that is x 90 or x 100 objective.

Gram positive isolates stained dark purple, blue or violet while gram negative isolates stained pale to dark red.

3.6.3.3 *Indole at 44^{o}C*

Using a sterile straight wire, 5ml of sterile Motility Indole Urea (MIU) medium was inoculated with a smooth colony of the test organisms. An indole paper strip was placed in the neck of the Motility Indole Urea tube above the medium and the stopper. This was incubated at 37^{o}C-44^{o}C over night and examined for indole production by looking for a reddening of the lower part of the strip.

Reddening of strip showed positive test (indole was produced). No red colour showed negative test (No indole was produced).

3.6.3.4 *Methyl Red Test:*

A colony of the test organisms was inoculated in 0.5ml of sterile Glucose Phosphate Broth. After overnight incubation at 35-37^{o}C, a drop of methyl red solution was added.

A positive methyl red test was shown by the appearance of a bright red colour, indicating acidity while a yellow or orange colour showed a negative test.

3.6.3.5 *Voges-Praskaur test:*

2ml of sterile glucose phosphate peptone water was inoculated with the isolates and incubated at 35-37^{o}C for 48hours. A very small amount of creatine was added and mixed thoroughly. 3ml of sodium hydroxide reagent was added and shaken. The bottle cap was removed and this was left for 1 hour at room temperature. Pink-red colour showed positive test. No pink-red colour showed negative test.

3.6.3.6 *Citrate Utilization Test:*

Using a sterile straight wire, 3-4ml of sterile koser’s citrate medium was inoculated with a culture of the isolates. The inoculated broth was incubated at 35-37^{o}C for up to 4 days, checking daily for growth.

Turbidity and blue colour showed positive test (Citrate was utilized). No growth showed negative test, (Citrate was not utilized).

3.6.3.7 *Catalase Test:*

A small portion of the colony was placed under test in a drop of hydrogen peroxide on a clean grease-free slide. Active bubbling or effervescence at the drop of hydrogen peroxode indicated positive test (Catalase was produced). No release of bubbles showed negative test (Catalase was not produced).

3.7 Determination of Organic Pollutants Using Gas Chromatrography-Mass Spectroscopy (GC-MS).

Procedure:

100ml of each sample was mixed with 20ml of hexane and the hexane was extracted and concentrated to a 5ml volume. This was then used to determine the organics using a GC – MS. GC - MS-QP2010 PLUS SHIMAD2U JAPAN auto sampler and auto analyzer model was fused with HP-innowax fused capillary column (60 x 0.25mm i.d) and helium as the carrier gas (flow rate:1.61cm^3/min). The injection temperature was 250^{o}C and oven temperature kept at 60^{o}C for 5 minutes, then kept constant at 140^{o}C for another 5 minutes and then programmed to 280^{o}C at a rate of 20^{o}C/min and then kept at 280^{o}C for 15 minutes. The end of the capillary column was inserted directly into the ion source of MS and interface temperature was maintained at 250^{o}C. The mass spectrometric data were acquired and processed with SHIMADZU MAT 330 data system. The run button was pressed and later the peak started appearing on the computer screen at different times. This profile was later printed out as shown in appendices. The instrument had an accompanying library embedded in the computer software attached to the equipment. The compounds were identified using the National Institutes of Standards and Technology (NIST) Mass spectral library based on their similarity.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results of the Mean Concentrations of the Heavy Metals

Mean concentrations of heavy metals in the effluent samples at various points of collection from the different food processing industries studied are shown in Tables 4.1, 4.2 and 4.3 (rainy season) and Tables 4.4, 4.5 and 4.6 (dry season).

Table 4.1 Mean levels of heavy metals (mg/L) in effluents during rainy season for Life breweries and Savana drinks

Heavy Metal	Life Breweries/Point of Collections			Savana Drinks/Point of Collections			FMEnv (1991) Effluent Limit (mg/L)
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Mercury (Hg)	1.206 ± 0483	1.106± 0.219	2.115± 0.488	1.985± 0.462	-	-	0.05
Nickel (Ni)	0.440 ± 0.194	0.960± 0.321	0.710± 0.501	0.790± 0.252	-	-	<1.0
Copper (Cu)	0.628± 0.170	0.713± 0.321	0.920± 0.269	0.703± 0.331	-	-	<1.0
Iron (Fe)	1.310± 0.040	0.685± 0.204	1.265± 0.175	1.373± 0.111	-	-	1.0
Gold (Au)	0.425± 0.005	0.498± 0.020	0.378± 0.175	0.500± 0.015	-	-	NA
Chromium (Cr)	1.685± 0.053	0.638± 0.120	1.225± 0.018	0.608± 0.104	-	-	1.00
Manganese (Mn)	0.428± 0.018	0.110± 0.010	0.193± 0.005	0.085± 0.002	-	-	NA
Bismuth (Bi)	0.788± 0.041	1.263± 0.306	2.595± 0.197	1.620± 0.147	-	-	NA
Lead (pb)	3.020± 0.111	2.665± 0.205	2.820± 0.174	2.495± 0.108	-	-	<1.0
Tin (Sn)	0.890± 0.001	0.820± 0.012	1.034± 0.010	0.928± 0.011	-	-	NA
Cobalt (Co)	0.003± 0.059	0.005± 0.060	0.425± 0.058	0.138± 0.057	-	-	NA
Cadmium (Cd)	0.220± 0.039	0.400± 0.196	0.328± 0.171	0.465± 0.106	-	-	1.0
Silver (Ag)	0.003± 0.050	0.061± 0.001	0.163± 0.005	0.528± 0.005	-	-	NA
Arsenic (As)	0.003± 0.059	0.340± 0.243	0.165± 0.220	0.208± 0.283	-	-	1.0
Selenium (Se)	0.195± 0.035	0.363± 0.190	0.600± 0.168	0.223± 0.103	-	-	NA
Zinc (Zn)	0.995± 0.035	4.518± 0.190	4.753± 0.168	4.753± 0.103	-	-	<1.0

NOTE: P_1 = Point of discharge of effluent P_2 = 15 meters aay from point of discharge P_3 = 30 meters away from point of discharge NA = Not Available

Table 4.1 shows that the concentrations of heavy metals at the various points of collection of the effluents (rainy season) did not follow any particular trend. For instance, the total mean concentrations of mercury (Hg) were highest at 30 meters away from the point of discharge of the effluents (P_3) in Life Breweries effluent, followed by the value (1.206±0.483mg/l) obtained at the point of discharge (P_1), while the least value of Hg (1.106±219mg/l) was obtained at 15 meters (P_2) away from the point of discharge of the effluent. However, this particular trend was not observed in the occurrence of other heavy metals in this effluent. The total mean concentrations of selenium (Se), silver (Ag), cobalt (Co), bismuth (Bi) and copper (Cu) were highest at 30 meters (P_3) away from the points of discharge of the effluents, followed by the values obtained 15 meters (P_2) while the least mean total concentrations of these heavy metals were obtained at the points of discharge of the effluents (P_1). This could probably be as a result of flow velocity factor leading to boundary effect at P_3, hence increase in the levels of these heavy metals at P_3 than P_2 and P_1.

Table 4.2 Mean levels of heavy metal (mg/l) in effluents during rainy season for KP Beverage and Obisco Beverage, Ogidi

Heavy Metal	**KP Beverage, Ogidi**			**Obisco Beverage, Ogidi**			**FMEnv (1991) Effluent Limit (mg/L)**
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Mercury (Hg)	0.138± 0.433	1.673± 0.225	1.945± 0.450	1.475± 0.192	2.533± 0.447	1.613± 0.276	0.05
Nickel (Ni)	0.405± 0.388	0.888± 0.210	1.248± 0.450	0.850± 0.475	0.390± 0.483	0.463± 0.446	<1.0
Copper (Cu)	0.465± 0.182	0.928± 0.303	0.570± 0.394	0.853± 0.424	1.020± 0.480	0.468± 0.308	<1.0
Iron (Fe)	0.960± 0.170	0.903± 0.063	0.788± 0.121	1.723± 0.070	2.965± 0.091	0.088± 0.099	1.0
Gold (Au)	0.160± 0.087	0.398± 0.063	0.260± 0.051	0.695± 0.015	0.735± 0.041	0.645± 0.019	NA
Chromium (Cr)	1.380± 0.165	0.385± 0.112	0.585± 0.136	0.160± 0.122	0.398± 0.141	1.020± 0.142	1.00
Manganese (Mn)	0.128± 0.060	0.360± 0.070	0.438± 0.066	0.675± 0.060	0.173± 0.054	0.170± 0.054	NA
Bismuth (Bi)	0.636± 0.118	2.741± 0.067	2.021± 0.082	2.115± 0.103	1.925± 0.183	0.186± 0.312	NA
Lead (pb)	0.563± 0.169	2.355± 0.115	0.818± 0.136	0.398± 0.123	0.630± 0.148	1.593± 0.145	<1.0
Tin (Sn)	0.563± 0.007	0.778± 0.004	0.808± 0.008	0.223± 0.012	1.535± 0.009	0.490± 0.012	NA
Cobalt (Co)	0.100± 0.180	0.005± 0.070	0.050± 0.055	0.258± 0.058	0.128± 0.059	0.009± 0.058	NA
Cadmium (Cd)	0.310± 0.117	1.033± 0.065	0.560± 0.072	0.728± 0.063	0.883± 0.089	1,123± 0.088	1.0
Silver (Ag)	0.253± 0.000	0.525± 0.003	0.578± 0.003	0.075± 0.003	0.328± 0.005	0.530± 0.005	NA
Arsenic (As)	0.090± 0.164	0.180± 0.111	0.153± 0.135	0.373± 0.127	0.330± 0.153	0.240± 0.146	1.0
Selenium (Se)	0.125± 0.105	0.725± 0.059	0.548± 0.070	0.778± 0.063	0.020± 0.088	0.223± 0.088	NA
Zinc (Zn)	0.025± 0.105	2.278± 0.059	2.425± 0.070	1.528± 0.063	1.025± 0.088	1.278± 0.088	<1.0

NOTE: P_1 = Point of discharge of effluent P_2 = 15 meters aay from point of discharge P_3 = 30 meters away from point of discharge NA = Not Available

Table 4.2 shows the variations of the mean ± S.D of the concentrations of heavy metals in the effluent samples from Kingsize Pharmaceutical Company (KP) and Obisco Beverages, Ogidi (in the rainy season) along the point of discharge of the effluents (P_1), 15 meters away from the point of discharge (P_2) and 30 meters away from the point of discharge (P_3) of the effluents. The Table shows marked variations in the heavy metal concentrations from the effluent samples at various points of collection. Total mean concentrations of heavy metals from the effluent samples did not follow clearly discernible pattern at different points of collection. For instance, the mean concentrations of Zinc at the point of discharge (P_1) of the effluent for KP was 0.025± 0.105mg/l (high) compared to the value obtained for this heavy metal from the same effluent 15 meters away from the point of discharge (P_2) which was 2.278 ±0.059mg/l (higher) and the value at 30 meters away from the point of discharge of the effluent at P_3 (2.425±0.070mg/l) (highest). This trend was also observed in the concentrations of silver in both KP and Obisco effluents, where highest concentrations was obtained from the effluent samples at P_3 (highest) through P_2 (higher) and then P_1 (high).

However, this trend was not observed for other heavy metals as some recorded mean values that were higher at P_1 than P_2 and P_3, while others had total mean concentrations that were highest at P_2 compared to the mean levels obtained at P_3 and P_1.

Table 4.3 Mean levels of heavy metal (mg/l) in effluents during rainy season for Golden Vegetable Oil, Onitsha and RIMCO, Nnewi

Heavy Metal	Golden Vegetable Oil, Onitsha			RIMCO, Nnewi			FMEnv (1991) Effluent Limit (mg/L)
	P_1	P_2	P_3	P_1	P_2	P_3	
Mercury (Hg)	1.810± 0.208	1.713± 0.224	2.283± 0.459	1.301± 0.333	1.348± 0.106	2.060± 0.293	0.05
Nickel (Ni)	0.425± 0.303	0.709± 0.664	0.890± 0.472	0.430± 0.508	0.373± 0.419	0.290± 0.401	<1.0
Copper (Cu)	0.460± 0.390	0.395± 0.217	1.003± 0.173	0.573± 0.138	1.200± 0.140	0.323± 0.275	<1.0
Iron (Fe)	0.973± 0.074	0.625± 0.098	2.470± 0.214	1.640± 0.125	0.830± 0.030	1.688± 0.044	1.0
Gold (Au)	1.199± 0.075	2.605± 0.002	0.970± 0.002	0.090± 0.037	0.308± 0.005	0.130± 0.001	NA
Chromium (Cr)	0.345± 0.136	1.445± 0.152	0.318± 0.273	0.248± 0.190	0.068± 0.090	0.975± 0.101	1.00
Manganese (Mn)	0.073± 0.063	0.145± 0.056	0.123± 0.061	0.025± 0.065	0.055± 0.065	0.195± 0.058	NA
Bismuth (Bi)	2.338± 0.079	2.020± 0.103	1.068± 0.216	4.680± 0.146	3.853± 0.282	2.598± 0.070	NA
Lead (pb)	2.320± 0.141	2.763+ 0.153	1.578± 0.274	4.295± 0.666	2.315± 0.172	2.765± 0.157	<1.0
Tin (Sn)	0.715± 0.003	0.701± 0.002	1.164± 0.002	2.168± 0.196	3.663± 0.088	1.443± 0.057	NA
Cobalt (Co)	0.128± 0.059	0.008± 0.088	0.013± 0.003	0.058± 0.117	0.063± 0.106	0.050± 0.110	NA
Cadmium (Cd)	1.093± 0.073	0.283± 0.102	0.910± 0.216	0.313± 0.242	0.745± 0.130	0.873± 0.153	1.0
Silver (Ag)	0.035± 0.000	0.200± 0.002	0.025± 0.003	0.480± 0.116	2.428± 0.123	0.788± 0.063	NA
Arsenic (As)	0.035± 0.130	0.070± 0.149	0.390± 0.270	1.180± 0.141	2.883± 0.123	0.913± 0.065	1.0
Selenium (Se)	0.503± 0.073	0.043± 0.096	0.150± 0.213	0.725± 0.125	0.523± 0.025	0.508± 0.043	NA
Zinc (Zn)	1.700± 0.072	0.773± 0.096	0.528± 0.213	4.255± 0.125	1.725± 0.025	1.263± 0.043	<1.0

NOTE: P_1 = Point of discharge of effluent P_2 = 15 meters aay from point of discharge P_3 = 30 meters away from point of discharge NA = Not Available

Table 4.3 shows that the concentrations of the heavy metals did not follow any particular trend at the various points of collection of the effluents from the two food industries (in the rainy season). Total mean concentrations of Zinc (Zn) from Golden and RIMCO effluents were highest at the points of discharge (P_1). For instance, Zn concentrations in Golden effluent were 1.700±0.072mg/l (P_1) > 0.773 ± 0.096mg/l (P_2) > 0.528 ± 0.21mg/l (P_3). In the case of RIMCO effluent samples, the total mean concentrations of Zn were 4.255±0.125mg/l(P_1),>1.725±0.025mg/l(P_2)>1.263± 0.043mg/l (P_3). This decrease in concentration from P_1 to P_3 could be as a result of seepage of this heavy metal into the soil as the effluent flowed from P_1 through P_2 to P_3, thus reducing the level of this toxicant in the effluent pathway.

However, this trend was not observed in the concentrations of other heavy metals at the various points of discharge as the concentrations of these heavy metals varied from the points of discharge of the effluents (P_1) to 30 meters away from the points of discharge (P_3) and vice versa.

Table 4.4 **Mean levels of heavy metal (mg/l) in effluents during dry season for Life Breweries and Savana drinks**

Heavy Metal	**Life Breweries**			**Savana Drinks**			**FMEnv (1991) Effluent Limit (mg/L)**
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Mercury (Hg)	3.128± 0.382	2.205± 0.638	2.633± 0.312	3.783± 0.355	-	-	0.05
Nickel (Ni)	BDL	BDL	BDL	BDL	-	-	<1.0
Copper (Cu)	BDL	BDL	BDL	BDL	-	-	<1.0
Iron (Fe)	2.155± 0.379	5.615± 0.538	2.485± 0.340	2.350± 0.411	-	-	1.0
Gold (Au)	BDL	BDL	BDL	BDL	-	-	NA
Chromium (Cr)	4.055± 0.159	1.895± 0.403	1.888± 0.292	0.635± 0.248	-	-	1.00
Manganese (Mn)	BDL	BDL	BDL	BDL	-	-	NA
Bismuth (Bi)	0.528± 0.154	3.225± 0.400	5.055± 0.285	0.993± 0.243	-	-	NA
Lead (pb)	5.080± 0.334	1.703± 0.458	1.705± 0.344	2.228± 0.301	-	-	<1.0
Tin (Sn)	BDL	BDL	BDL	BDL	-	-	NA
Cobalt (Co)	0.103± 0.033	0.033± 0.041	0.030± 0.113	0.085± 0.053	-	-	NA
Cadmium (Cd)	0.635± 0.299	0.733± 0.390	1.520± 0.188	1.505± 0.195	-	-	1.0
Silver (Ag)	BDL	BDL	BDL	BDL	-	-	NA
Arsenic (As)	0.380± 0.207	0.930± 0.502	0.938± 0.400	0.205± 0.468	-	-	1.0
Selenium (Se)	1.373± 0.154	0.805± 0.400	1.313± 0.288	0.250± 0.243	-	-	NA
Zinc (Zn)	5.635± 0.206	14.470± 0.434	14.180± 0.350	7.723± 0.308	-	-	<1.0

NOTE: P_1 = Point of discharge of effluent P_2 = 15 meters aay from point of discharge P_3 = 30 meters away from point of discharge NA = Not Available

Table 4.4 shows the mean ± S.D of the heavy metal concentrations in the effluents from Life Breweries and Savana drink along the various points of discharge of the effluents for the dry season period. The mean concentrations of Hg in the effluent sample from Life Breweries was 3.128±0.382mg/l at the point of discharge of the effluent (P_1), 2.205±0.630mg/l (P_2) and 2.633+0.312mg/l (P_3). This showed that the total mean concentrations of Hg was highest at P_1, followed by P_3 and the least was the value obtained at P_2.

Though the concentrations of Hg was higher in the dry season than in the rainy season, at all the points of collection of the waste water (Tables 4.1 and 4.4), there was no particular trend in its occurrence, Hg was highest at P_2 in the rainy season but highest at P_3 in the dry season (Life Breweries effluent). nickel, copper, gold, manganese, tin and silver were below the detection limit (BDL) of the instrument in the dry season in both Life and Savana effluents, but were detected in the rainy season from these effluent samples.

Table 4.5 Mean levels of heavy metal (mg/l) in effluents during dry season for KP beverage, Ogidi and Obisco beverage, Ogidi

Heavy Metal	**KP Beverage, Ogidi**			**Obisco Beverage, Ogidi**			**FMEnv (1991) Effluent Limit (mg/L)**
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Mercury (Hg)	2.053± 0.463	3.035± 0.239	3.085± 0.264	2.995± 0.391	3.393± 0.417	3.090± 0.231	0.05
Nickel (Ni)	BDL	BDL	BDL	BDL	BDL	BDL	<1.0
Copper (Cu)	BDL	BDL	BDL	BDL	BDL	BDL	<1.0
Iron (Fe)	4.785± 0.387	3.613± 0.174	3.925± 0.422	5.358± 0.267	6.543± 0.293	1.385± 0.373	1.0
Gold (Au)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Chromium (Cr)	1.740± 0.225	0.455± 0.122	2.878± 0.227	2.528± 0.203	2.740± 0.218	3.135± 0.205	1.00
Manganese (Mn)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Bismuth (Bi)	3.285± 0.222	5.253± 0.117	4.510± 0.200	5.535± 0.192	3.830± 0.218	3.468± 0.204	NA
Lead (pb)	4.967± 0.286	4.628± 0.182	0.345± 0.258	1.368± 0.250	2.980± 0.270	3.940± 0.261	<1.0
Tin (Sn)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Cobalt (Co)	0.085± 0.057	0.088± 0.028	0.030± 0.028	0.113± 0.165	0.168± 0.052	0.308± 0.114	NA
Cadmium (Cd)	1.883± 0.182	0.500± 0.123	0.560± 0.188	0.650± 0.187	1.750± 0.183	0.458± 0.174	1.0
Silver (Ag)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Arsenic (As)	0.698± 0.423	0.805± 0.192	0.325± 0.445	0.640± 0.255	1.013± 0.293	0.988± 0.305	1.0
Selenium (Se)	0.555± 0.222	1.723± 0.117	1.595± 0.200	1.623± 0.192	1.290± 0.218	0.453± 0.204	NA
Zinc (Zn)	3.053± 0.286	11.558± 0.182	4.818± 0.253	5.718± 0.250	3.035± 0.270	2.598± 0.251	<1.0

NOTE: P_1 = Point of discharge of effluent P_2 = 15 meters aay from point of discharge P_3 = 30 meters away from point of discharge NA = Not Available

Table 4.5 shows the mean ± S.D of heavy metals in KP and Obisco beverages, Ogidi (Dry season). It was observed that nickel, copper, gold, manganese, tin and silver were below the detection limit (BDL) of the instrument and were not detected from the effluent samples from both industries in the dry season, but were detected in the rainy season (Table 4.2). Total mean levels of Hg were highest at P_3 in KP effluent while for Obisco effluent the highest mean concentration of Hg was obtained at P_2. In both effluents, the points of discharge of the effluents (P_1) recorded the least mean concentrations of Hg. Again, the total mean levels of Zn obtained from these effluents (dry season) were higher than the total mean concentrations of Zn obtained in the rainy season. The levels of this heavy metal was highest at P_2 in KP effluent (11.558±0.182mg/l, dry season), while in Obisco effluent, the highest level of Zn was obtained at the point of discharge of the effluent (P_1) in the same season. This was also the same with other heavy metals as no particular order was observed in the occurrence of these heavy metals in the two effluents monitored.

Table 4.6 Mean levels of heavy metal (mg/l) in effluents during dry season for Golden Vegetable Oil, Onitsha and RIMCO, Nnewi

Heavy Metal	Golden Vegetable Oil, Onitsha			RIMCO, Nnewi			FMEnv (1991) Effluent Limit (mg/L)
	P_1	P_2	P_3	P_1	P_2	P_3	
Mercury (Hg)	3.348± 0.367	1.090± 0.340	4.145± 0.500	0.70± 0.325	0.553± 0.065	1.310± 0.167	0.05
Nickel (Ni)	BDL	BDL	BDL	BDL	BDL	BDL	<1.0
Copper (Cu)	BDL	BDL	BDL	BDL	BDL	BDL	<1.0
Iron (Fe)	4.970± 0.379	1.888± 0.422	5.560± 0.494	2.153± 0.221	1.058± 0.121	2.280± 0.269	1.0
Gold (Au)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Chromium (Cr)	1.020± 0.187	1.870± 0.203	1.355± 0.329	0.548± 0.131	1.630± 0.032	1.068± 0.051	1.00
Manganese (Mn)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Bismuth (Bi)	4.800± 0.187	4.738± 0.201	0.178± 0.327	3.898± 0.142	2.060± 0.047	1.268± 0.081	NA
Lead (pb)	4.588± 0.246	2.085± 0.251	3.988± 0.397	2.295± 0.242	2.368± 0.140	2.733± 0.115	<1.0
Tin (Sn)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Cobalt (Co)	0.225± 0.164	0.340± 0.225	0.445± 0.025	0.218± 0.059	0.163± 0.167	0.135± 0.249	NA
Cadmium (Cd)	0.273± 0.174	0.568± 0.158	0.520± 0.167	0.092± 0.119	0.238± 0.123	0.135± 0.113	1.0
Silver (Ag)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Arsenic (As)	0.660± 0.367	0.240± 0.376	0.468± 0.552	0.710± 0.241	3.908± 0.176	0.890± 0.273	1.0
Selenium (Se)	0.723± 0.187	2.470± 0.201	1.498± 0.327	1.698± 0.231	1.498± 0.033	1.185± 0.050	NA
Zinc (Zn)	5.975± 0.246	9.720± 0.254	8.815± 0.385	12.840± 0.198	6.625± 0.085	5.380± 0.115	<1.0

NOTE: P_1 = Point of discharge of effluent P_2 = 15 meters aay from point of discharge P_3 = 30 meters away from point of discharge NA = Not Available

Table 4.6 was the mean of heavy metals in Golden and RIMCO effluents (Dry season). Total mean levels of Hg from the two effluents followed the trend of $P_3>P_1>P_2$. This could be as a result of the combination of flow velocity factor and boundary effects. This trend was also observed in the occurrence of Fe in both effluents. However, other heavy metals did not follow this trend at the various points of collection from the two industries. Some heavy metals were highest at the point of discharge of the effluents (P_1), while others were highest at P_3 in both companies.

Nevertheless, nickel (Ni), copper (Cu), gold (Au), manganese (Mn), tin (Sn), and silver (Ag) were not detected in the dry season from all the effluent samples monitored. This could be as a result of the fact that these heavy metals were suspended in the air as sprays, droplets and dust particles (in the dry season) and with the arrival of rain, were washed down into the effluent pathways by precipitation, thus were detected in the rainy season. Concentrations of other heavy metals monitored were higher in the dry season than in the rainy season. Low levels of these heavy metals in the rainy season could be as a result of dilution through precipitation and continuous exchange of water along the effluent pathways which reduced the concentration of these toxicants in the rainy season.

4.2 Pooled Mean of the Concentrations of Heavy Metals

The results of the pooled mean of the concentrations of heavy metals in the effluent samples from the various food processing industries studied in both rainy and dry seasons were shown in Tables 4.7 and 4.8, then Figures 4.1 to 4.16. The result of the Analysis of Variance (ANOVA), showing seasonal variations of the mean heavy metal levels in the effluent samples from the food processing industries studied between rainy and dry season and variation of these heavy metals in the effluents among these industries were shown in Appendix 3, while that of coefficient of variations between the two seasons were shown in Appendix 4.

Table 4.7: Pooled Mean of the Heavy Metal Concentrations of the Effluents in the rainy season (June – September)

Heavy metal (mg/l)	Effluent Samples						
	Life Breweries Onitsha	Savana Drinks	KP Beverages Ogidi	Obisco Beverages Ogidi	Golden Oil Osha	RIMCO Nnewi	FMEnv (1991) Effluent Limit
Mercury	1.638± 0.497	1.985± 0.860	1.252± 0.497	1.874± 0.497	1.935± 0.497	1.564± 0.497	<0.05
Nickel	0.038± 0.234	1.053 ± 0.406	1.129± 0.234	0.757± 0.234	0.899± 0.234	0.559± 0.234	<1.000
Copper	1.004 ± 0.294	0.937± 0.509	0.872± 0.294	1.040± 0.294	0.844± 0.294	0.930± 0.294	<1.000
Iron	1.449 ± 0.817	1.830 ± 1.412	1.178± 0.815	2.567± 0.815	1.808± 0.815	2.772± 0.999	1.000
Gold	0.867 ± 0.259	1.000 ± 0.449	0.545± 0.259	1.383 ± 0.259	1.016± 0.259	0.703± 0.366	NA
Chromium	1.577 ± 0.571	0.810 ± 0.988	1.044 ± 0.571	0.701 ± 0.571	0.937± 0.571	1.692 ± 0.699	1.000
Manganese	0.543 ± 0.183	0.110 ± 0.367	0.617 ± 0.150	0.290 ± 0.212	0.227 ± 0.150	0.367 ± 0.212	NA
Bismuth	1.548 ± 0.716	1.642 ± 1.240	1.800 ± 0.716	1.409 ± 0.716	1.809 ± 0.716	3.710 ± 0.716	NA
Lead	2.835 ± 0.719	2.495 ± 1.246	1.645 ± 0.719	0.873 ± 0.719	2.220 ± 0.719	2.446 ± 0.719	< 1.000
Tin	1.164 ± 0.527	1.237 ± 0.912	0.843 ± 0.527	1.443 ± 0.527	1.147 ± 0.527	3.231 ± 0.527	NA
Cobalt	0.577 ± 0.225	0.550 ± 0.389	0.207 ± 0.225	0.523 ± 0.225	0.197 ± 0.225	0.083 ± 0.159	NA
Cadmium	0.632 ± 0471	0.930 ± 0816	1.268 ± 0471	1.828 ± 0471	1.523 ± 0471	0.818 ± 0.385	1.000
Silver	0.301 ± 1.302	2.110 ± 2.255	1.807 ± 1.302	1.243 ± 1.302	0.243 ± 1.302	2.463 ± 0.920	NA
Arsenic	0.492 ± 0.547	0.405 ± 0.948	0.282 ± 0.547	0.628 ± 0.547	0.335 ± 0.547	2.211 ± 0.447	1.000
Selenium	1.543 ± 0.645	0.890 ± 1.117	1.867 ± 0.645	1.360 ± 0.645	0.927 ± 0.645	2.340 ± 0.645	NA
Zinc	13.373 ± 3.406	16.010 ± 5.899	6.303 ± 3.406	5.107 ± 3.406	4.000 ± 3.406	9.657 ± 3.406	<1.000

NOTE: P_1 = Point of discharge of effluent P_2 = 15 meters aay from point of discharge P_3 = 30 meters away from point of discharge NA = Not Available

All the heavy metals monitored in this season (rainy season) were detected from all the effluent samples though in lower concentrations compared to the dry season readings (except RIMCO effluents where reverse was the case in the mean concentrations of Hg, Fe, Bi, Cu, Zn, Cd and As). Lower levels of these heavy metals in rainy season (Table 4.7) could be attributed to dilution from precipitation, short residence time and continuous exchange of water in the effluent pathway leading to decrease in levels of these toxicants. The total mean concentrations of Hg, Fe, Pb and Zn obtained from these effluents in the rainy season were higher than the values recommended by the Federal Ministry of Environment, (1991) for industrial effluent limit. Arsenic levels were within this limit (except values obtained from RIMCO effluents where reverse was the case).

Moreover, the total mean nickel obtained in this work were higher than mean nickel value (0.183mg/l) reported by Fufeyin, (1994) for Ikpoba reservoir water though lower than the value (44.50mg/l) reported for Warri River by Egborge, (1991). The pooled mean levels of copper obtained from all the effluent samples monitored in the rainy season were higher than copper value (0.194mg/l) reported by Oguzie and Okhagbuzo (2010) in effluent discharges down stream of Ikpoba River, in Benin City. The Federal Ministry of Environment Limitation guideline wa not available for gold, manganese, bismuth, tin, cobalt, silver and selenium, though mean concentrations of manganese and silver obtained from all the effluent samples (rainy season) were higher than the limit (0.05mg/l) allowed for these two metals by the World Health Organization, (1989) for drinking water.

Sindnu, (2002) reported that micro-organisms can suffer from growth decline due to the presence of nickel, though they usually develop resistance to it after a while. The author also stated that nickel is not known to accumulate in plants or animals and as a result has not been found to biomagnify up the food chain. Copper on the other hand, is important to root metabolism and helps form proteins, amino acids and a host of organic compounds.

Table 4.8: Pooled Mean of the Heavy Metal Concentrations of the Effluents in the Dry season (October – January)

Heavy metal (mg/l)	Effluent Samples						
	Life Breweries Onitsha	Savana Drinks	KP Beverages Ogidi	Obisco Beverages Ogidi	Golden Oil Osha	RIMCO Nnewi	FMEnv (1991) Effluent
Mercury	2.655 ± 0.497	2.883 ± 0.860	2.724 ± 0.497	3.182 ± 0.497	2.865 ± 0.497	0.878 ±	<0.05
Nickel	BDL	BDL	BDL	BDL	BDL	BDL	<1.000
Copper	BDL	BDL	BDL	BDL	BDL	BDL	<1.000
Iron	3.427 ± 0.706	2.350 ± 1.223	2.350 ± 0.706	4.107 ± 0.706	4.428 ± 0.706	4.139 ± 0.706	1.000
Gold	BDL	BDL	BDL	BDL	BDL	BDL	NA
Chromium	2.946 ± 0.494	0.635 ± 0.856	1.692 ± 0.494	2.801 ± 0.494	1.415 ± 0.494	1.082 ± 0.494	1.000
Manganese	BDL	BDL	BDL	BDL	BDL	BDL	NA
Bismuth	3.914 ± 0.827	1.323 ± 1.432	5.812 ± 0.827	5.266 ± 0.827	4.318 ± 0.827	3.211 ± 0.827	NA
Lead	2.813 ± 0.719	2.225 ± 1.246	3.313 ± 0.719	2.763 ± 0.719	2.763 ± 0.719	3.533 ± 0.719	< 1.000
Tin	BDL	BDL	BDL	BDL	BDL	BDL	NA
Cobalt	0.220 ± 0.225	0.340 ± 0.389	0.230 ± 0.225	0.783 ± 0.225	1.347 ± 0.225	0.693 ± 0.225	NA
Cadmium	1.283 ± 0.385	2.007 ± 0.666	1.308 ± 0.385	1.270 ± 0.385	0.604 ± 0.385	0.206 ± 0.385	1.000
Silver	BDL	BDL	BDL	BDL	BDL	BDL	NA
Arsenic	0.749 ± 0387	0.205 ± 0.670	0.602 ± 0.387	0.878 ± 0.387	0.456 ± 0.387	1.836 ± 0.387	1.000
Selenium	1.603 ± 0.372	0.333 ± 0.645	1.688 ± 0.372	1.496 ± 0.372	2.104 ± 0.372	0.387 ± 0.372	NA
Zinc	14.636 ± 1.966	10.293 ± 3.406	6.476 ± 1.703	3.783 ± 1.703	8.170 ± 1.703	8.282 ± 1.703	<1.000

NOTE: P_1 = Point of discharge of effluent P_2 = 15 meters aay from point of discharge P_3 = 30 meters away from point of discharge NA = Not Available

Table 4.8 shows that Ni, Cu, Au, Mn, Sn, and Ag were not detected in the effluent samples monitored in the dry season; they were below the detection limit (BDL) of the instrument. This could be as a result of the fact that these heavy metals were accumulated in the air around the food industries as sprays, droplets and dust particles and with the arrival of rain, they were washed down by precipitation and mixed with the effluents, leading to increase in the concentrations of these heavy metals in the rainy season than dry season. This was in line with the findings of Singare et al., (2011) who reported that nickel is released into the air by power plants and trash incinerators and will settle to the ground or fall down after it reacts with precipitation.

The total mean concentrations of all the heavy metals (except Ni, Cu, Au, Mn, Sn and Ag) were higher in the dry season from all the effluent samples monitored than the values obtained in the rainy season (Tables 4.7 and 4.8). This could be as a result of the explanation offered for these heavy metals in Table 3.7. Nevertheless, total mean concentrations of Hg, Fe, Cr, Pb, Cd, Zn and As (from RIMCO effluent) were higher than the values recommended by the Federal Ministry Environment (1991) for industrial effluent limit for these heavy metals. Lead is a major constituent of the lead-acid battery and used extensively in car batteries, as colouring agents in ceramic glazes, in some candles to treat the wicks, cables, glass ware and ammunitions. One of the major uses of Pb is in the glass of computer and television screens where it shields the viewer from radiation. The authors further stressed that most lead concentration that are found in the environment are due to human activities especially burning of car engines and hence it is released into the environment easily. This could be responsible for the high level of Pb obtained from this work from all the effluent samples monitored.

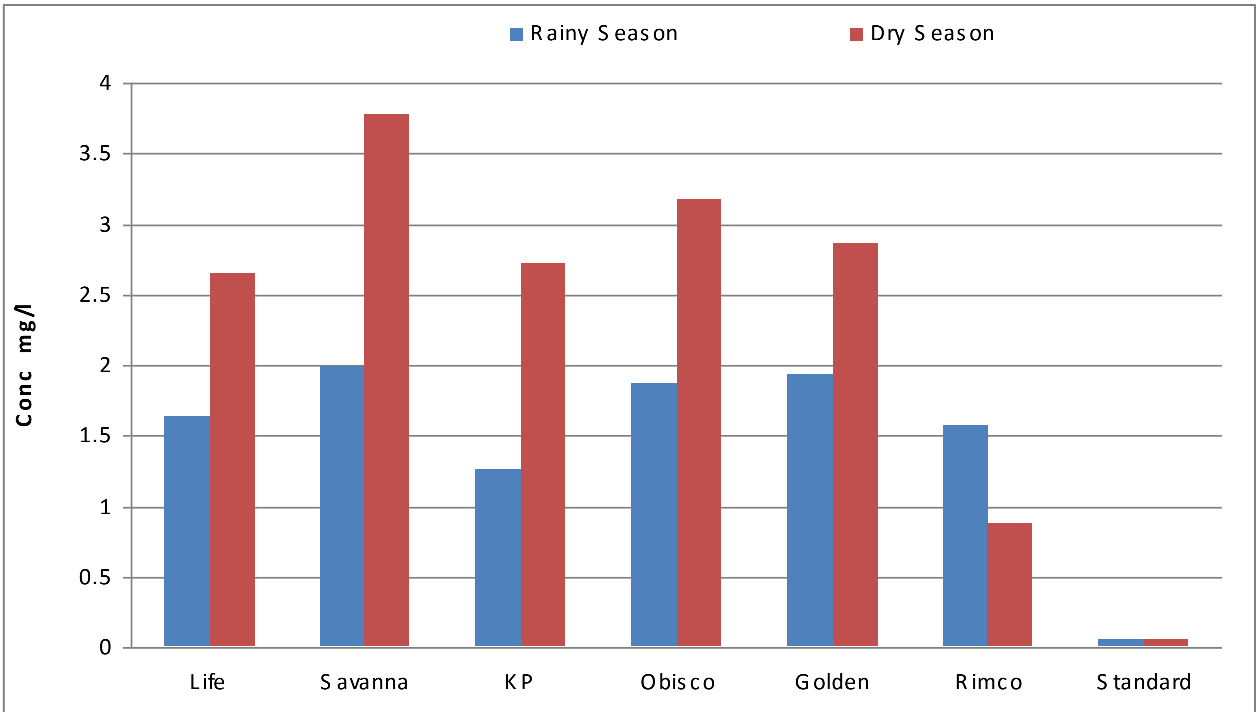


Fig: 4.1 Mercury levels by season and locations

Apart from Resource Improvement and Manufacturing Company (RIMCO), Nnewi, Mercury levels in the effluent samples of all the food industries studied were higher in the dry season than in the rainy season. Concentrations of mercury in the dry season decreased in the following order: 3.82 ± 0.497 (Obisco) > 2.865 ± 0.497 (Golden) > 2.783 ± 0.860mg/l (Savana) > 2.724 ± 0.497mg/l (KP) > 2.665 ± 0.497mg/l (Life breweries) > 0.878 ± 0.497mg/l (RIMCO) respectively compared to the rainy season levels of 1.985 ± 0.860mg/l (Savana)> 1.935 ± 0.497mg/l (Golden)> 1.874 ± 0.497mg/l (Obisco) > 1.638 + 0.497mg/l (Life) > 1.564 + 0.497mg/l (RIMCO) > 1.252 ± 0.492mg/l (KP).

Low levels of mercury metal in the effluent samples in the rainy season might be attributed to dilution or even leaching out of this metal through flood into a receiving water body. RIMCO recorded the least mean concentration of mercury in the two seasons while Savana was the highest in mercury level in both seasons. Values obtained for this metal in the effluent samples from all the food industries studied were far above the maximum allowable limit of 0.05mg/l prescribed by the Federal Ministry of Environment (FMENV), (1991) for industrial effluent.

Statistical analysis confirmed that the concentrations of mercury in the effluent samples from all the food processing industries studied were significant ($P < 0.05$) between rainy and dry season (Appendix 3a). Mercury levels were significantly higher in the dry season than in the rainy season, though the coefficient of variation (94.3%) was higher in the rainy season than in the dry season (76.2). This not withstanding, there was no significant difference ($P>0.05$) in the mean concentrations of mercury among the various food industries studied, but differences were seen in Savana and RIMCO, with coefficient of variations of 72.6 and 106.8, Obisco and RIMCO with CV of 71.8 and 106.8; Golden and RIMCO with CV of 80.3 and 106.8 respectively (Appendix 4).

Mercury, according to Asonye et al., (2007) is known to interfare with metabolism and function of living things by combining with phosphoryl, carboxyl, amides and amine groups, resulting in the enzyme inhibition and protein precipitation. The danger of the presence of mercury in seafood were demonstrated by the appearance in the 1950s and 60s of a crippling neurological disorder among the inhabitants of a town in Southern Japan where Peter and Micheal (2005) reported that victims were poisoned by eating fish and shell fish that had concentrated mercury discharged at sea by a chemical plant. Begum *et al.,* (2009) also stressed that when larger animals feed on these contaminated organisms, the toxins are taken into their bodies, moving up food chain with increasing concentration in a process known as magnification. Aloa *et al.,* (2010) also reported that pesticide residues on vegetable crops, mercury in fish and many industrially produced chemicals might cause cancer, birth defects, genetic mutations or death.

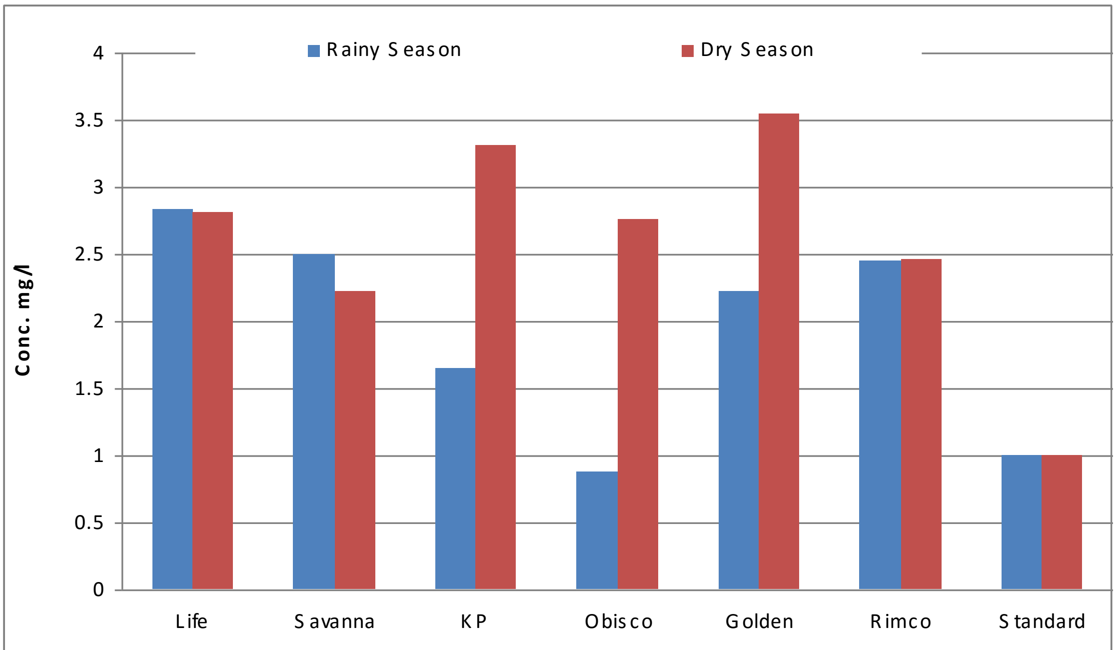


Fig. 4.2 :Lead levels by season and location

Apart from Life breweries and Savana, the mean concentrations of lead in the effluent samples from KP, Obisco, Golden and RIMCO were higher in the dry season than in the rainy season. In both seasons, the mean concentrations of lead in the effluent samples (except Obisco; rainy season) violated the allowable limit of <1.00mg/l set by FMEnv, (1991) for industrial effluent to be discharged into surface water (Fig 4.2). This was in line with the findings of Oguzie, (1999) who reported high levels of cadmium, lead and copper in effluents discharged into Ikpoba River. The minimum concentration of lead (0.873 ± 0.719mg/l) in Obisco effluent in the rainy season; and the maximum level (3.553 ± 0.719mg/l) obtained in Golden effluent in the dry season in this work were higher than lead values (0.034mg/l) reported by Oguzie, (1999) for Ikpoba River.

The pooled mean levels of lead from the polluted effluents (Tables 4.7 and 4.8) which was found to be above the maximum permissible level, could exert toxic effects on human beings if consumed from water or irrigated agricultural products from these areas. Lead interfares with functions performed by essential mineral elements such as calcium, iron, copper and zinc (Bala *et al.*, 2008). Moreover, Vasudevan and Streakumari, (2000), reported that lead also inhibits red blood cell-enzyme systems. Similarly, lead can displace calcium in bone to form softer denser sports which according to Underwood, (2002) activates cysteine containing enzymes allowing more internal toxicity from free radical chemicals and other heavy metals. Lead also causes disruption of the biosynthesis of haemoglobin, rise in blood pressure, kidney damage and brain damage. (Akaninwor and Gwin 2006; Ademoroti, 1998).

Though the concentrations of lead in the various effluents were higher in the dry season than in the rainy season (Table 4.3), statistical analysis showed that there was no significant difference ($P > 0.05$) in the mean concentrations of this metal between rainy and dry season (F-value 2.578; P-value 0.111). Rainy season Coefficient of Variation (CV) of lead was 106.0 compared to that of dry season value of 92.8. In the case of food industries, there was also no significant difference ($P>0.05$) in the mean concentrations of lead among their effluents.

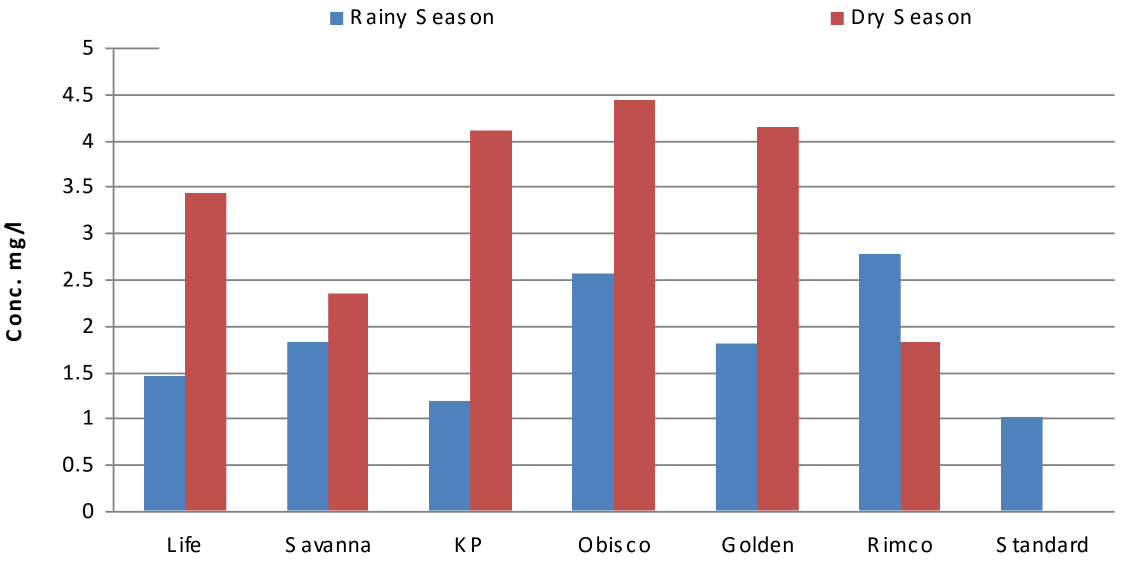


Fig. 4.3 : Iron levels by Season and location

With the exception of RIMCO effluent, other effluent studied recorded lower iron levels in the rainy season than in the dry season. All the effluent samples gave pooled mean iron concentrations that were far above the value recommended by FMEnv; (1991) in industrial effluents to be discharged into receiving stream (Table 4.7 and Fig. 4.3). Values obtained in the dry season were in the increasing order of 1.830 ± 0.706mg/l (RIMCO) < 2.350 ± 1.223mg/l (Savana) < 3.427 ± 0.706mg/l (Life) <4.107 ± 0.076mg/l (KP) < 4.139 ± 0.076mg/l (Golden) <4.428 ± 0.706mg/l (Obisco) respectively compared to the rainy season values of 1.178 ± 0.815mg/l (KP) < 1.449 ± 0.815mg/l (Life) < 1.808 ± 0.815mg/l (Golden) < 1.830 + 1.412mg/l (Savana) < 2.567 ± 0.815mg/l (Obisco) < 2.772 ± 0.999mg/l (RIMCO).

The mean concentrations of Iron were highly significant (P<0.05) between rainy and dry season (Appendix 3c). Levels of iron obtained in the dry season were very high compared to the rainy season values (Table 4.7 and 4.8) but the coefficient of variation was higher in the rainy season (94.3%) than in the dry season (81.4%). However, there was no significant difference (P>0.05) in the total mean concentration of iron among the various food industries studied though the coefficient of variations ranged from 76.1% (Savana, rainy) through 84.035% (Obisco, rainy) to 102.2% (Golden, rainy) compared to the coefficient of variations in the dry season which ranged from 32.9 (Savana) through 81.1 (Obisco) to 117.8 (RIMCO).

From the foregoing, it was observed that Obisco beverage, Ogidi recorded the highest iron concentration in the dry season while RIMCO had the highest value of iron in the rainy season. Low concentrations of iron in the rainy season compared to the dry season in the effluent samples studied could be as a result of the fact that during rainy season, there was twice increase in dilution from precipitation, short residence time and continuous exchange of water; thus, most of the materials were discharged into a receiving water body leaving a comparatively small quantity in the effluent pathway. This was in line with the findings of Moore and Ramamorathy, (1984).

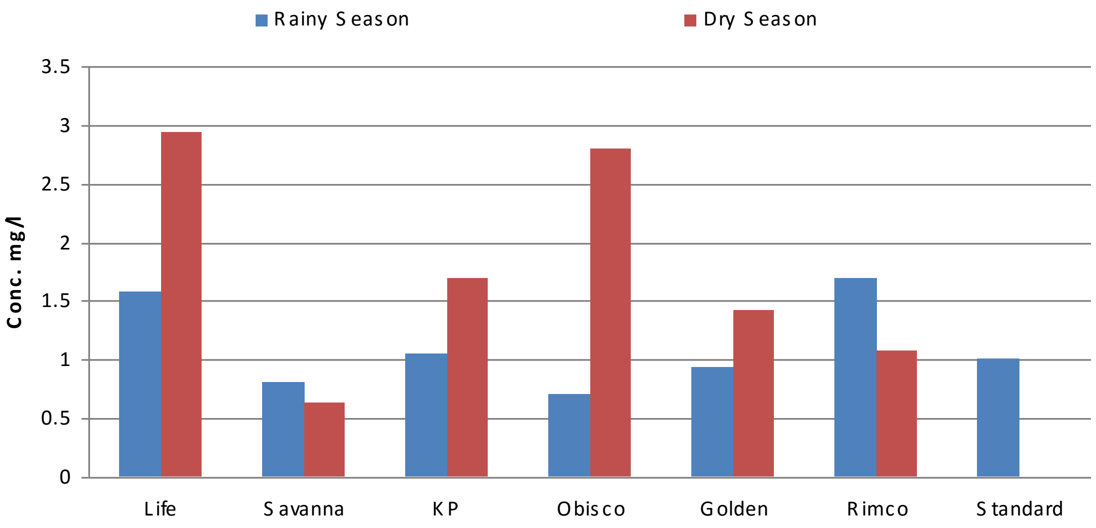


Fig. 4.4 :Chromium Levels by Season and locations

Mean chromium concentrations in the effluent samples of all the food industries investigated were again higher in the dry season than in the rainy season with the exception of Savana and RIMCO effluents which recorded higher values in the rainy season than in the dry season (Table 4.7). Lower values of chromium in the rainy season could also be as a result of dilution from precipitation or even leaching out of this pollutant into a receiving water body.

Apart from Savana, both rainy (0.810 ± 0.988mg/l) and dry (0.635 ± 0.856mg/l) seasons; Obisco (0.701 ± 0.571mg/l) and Golden (0.937 ± 0.571mg/l) both rainy seasons, other effluent samples had their pooled mean chromium concentration above the standard prescribed by FMEnv, (1991) in both seasons. Total mean chromium concentrations obtained in this work ware higher than total mean chromium level (0.534mg/l) reported by Egborge, (1991) for Warri River and that (0.079mg/l) reported by Oguzie and Okhagbuzo, (2010) for effluent discharges downstream of Ikpoba river in Benin City.

Total mean chromium levels were not significant (P>0.05) in the effluent samples between rainy and dry season (f – value 3.074, P – value 0.83) (Appendix 3d), but recorded higher coefficient of variation in the rainy season (135.7) than in the dry season (99.8%). Again, there was no significant difference (P>0.05) in the concentrations of chromium in the effluents from various food industries with slight variations observed between Life and Golden (p – value 0.032); Life and Savana (p – value 0.030).

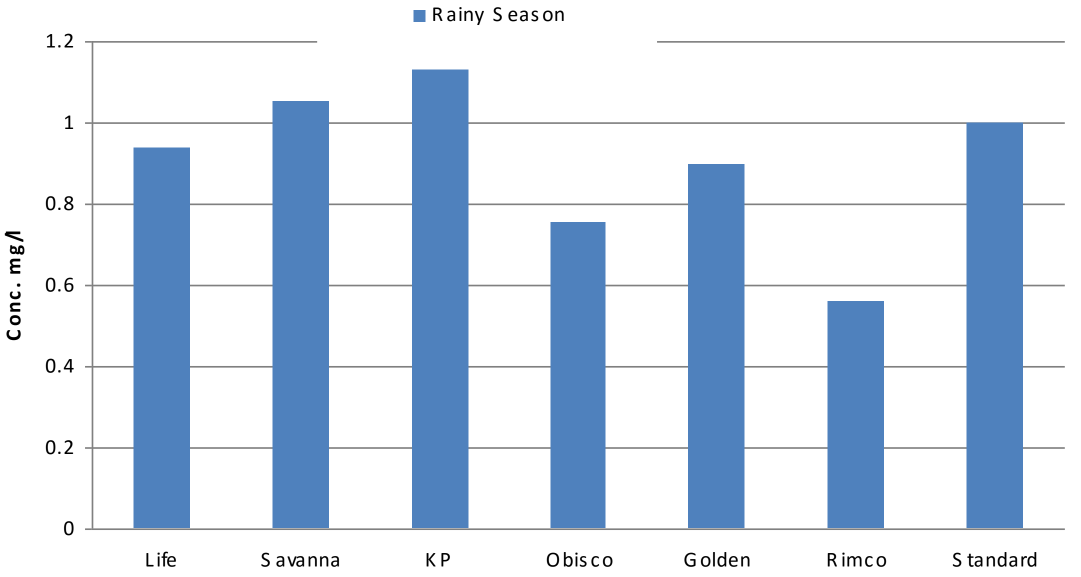


Fig. 4.5 : Nickel levels by season and locations

Figure 4.5 showed that nickel was not detected in the dry season from all the effluent samples studied. It was below the detection limit of the instrument during this season probably because it was accumulated in the air around the food industries as sprays, droplets and dust particles, hence was not detected. With the arrival of rain, it was washed down by precipitation where it mixed with the effluent pathway leading to increase in the concentration of this metal in the rainy season than in the dry season. This was in line with the findings of Singare *et al.*, (2011) who reported that Nickel is released into the air by power plants and trash incinerators and will settle to the ground or fall down after it reacts with precipitation. Highest cocnentration of this metal was recorded in KP beverages, Ogidi (1.129 $\pm$ 0.234mg/l) which was above the standard allowed by the Federal Ministry of Environment (1991) for effluent limit (<1.00mg/l). RIMCO, Nnewi gave the least value of nickel (0.938 $\pm$ 0.234mg/l) (Table 4.7) which was within the limit set by the Federal Ministry of Environment, (1991) for industrial effluent limit.

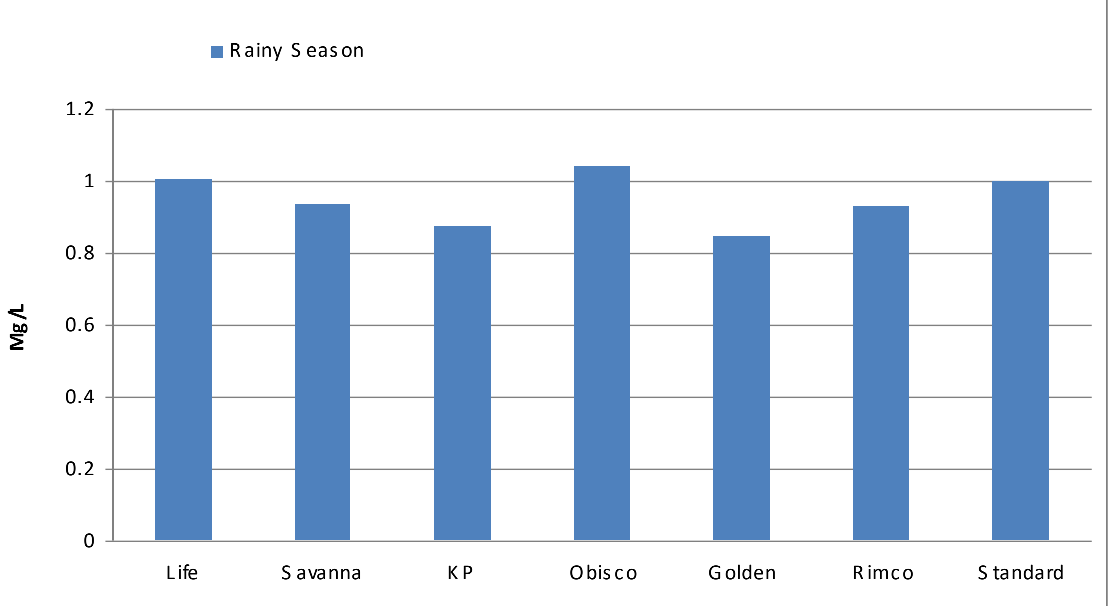


Fig. 4.6 :Copper levels by season and locations

Figure 4.6 showed that copper, also was not detected in the dry season in all the effluent samples studied. Copper was below the detection limit of the instrument and was not detected. This could be as a result of the fact that this metal was also concentrated in the air around the food industries as sprays, dust particles and even droplets during the dry season and with the coming of rain, it was washed down by precipitation and mixed with the effluent pathway, hence the increase in the concentration of this metal in the effluent samples from all the food industries in the rainy season than in the dry season (Tables 4.7 and 4.8).

Obisco beverages, Ogidi and Life breweries, Onitsha gave mean values of copper (1.014 + 0.294mg/l) and (1.004 + 0.294mg/l) that were above the values allowed by the FMEnv, (1991) for industrial effluent discharges (Fig 4.6). Other effluents from RIMCO, Savana, KP and Golden gave mean copper concentrations that were within the FMEnv, (1991) effluent limit.

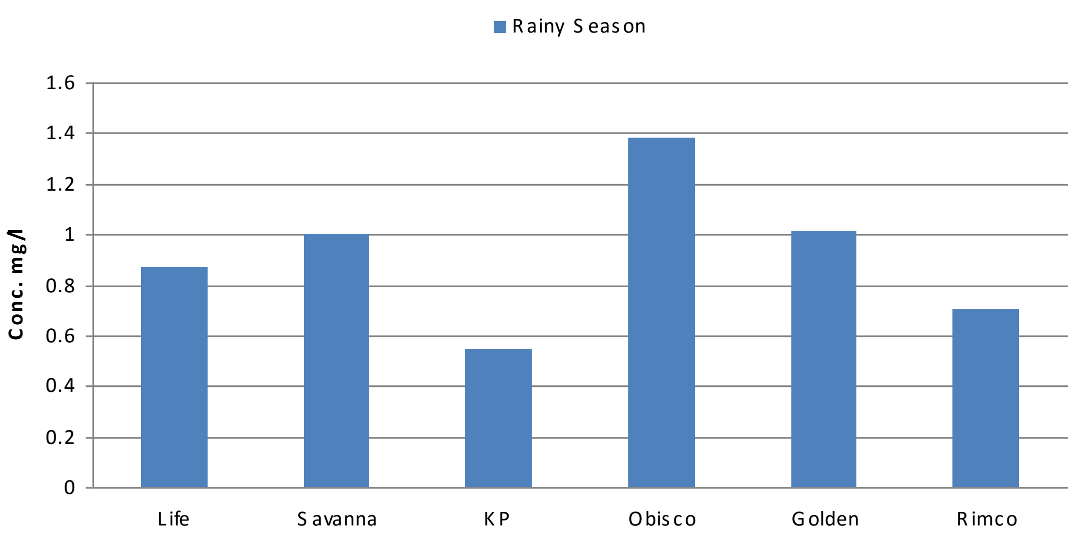


Fig. 4.7 :Gold levels by season and locations

Gold was not detected in the dry season (Fig 4.7) from all the effluent samples studied. It was also below the detection limit of the instrument in the dry season but was detected in the rainy season. This could be as a result of the reason offered for nickel and copper in figures 4.5 and 4.6. Obisco beverages, Ogidi recorded the highest mean level of gold but there were neighter FMEnv, (1991) effluent limit for gold nor WHO limit for gold in drinking water.

The trend of gold cocnentrations in rainy season for the food industries studied was Obisco > Golden > Savana > Life > RIMCO > KP respectively.

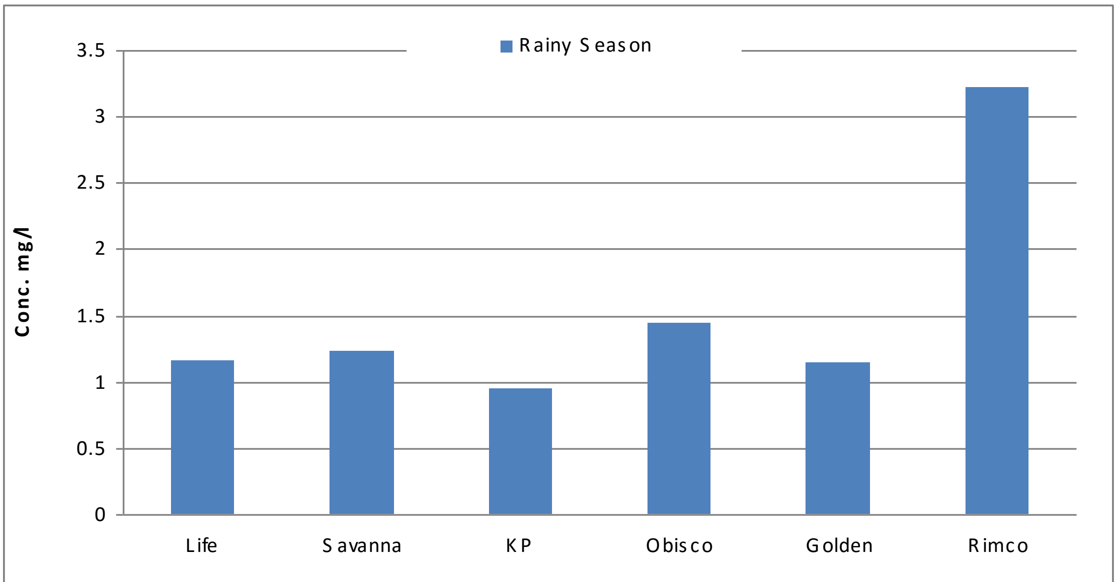


Fig. 4.8 :Tin levels by season and locations

Similarly, Fig 4.8 showed that tin was not detected in the dry season or was rather below the detection limit of the instrument. Resource Improvement and Manufacturing Company, Nnewi recorded the highest mean concentration of tin compared to other food industries studied (3.231 ± 0.527mg/l) while the least value of tin was obtained in effluent from KP beverages, Ogidi (0.943 ± 0.527mg/l).

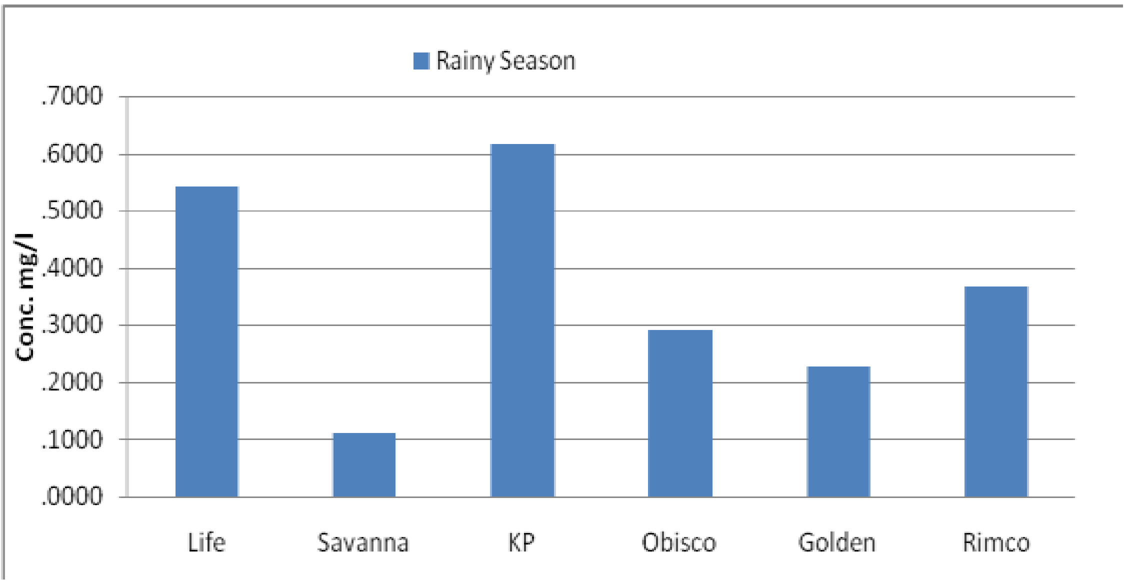


Fig. 4.9: Manganese levels by season and locations

Manganese was not detected in the dry season in all the effluent samples studied. This could be as a result of the fact that this metal was accumulated in the air around the food industries as sprays, droplets and dust particles in the dry season and with the arrival of rain, it was washed down through preciptation and mixed with the effluents, leading to increase in the concentrations of manganese in the rainy season than in the dry season (Fig 4.9).

The highest concentration of manganese was obtained in the effluent from KP beverages, Ogidi while the least level was recorded by Savana effluent. FMEnv, (1991) effluent limit for manganese was not available, but values obtained for this metal in all the effluent samples studied (rainy season) were above the limit (0.05mg/l) set by the WHO, (1989) for drinking water.

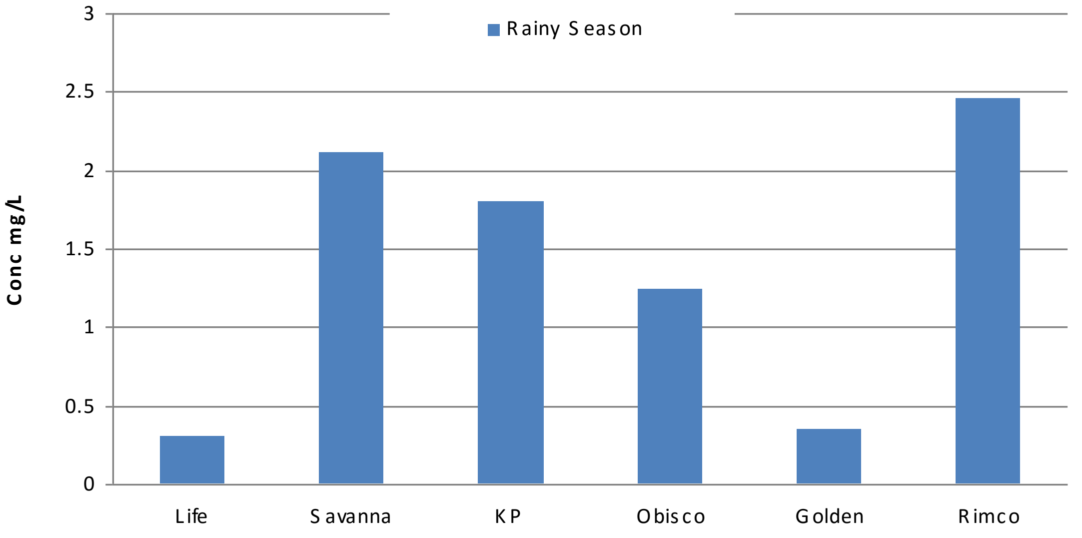


Fig. 4.10 :Silver levels by season and locations

Figure 4.10 showed that silver was below the detection limit of the instrument and was not detected in the dry season from all the effluent samples studied. This could be as a result of the reason given for inability to detect manganese in Fig 4.9. The mean concentration trend for silver in the rainy season for the industries was RIMCO > Savana > KP > Obisco > Golden > Life. FMEnv, (1991) industrial effluent limit for silver was not available but values obtained for this metal (rainy season) in all the effluent samples were above the limit (0.05mg/l) set by WHO, (1989), for drinking water.

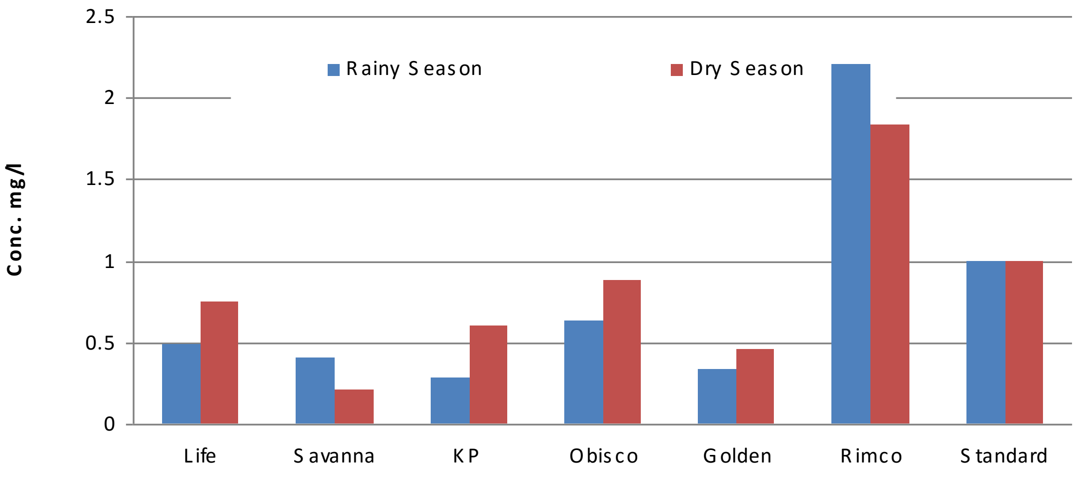


Fig. 4.11 :Arsenic levels by season and locations

With the exception of Savana and RIMCO effluent samples, the total mean concentrations of Arsenic in all the effluent samples studied were higher in the dry season than in the rainy season. Values obtained ranged from a minimum of 0.282 + 0.547mg/l in KP effluent to a maximum of 2.211 + 0.447mg/l in RIMCO effluent for the rainy season respectively compared to the minimum value of 0.205 + 0.670mg/l in Savana effluent to a maximum of 1.836 + 0.387mg/l in RIMCO effluents for the dry season (Tables 4.7 and 4.8). This showed that RIMCO Industry had the highest concentration of Arsenic in both seasons which was higher than the FMEnv, (1991) industrial effluent limit for this heavy metal. On the other hand, Savana had the least Arsenic levels in the dry season. Other effluent samples studied recorded total mean arsenic levels that are within the limit allowed by FMEnv, (1991) (Table 4.8 and Fig. 4.11).

Nevertheless, arsenic concentrations varied significantly ($P<0.05$) in the effluent samples among the food industries, especially between Life and RIMCO with coefficient of variation of 80.886 and 132.6) Savana and RIMCO (76.5 and 132.6); KP and RIMCO (93.3 and 132.6); Golden and RIMCO (115.8 and 132.6); Obisco and RIMCO (69.5 and 132.6) respectively (Appendix 4f).

Arsenic is actually toxic to man and if detected in drinking water should give cause for concern. Investigation showed that a severe poisoning could arise from ingestion of as little as 100mg arsenic as a result of pollution from weedkillers and pesticides containing arsenical compounds. Exposure to inorganic arsenic can cause irritation of the stomach and intestine, decreased production of red and white blood cells and significant amount of arsenic can intensify chances of cancer development.

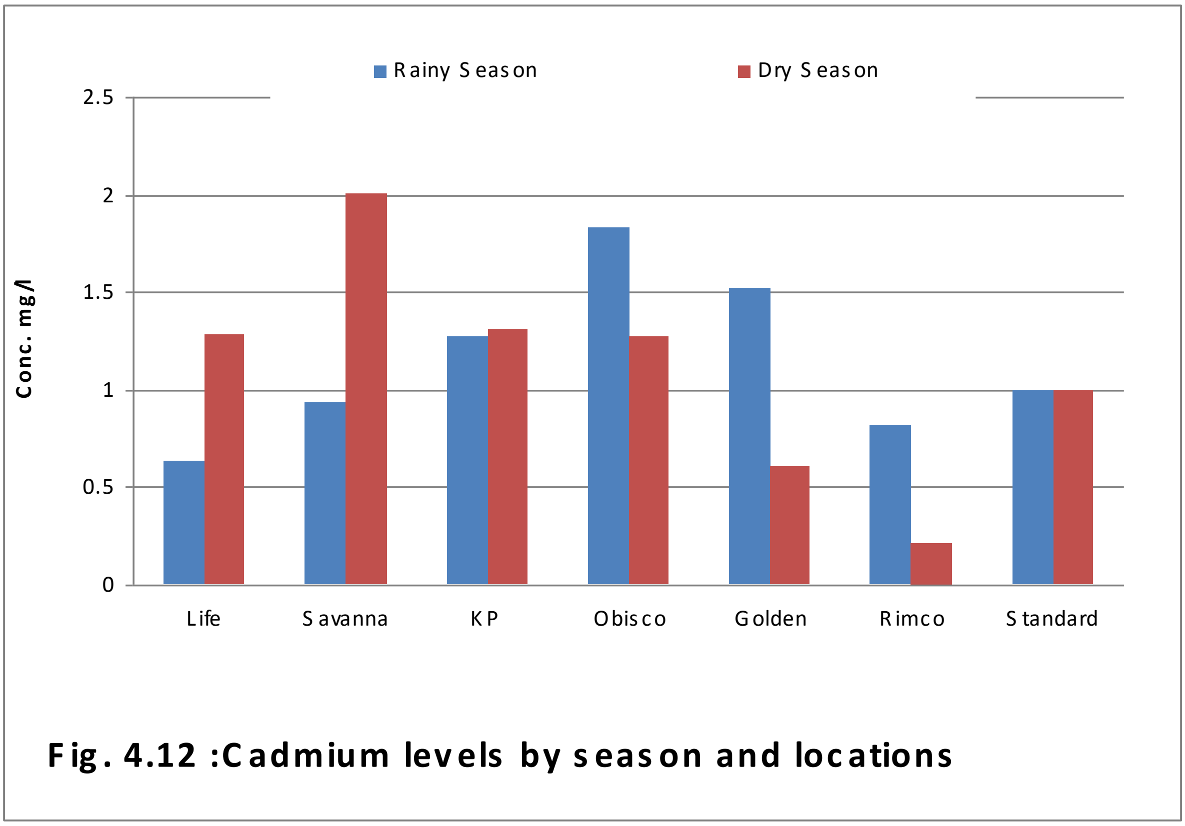


Fig. 4.12 :Cadmium levels by season and locations

Cadmium levels were highest in the effluent samples from Savana (dry season), followed by Obisco effluent (rainy season) and Golden oil effluent (rainy season) (Fig 4.12). Effluent samples from other food industries studied recorded total mean cadmium concentrations that were either within or slightly above the allowable limit of 1.00mg/l (FMEnv, 1991). This was in line with the findings of Oguzie and Okhagbuzo, (2010) who reported low cadmium levels in effluents discharges of Ikpoba river; but higher than the value reported by Obasohan *et al*., (2006) for Ogbar river water.

High exposure to cadmium could lead to lung diseases and has been linked to lung cancer and damage to human respiratory systems. Adeyemi *et al*., (2007) reported that people who consume cadmium in excess of the permissible level will suffer from renal tubular disease.

However, there was no significant difference ($P>0.05$) in the total cadmium levels among the food industries under study except that seen between Obisco and RIMCO (f – value 0.018).

Although the total mean concentrations of Arsenic and Cadmium were slightly higher in the dry season than in the rainy season, in almost all the effluent samples studied, there was no significant difference ($P>0.05$) in the levels of these two metals between the two seasons but the coefficient of variation for arsenic was higher in the rainy season (181.8%) than in the dry season (150.0%) compared to that of cadmium which was higher in the dry season (112.6%) than in the rainy season (107.7). Nevertheless, arsenic concentrations varied significantly ($P<0.05$) in the effluent samples among the food industries, especially between Life and RIMCO with coefficient of variation of 80.9 and 132.6) Savana and RIMCO (76.5 and 132.6); KP and RIMCO (93.3 and 132.6); Golden and RIMCO (115.8 and 132.6); Obisco and RIMCO (69.5 and 132.6) respectively (Appendix 4f).

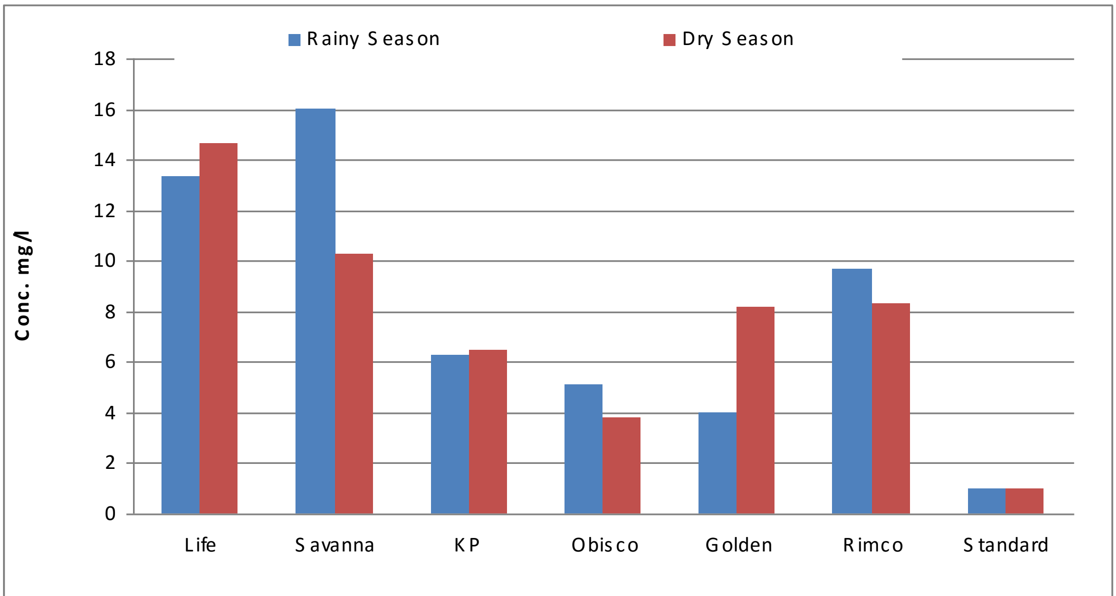


Fig. 4.13: Zinc levels by season and locations

Zinc, on the otherhand, recorded values that are significantly high in the effluent samples from all the food industries investigated in both seasons when compared to the value recommended by FMEnv, (1991) (<1.00mg/l) in industrial effluents (Fig 4.13). In the rainy season, the highest value was obtained in Savana effluent (16.010 ± 5.899mg/l) against 4.000 ± 3.406mg/l in Golden oil effluent (least value). Life breweries effluent recorded the highest value in the dry season (14.636 ± 1.966mg/l) while Obisco effluent had the value (3.783 ± 1.703mg/l) in the same season.

Concentrations of zinc in all the effluent samples were alarmingly high and violated the FMEnv, (1991) industrial effluent limit for zinc. Kolo *et al*., (2009) reported that zinc is one of the general essential elements for human health and metabolism and should be available in normal drinking water which according to Rajaram and Ashutost, (2008) may be higher if the water is stored in metal tanks.

Though total mean concentrations of zinc obtained in this work were high, they were within the value (15.00mg/l) recommended by the World Health Organization (WHO),

(1989) in drinking water except effluent sample from Savana (rainy season) which was higher than the WHO, (1989) value in drinking water.

Statistical analysis confirmed that the industries investigated showed no significant difference ($P>0.05$) between rainy and dry season with coefficient of variations of 74.0 (rainy season) and 81.9 (dry season) respectively. In the case of industries, there were significant difference ($P<0.05$) in the level of zinc among the effluents from these industries. For instance, there was significant difference in the mean zinc levels between Life and KP (p – value 0.001); Life and Obisco (p – value 0.000); Life and Golden (p – value 0.003); Life and RIMCO (p – value 0.014); Savana and Obisco (p – value 0.024); Obisco and RIMCO (p – value 0.040) respectively (Appendix 3j). Among the heavy metals, zinc is the least toxic and an essential element in human diet as it is required to maintain the functioning of the immune system. The recommended dietary allowance for zinc is 15mg/day for men and 12mg/day for women (ATSDR, 1994).

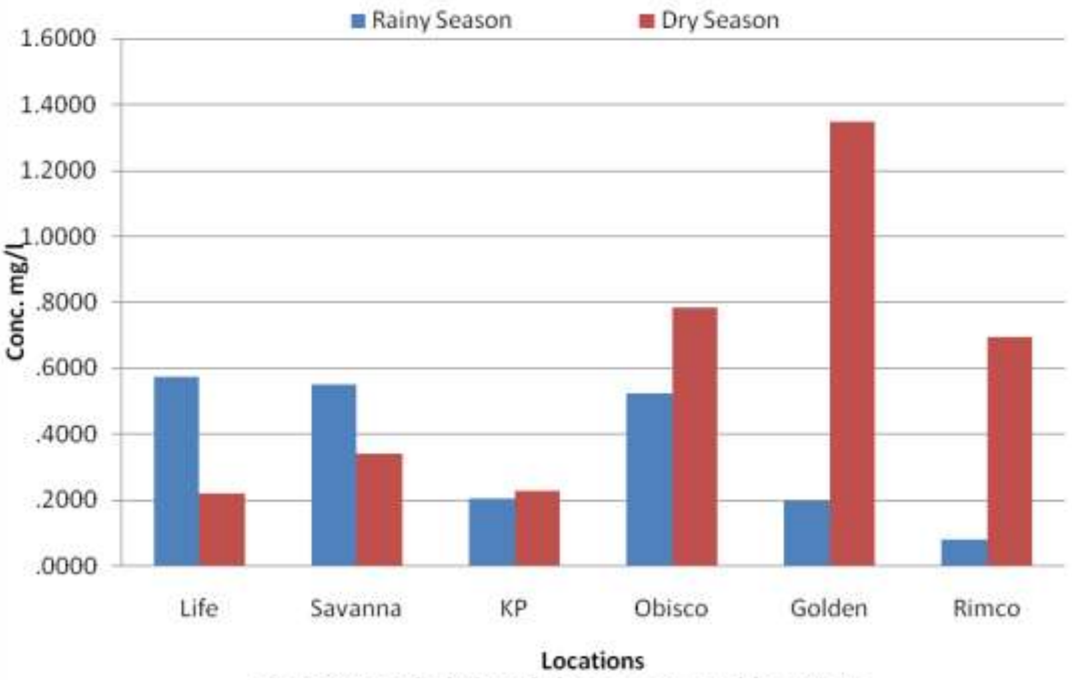


Fig. 4.14: Cobalt levels by season and locations

Figure 4.14 showed that cobalt concentration was higher in the dry season than in the rainy season with the exception of Life breweries, Onitsha and Savana effluent where reverse was the case. Low levels of this metal (Cobalt) in the rainy season compared to the dry season could be as a result of dilution through precipitation or leaching out of this heavy metal into a receiving water body by flood thereby lowering the concentration of cobalt in the effluent pathway in the rainy season than in the dry season. Golden vegetable oil, Onitsha recorded the highest mean concentration of cobalt in the dry season. The trend of cobalt concentration in the dry season for the food industries was Golden > Obisco > RIMCO > Savana > KP > Life respectively. Similarly, the cobalt concentration trend for the industries in the rainy season was Life > Savana > Obisco > Golden > KP > RIMCO.

The total mean concentrations of cobalt in the wastewater samples were not significant ($p > 0.05$) between the rainy and the dry seasons (f – value: 2.782; p – value: 0.109) (Appendix 3g). In a similar note, there was also no significant difference ($p > 0.05$) in the total mean concentrations of cobalt in the effluent samples of the different industries monitored, though slight variations was observed in the mean levels of cobalt in the effluent samples from Golden and RIMCO (p – value: 0.027); KP and Golden (p – value: 0.22) where cobalt level was slightly higher in Golden effluent than the values obtained from RIMCO and KP effluents.

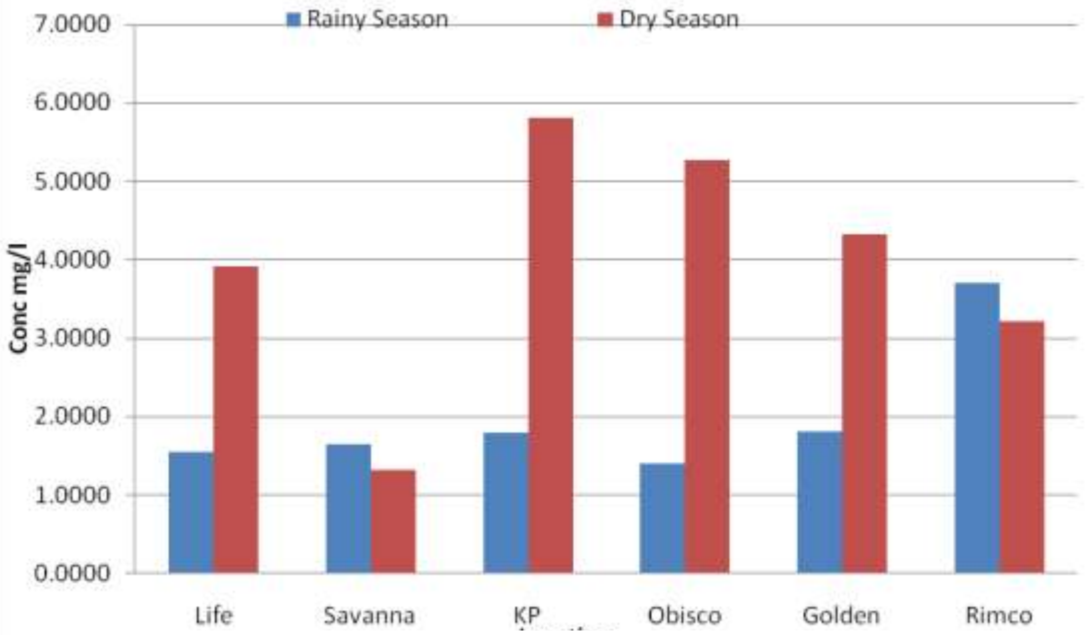


Fig. 4.15: Bismuth levels by season and locations

Similarly, Fig 4.15 showed that bismuth levels were higher in the dry season than in the rainy season (with the exception of Savana and RIMCO effluents) in all the effluent samples studied. Low concentrations of bismuth in the rainy season compared to the dry season could be as a result of dilution through preciptiation or by flood which washed away the metal into receiving water bodies, thus reducing its cocnentrations in the effluent pathways in the rainy season. The highest mean concentration of bismuth in the dry season was obtained from KP effluent sample. The trend of bismuth concentration in the dry season for the food industries studied was KP > Obisco > Golden > Life > RIMCO > Savana. Similarly, the bismuth concentration trend for the food industries in the rainy season was RIMCO > Golden > KP > Savana > Life > Obisco respectively.

Appendix 3f showed that the mean concentration of Bismuth in the effluent samples was highly singificant ($p < 0.05$) between the rainy and dry seasons. The levels of Bismuth obtained in this work was higher in the dry season than the values obtained in the rainy season as confirmed by the ANOVA Table (Appendix 3f) in all the effluent samples monitored. Nevertheless, the coefficient of variation was higher in the rainy season (117, 8558) than in the dry season (64.7429). Nevertheless, Appendix 3f showed that mean concentrations of Bismuth in the different food processing industrial effluents were not significant ($p > 0.05$). this showed that the Bismuth concentrations in the effluent samples of the different industries studied were not different from each other.

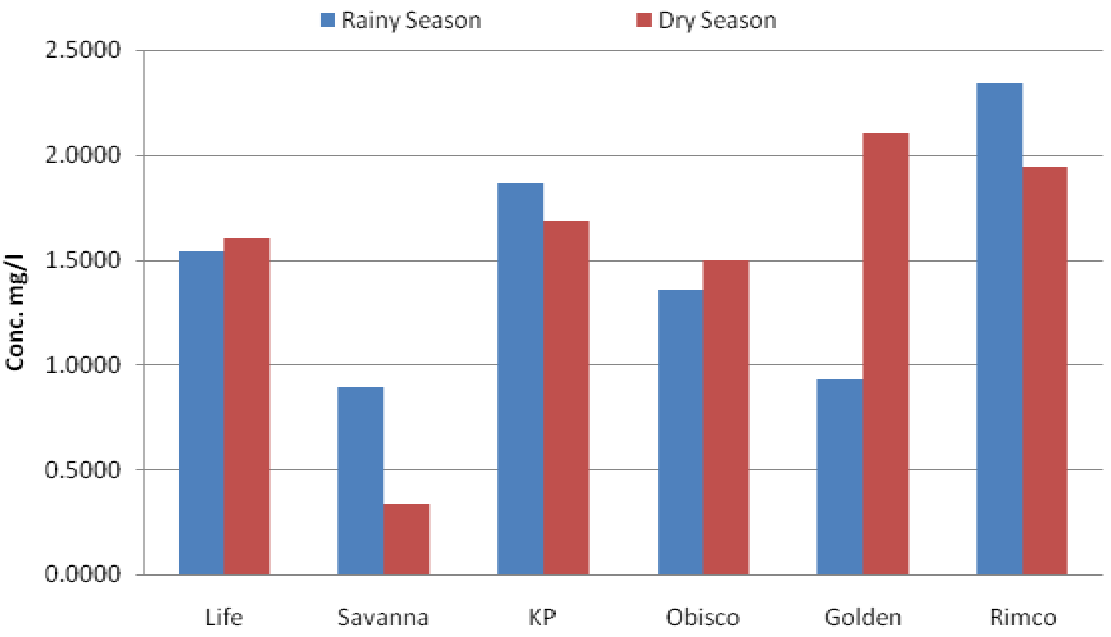


Fig. 4.16: Selenum levels by season and locations

Figure 4.16 showed that the mean concentrations of selenium was higher in the dry season than in the rainy season in effluent samples from Golden vegetable oil, Onitsha, Obisco beverages, Ogidi and Life breweries, Onitsha. Conversely, this metal was higher in the rainy season than in the dry season in effluent samples from RIMCO, KP and Savana. The decrease in the levels of selenium in the rainy season could be because of dilution by rain fall which lowered the concentrations of this metal in the effluent pathways. There was no FMEnv, (1991) effluent limit for selenium but mean concentrations of selenium obtained in the wastewater samples studied were higher than the value (0.01mg/l) recommended by WHO, (1989) in drinking water.

The ANOVA Table of between subjects effects for selenium was shown in Appendix 3i. From the Appendix, it was observed that there was no significant difference ($p > 0.05$) in the mean concentrations of selenium between the rainy and dry seasons studied (f – value: 0.013; p – value: 0.908). Similarly, the same Appendix showed that there was no significant difference ($p > 0.05$) in the variation of the concentrations of selenium in the effluent samples from the different industries monitored, though a slight difference was observed between Savana and Golden (p – value 0.043), Savana and RIMCO (p – value: 0.018) respectively.

Table 4.9: Pollution Index of the Heavy Metals

Rainy Season

	Mercury	Iron	Chromium	Lead	Cadmiun	Zinc	Arsenic	Polution index
Life	1.6385	1.4489	1.5767	2.8350	.6317	13.3733	.4917	7.5896
Savanna	1.9850	1.8300	.8100	2.4950	.9300	16.0100	.4050	8.8829
KP	1.2518	1.1778	1.0444	1.6450	1.2683	6.3033	.2817	5.2510
Obisco	1.8735	2.5667	.7011	.8733	1.8283	5.1067	.6283	7.0249
Golden	1.9352	1.8078	.9367	2.2200	1.5233	4.0000	.3350	7.0752
Rimco	1.5643	2.7717	1.6917	2.4458	.8178	9.6567	2.2111	7.2688
Dry Season								
Life	2.6550	3.4267	2.9458	2.8125	1.2833	14.6356	.7491	11.2790
Savanna	3.7825	2.3500	.6350	2.2250	2.0067	10.2933	.2050	13.3379
KP	2.7242	4.1075	1.6917	3.3133	1.3078	6.4758	.6017	10.2830
Obisco	3.1817	4.4283	2.8008	2.7633	1.2700	3.7833	.8783	11.3654
Golden	2.8650	4.1392	1.4150	3.5533	.6044	8.1700	.4559	10.8054
Rimco	.8778	1.8300	1.0817	2.4650	.2064	8.2817	1.8358	4.7510
Total								
Life	2.1468	2.5790	2.3590	2.8238	1.0227	14.3200	.6633	9.5290
Savanna	2.8838	2.1271	.7100	2.3600	1.5760	11.7225	.2717	10.9203
KP	1.9880	2.8519	1.4143	2.4792	1.2920	6.4413	.4950	7.8191
Obisco	2.5276	3.6305	1.9010	1.8183	1.4933	4.0480	.7950	9.1768
Golden	2.4001	3.1400	1.2100	2.8867	.9720	7.3360	.4156	9.1374
Rimco	1.2211	2.1439	1.2850	2.4554	.5121	8.5567	1.9967	5.9102

The levels of pollution index of the heavy metals from the food industries are shown in Table 4.9. The most polluting industry in the rainy season was Savana with a pollution index of 8.9 which was very high compared to the tolerable limit of 1.00, while the least was KP beverage, Ogidi with a pollution index of 5.3 in the same season. In the dry season (Table 4.9), Savana again recorded high pollution index (13.3), while RIMCO had the least value (4.8) in the same season.

Generally, the highest pollution index was obtained in Savana effluents in both seasons (10.9), followed by Life breweries effluents (9.5), while the least pollution index was obtained in RIMCO effluents (5.9), followed by KP beverage effluents (7.8).

Nevertheless, a critical look at the values obtained for the pollution index showed that all the food industries studied were polluted since the pollution index values obtained were above the tolerable limit of 1.00, though some are more polluted than the others. A higher degree of pollution was evident in Savana effluents than that seen in RIMCO effluents in both seasons. Pollution in terms of heavy metal in the food industries studied ranked in the order Savana > Life > Obisco > Golden > KP > RIMCO respectively.

Toxic metals may be absorbed by vegetables through several processes and finally enter the food chain at high concentrations capable of causing a serious health risk to consumers. Their toxicity according to Charles *et al.*, (2011) reduce mental and central nervous functions, lower energy levels and damage to blood composition, lungs, kidneys, liver and other vital organs. The authors also asserted that long term exposure to these heavy metals may result in slowly progressing physical, muscular and neurological degenerative processes that cause muscular dystrophy and multiple sclerosis.

Uba and Agbogho, (2001) reported that Arsenic and Chromium cause cancer while Mercury affects the kidney and central nervous system, lead affects mental development in infants, toxic to the central and peripheral nervous system.

These effluents, therefore need to be appropriately treated with respect to these heavy toxic metallic elements before discharge into receiving water body. Soil contaminated by these heavy metals in the effluent samples might produce unhealthy crops which when consumed by humans might be dangerous to health.

4.4 Results of the Physico-Chemical Parameters of the Effluents:

The Results of all the Physico-Chemical Parameters in the effluent samples of all the food processing industries studied were expressed as mean ± SD in Tables 4.10 – 4.12 (rainy season) and Tables 4.13 – 4.15 (dry season).

Table 4.10 Mean levels of Physico-chemical parameters for the months of June – September (Rainy Season) for life and Savana effluents

Food Industry	**Life Breweries Effluent**			**Savana Drink Effluents**			**FMEnv (1991)**
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Acidity (mg/L)	0.216 ± 0.113	0.103 ± 0.086	0.462 ± 0.713	0.187 ± 0.154	-	-	NA
Total Hardness (mg/L)	250.00 ± 50.000	20.000 ± 40.000	70.000 ± 140.000	BDL	-	-	100mg/L
Chloride Content (mg/L)	3.231 ± 2.204	3.708 ± 2.632	4.725 ± 2.489	4.473 ± 1.905	-	-	200 mg/L
Hydroxyl (mg/L)	11.900 ± 23.800	15.300 ± 30.600	51.000 ± 102.000	BDL	-	-	NA
Bicarbonate Content(mg/L)	210.000 ± 240.000	210.000 ± 420.000	900.000 ± 1,800.000	BDL	-	-	NA
Total Alkalinity (mg/L)	35.000 ± 70.000	35.000 ± 70.000	150.000 ± 300.000	BDL	-	-	NA
pH Values	3.500 ± 2.467	5.200 ± 3.526	5.000 ± 3.434	2.650 ± 0.904	-	-	6 – 9
Nitrate Concentration (mg/L)	0.875 ± 0.480	0.513 ± 0.473	2.913 ± 0.659	1.050 ± 0.672	-	-	50 mg/L
Sulphate Concentration (mg/L)	40.500 ± 28.723	38.375 ± 24.377	69.625 ± 70.995	84.250 ± 61.299	-	-	250 mg/L
Total Solids (TS) (mg/L)	1125.000± 629.153	1450.000 ±640.312	1000.000± 0.000	475.000 ± 125.831	-	-	2030 mg/L
TSS (mg/L)	0.475 ± 0.386	0.325 ± 0.206	0.250 ± 0.191	0.200 ± 0.200	-	-	30 mg/L
TDS (mg/L)	1124.525± 628.775	1449.675 ± 643.567	999.750 ± 0.191	474.800 ± 125.698	-	-	2000 mg/L

NOTE: TS = Total Solids TSS = Total Suspended Solids TDS= Total Dissolved Solids BDL = Bellow Detection Limit

Table 4.10 shows the mean levels of the concentrations of the physico-chemical properties of the effluent samples from Life Breweries and Savana drinks from different points of collection ranging from the point of discharge of the effluent (P_1) through 15 meters away from the point of discharge (P_2) to 30 meters away from the point of discharge (P_3) for the rainy season (June- September). In Life Breweries effluent, total hardness was observed to be highest at the point of discharge of the wastewater (P_1) compared to the values obtained at P_2 and P_3. For Savana effluent, this parameter (hardness) was below the detection limit (BDL) and was not detected. This was also the case with hydroxyl, bicarbonate and total alkalinity which were not detected in the rainy season from Savana effluent, but were detected in Life Breweries effluent.

Again, there was an increase in the pH levels of the wastewater sample from Life Breweries from the point of discharge of the wastewater (3.500 ± 2.467) to P_2 (5.200 ± 3.526) and then a decrease (5.00 ± 3.434) at 30 meters away from the point of discharge of the wastewater (P_3). However, other physico-chemical parameters did not follow clearly any discernible pattern as some parameters were highest at P_1 than P_2 and P_3 while others were highest at P_3 compared to the values obtained at P_2 and P_1 and vice versa.

Table 4.11: Mean levels of Physico-chemical parameters for the months of June – September (Rainy Season) for KP and OBISCO effluents

Food Industry	**KP Beverage Ogidi/Point of Collections**			**Obisco Beverage Ogidi/Point of Collections**			**FMEnv (1991)**
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Acidity (mg/L)	0.053 ± 0.051	0.049 ± 0.042	0.131 ± 0.106	0.115 ± 0.021	0.083 ± 0.041	0.128 ± 0.065	NA
Total Hardness (mg/L)	77.000 ± 76.131	66.000± 63.203	442.000 ± 773.043	242.000 ± 380.337	240.000 ± 380.876	239.800 ± 380.495	100mg/L
Chloride Content (mg/L)	6.958 ± 3.807	7.455 ± 4.408	7.455 ± 4.408	7.952 ± 4.295	8.449 ± 4.408	8.946 ± 4.732	200 mg/L
Hydroxyl (mg/L)	BDL	BDL	BDL	6.800 ± 13.600	6.800 ± 13.600	13.600 ± 27.200	NA
Bicarbonate Content (mg/L)	BDL	BDL	BDL	120.000 ± 240.000	120.000 ± 240.000	240.000 ± 480.000	NA
Total Alkalinity (mg/L)	BDL	BDL	BDL	20.000 ± 40.000	20.000 ± 240.000	40.000 ± 80.000	NA
pH Values	5.525 ± 0.126	5.520 ± 0.206	5.475 ± 0.340	5.600 ± 0.337	5.625 ± 0.330	5.625 ± 0.520	6 – 9
Nitrate Concentration (mg/L)	1.200 ± 1.145	1.238 ± 0.694	0.638 ± 0.502	2.825 ± 2.575	4.400 ± 3.075	5.273 ± 1.626	50 mg/Ll
Sulphate Concentration (mg/L)	78.750 ± 68.163	99.750 ± 62.185	85.250 ± 68.178	56.000 ± 55.785	49.500 ± 51.235	54.250 ± 48.230	250 mg/L
Total Solids (TS) (mg/L)	125.000 ± 629.123	1100.000±163.325	1300.00 ± 871.780	850.000 ± 300.000	850.000 ± 300.000	650.000 ± 58.230	2030 mg/L
TSS (mg/L)	0.437 ± 0.415	0.200 ± 0.200	0.350 ± 0.235	0.300 ± 0.231	0.275 ± 0.206	0.525 ± 0.05	30 mg/L
TDS (mg/L)	1124.563± 629.256	1099.800±663.345	1299.650±871.680	849.700 ± 300.133	849.725 ± 300.150	649.475 ± 580.181	2000 mg/L

NOTE: TS = Total Solids TSS = Total Suspended Solids TDS= Total Dissolved Solids BDL = Bellow Detection Limit

From Table 4.11, it was observed that mean total hardness were highest from the effluent sample collected 30 meters away from the point of discharge (P_3) in KP effluent, while in Obisco effluent, the highest mean hardness was recorded at the point of discharge of the effluent (P_1). Values of hardness obtained from Obisco effluent at the various points of discharge and that obtained from KP effluent (P_3) were higher than the value recommended by the Federal Ministry of Environment, (1991) in industrial effluent to be discharged into the environment. Bicarbonate and alkalinity were below the detection limit (BDL) of the instrument in KP effluent at all the points of discharge (rainy season, Table 4.11), but were detected in Obisco effluent in the same season.

In both effluents (KP and Obisco), pH values increased from the points of discharge of the effluents (P_1) through 15 meters away from the points of discharge (P_2) to 30 meters from the points of discharge of the effluents (P_3). However, other parameters showed no particular trend of occurrence at the different points of discharge of the effluents in both companies (rainy season, Table 4.11).

Table 4.12: Mean levels of Physico-chemical parameters for the months of June – September (Rainy Season) for Golden and RIMCO effluents.

Food Industry	**Golden Vegetable Oil Onitsha /Point of Collections**			**RIMCO Nnewi/Point of Collections**			**FMEnv (1991)**
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Acidity (mg/L)	0.362±0.108	0.395 ± 0.134	0.395 ± 0.180	0.271±0.046	0.306±0.034	0.270±0.092	NA
Total Hardness (mg/L)	13.000 ± 26.000	BDL	100.00±200.000	171.500±286.442	314.000±591.256	150.000±300.000	100mg/l
Chloride Content (mg/L)	6.457 ± 3.396	6.457±3.396	6.954 ± 3.808	3.479±0.994	3.231±1.491	3.231±1.490	200 mg/l
Hydroxyl (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Bicarbonate Content (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	NA
Total Alkalinity (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	NA
pH Values	3.225 ± 1.541	3.175±1.457	3.200 ± 1.499	3.100±2.069	2.850±1.634	2.800±1.667	6 – 9
Nitrate Concentra-tion (mg/L)	0.713 ± 34.073	1.625±1.554	1.275 ± 1.165	1.600±0.057	1.200±0.813	1.450±0.951	50 mg/l
Sulphate Concentration (mg/L)	40.500 ± 34.073	52.500±40.286	49.750 ± 35.519	44.875±37.417	37.500±22.128	48.250±26.424	250 mg/l
Total Solids (TS) (mg/L)	675.000±427.200	750.000±288.675	750.000±288.675	650.000± 238.048	625.000±250.000	450.000±57.735	2030 mg/l
TSS (mg/L)	0.350± 0.300	0.250±0.191	0.225 ± 0.189	0.325±0.126	0.425±0.222	0.425±0.222	30 mg/l
TDS (mg/L)	674.650±427.134	749.750±288.502	749.775±288.531	649.675±238.083	624.575±250.083	449.57±57.880	2000 mg/l

NOTE: TS = Total Solids TSS = Total Suspended Solids TDS= Total Dissolved Solids BDL = Bellow Detection Limit

Table 4.12 shows that bicarbonates, and alkalinity were below the detection limit (BDL) of the instrument and hence were not detected from the effluent samples from Golden and RIMCO in the rainy season. Mean pH levels of the effluents decreased from P_1 (3.00±2.069) through P_2 (2.850±1.634) and then to P_3 (2.800±1.667) in RIMCO effluent sample. However, this trend was not observed in the pH levels of the Golden oil effluents as there was a decrease from P_1 to P_2 and then an increase from P_2 to P_3.

Total solids levels obtained from RIMCO effluents decreased from the point of discharge of the effluent (P_1) through 15 meters away from the point of discharge (P_2) and then 30 meters away from the point of discharge of the effluent (Table 4.12), but in Golden effluent, this trend was not observed in the mean levels of total solids at the various points of discharge of the effluents.

Other physico-chemical parameters monitored for Golden and RIMCO effluents did not follow a particular trend in their occurrence at the different points of discharge of the effluents.

Table 4.13: Mean levels of Physico-chemical parameters for the months of October – January (Dry Season) for Life and Savana effluents

Food Industry	**Life Breweries Effluent**			**Savana Drink Effluent**			**FMEnv (1991)**
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Acidity (mg/L)	0.175 ± 0.178	0.142 ± 0.175	0.162 ± 0.188	0.175 ± 0.122	-	-	NA
Total Hardness (mg/L)	98.800 ± 73.976	127.000 ± 86.925	97.000 ± 56.415	107.000± 72.544	-	-	100mg/L
Chloride Content (mg/L)	7.455 ± 6.958	6.958 ± 5.964	6.958 ± 5.964	5.219 ± 3.182	-	-	200 mg/L
Hydroxyl (mg/L)	10.200 ± 20.400	22.100 ± 44.200	13.600 ± 27.200	BDL	-	-	NA
Bicarbonate Content (mg/L)	180.000 ± 360.000	390.000 ± 780.000	240.000 ± 480.000	BDL	-	-	NA
Total Alkalinity (mg/L)	300.000 ± 600.000	65.000 ± 130.000	40.000 ± 80.000	BDL	-	-	NA
pH Values	6.063 ± 3.960	6.050 ± 3.842	5.988 ± 3.683	5.325 ± 3.176	-	-	6 – 9
Nitrate Concentration (mg/L)	0.663 ± 0.442	1.025 ± 0.953	1.313 ± 0.838	1.525 ± 0.450	-	-	50 mg/L
Sulphate Concentration (mg/L)	11.250 ± 10.104	15.500 ± 9.747	15.600 ± 11.758	13.000 ± 13.491	-	-	250 mg/L
Total Solids (TS) (mg/L)	600.000±294.3920	525.000 ± 320.156	412.500 ± 118.145	275.000± 50.000	-	-	2030 mg/L
TSS (mg/L)	0.525 ± 0.171	0.750 ± 0.191	0.750 ± 0.205	0.700 ± 0.245	-	-	30 mg/L
TDS (mg/L)	599.475 ± 294.29	524.250± 320.00	411.750 ± 118.124	274.300 ± 49.867	-	-	2000 mg/L

NOTE: TS = Total Solids TSS = Total Suspended Solids TDS= Total Dissolved Solids BDL = Bellow Detection Limit

Table 4.13 shows the mean levels of the physicochemical properties of the effluents from Life Breweries and Savana in the dry season (October- Jan) from the different points of discharge (P_1-P_3). Total mean pH levels obtained from the various points of discharge of the wastewater in Life effluent samples decreased in the order P_1 (6.063±3.960)> P_2 (6.050+3.842)>P_3 (5.988±3.683). This trend showed a decrease in the pH of the wastewater from the point of discharge of the effluent (P_1) to 30 meters away from the point of discharge (P_3). However, mean pH values obtained from Savana effluent (P_1) was lower than the values obtained at the different points in Life Breweries effluent sample.

Nevertheless, hydroxyl, bicarbonate and total alkalinity were below the detection limit (BDL) of the instrument and were not detected in both seasons from Savana effluent (Table 4.10 and 4.11). Other physico-chemical parameters showed no particular order in their occurrence from the different points of discharge of the effluents in Life Breweries effluents.

Table 4.14: Mean levels of Physico-chemical parameters for the months of October – January (Dry Season) for KP and OBISO effluents.

Food Industry	KP Beverage Ogidi/Point of Collections			Obisco Beverage Ogidi/Point of Collections			FMEnv (1991)
	P_1	P_2	P_3	P_1	P_2	P_3	
Acidity (mg/L)	0.209 ± 0.212	0.186 ± 0.188	0.180 ± 0.138	0.189 ± 0.160	0.184 ± 0.173	0.185 ± 0.192	NA
Total Hardness (mg/L)	95.000 ± 90.059	86.000 ± 64.457	82.000 ± 69.244	249.000 ± 371467	244.200±371.947	235.000±378.564	100mg/L
Chloride Content (mg/L)	7.952 ± 7.952	8.448 ± 8.947	9.940 ± 11.928	7.957 ± 7.949	9.443 ± 10.934	6.958 ± 5.964	200 mg/L
Hydroxyl (mg/L)	17.050 ± 19.688	22.050 ± 26.713	23.750 ± 11.928	32.300 ± 29.050	25.500 ± 29.575	27.958 ± 28.850	NA
Bicarbonate Content (mg/L)	300.000± 346.410	390.000±473.709	420.000± 567.098	570.000 ±512.640	450.000 ±521.920	480.000±509.117	NA
Total Alkalinity (mg/L)	50.000 ± 57.735	65.000 ± 78.951	70.000 ± 94.516	365.000 ±562.939	165.000 ±177.670	215.000±270.000	NA
pH Values	6.800 ± 1.211	6.625 ± 0.991	6.400± 0.622	5.250 ± 2.838	5.175 ± 3.058	4.215 ± 3.342	6 – 9
Nitrate Concentration (mg/L)	2.213 ± 1.825	2.213 ± 1.321	1.725 ± 2.274	2.213 ± 1.509	2.013 ± 1.217	2.188 ± 0.936	50 mg/L
Sulphate Concentration (mg/L)	9.250 ± 5.825	13.500 ± 10.344	9.625 ± 7.274	6.800 ± 5.902	7.750 ± 2.062	10.000 ± 5.477	250 mg/L
Total Solids (TS) (mg/L)	500.000 ± 81.650	425.000±125.831	300.000± 115.470	550.000± 341.565	475.000 ±350.000	412.500±392.375	2030 mg/L
TSS (mg/L)	0.550 ± 0.129	0.525 ± 0.206	0.625 ± 0.15	0.725 ± 0.150	0.725 ± 0.189	2.975 ± 4.690	30 mg/L
TDS (mg/L)	499.450 ± 81.731	424.475± 125.678	299.375 ± 115.499	574.275 ± 309.707	474.275 ±349.81	409.525±387.706	2000 mg/L

NOTE: TS = Total Solids TSS = Total Suspended Solids TDS= Total Dissolved Solids BDL = Bellow Detection Limit

From Table 4.14, it was observed that the total mean hardness was highest at the point of discharge of the effluents (P_1) in Obisco effluent (249.00±371.467mg/L) and least at 30 meters away from the point of discharge (P_3). Total mean hardness levels obtained from this effluent at all the points of collection were higher than the value recommended by the Federal Ministry of Environment, (1991) for industrial effluent limit. This trend was also observed in KP effluent sample though total mean hardness levels from KP effluent were within the limit specified for industrial effluent.

pH levels of the two effluents (KP and Obisco) were also highest at the points of discharge (P_1) and least at 30 meters away from the points of discharge of the effluents (P_3). This particular trend was again observed in the levels of total solids and total suspended solids at the different points of discharge of the effluents from both KP and Obisco effluents. However, other physicochemical parameters from these effluents varied from one point to the other at the different points of discharge.

Table 4.15: **Mean levels of Physico-chemical parameters for the months of October – January (Dry Season) for Golden and RIMCO effluents.**

Food Industry	**Golden Vegetable Oil Onitsha/Point of Collections**			**RIMCO Nnewi/Point of Collections**			**FMEnv (1991)**
	P_1	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**	
Acidity (mg/L)	0.350 ± 0.349	0.373 ± 0.274	0.358 ± 0.274	0.354±0.204	0.342 ± 0.214	0.356 ± 0.212	NA
Total Hardness (mg/L)	507.500 ± 591.672	517.500±580.835	525.000±573.303	450.000±416.493	500.000±469.326	522.500± 588.114	100mg/L
Chloride Content (mg/L)	8.449 ± 2.982	17.395 ± 19.094	11.928 ± 8.434	3.231±1.491	3.231 ± 1.491	3.479 ± 0.994	200 mg/L
Hydroxyl (mg/L)	8.500 ± 17.000	8.500 ± 17.000	8.500 ± 17.000	10.200±13.021	6.800 ± 7.8852	8.500 ± 10.200	NA
Bicarbonate Content (mg/L)	150.000 ± 300.000	150.000±300.000	150.000±300.000	80.000±229783	120.000±138.564	150.000±180.000	NA
Total Alkalinity (mg/L)	25.000 ± 50.000	25.000 ± 50.000	250.000±50.000	30.000±38.297	20.000 ± 23.094	25.000 ± 30.000	NA
pH Values	5.175 ± 0.624	5.075 ± 0.299	5.375 ± 0.330	5.275±1.413	4.925 ± 1.539	4.900 ± 1.587	6 – 9
Nitrate Concentration (mg/L)	1.663 ± 6.266	1.875 ± 0.247	2.150 ± 1.178	0.800±0.577	0.538 ± 0.453	0.713 ± 0.375	50 mg/L
Sulphate Concentration (mg/L)	6.875 ± 3.924	6.875 ± 3.924	8.750 ± 2.363	7.250 ± 7.354	7.250 ± 8.529	10.875 ± 10.299	250 mg/L
Total Solids (TS) (mg/L)	450.000 ± 129.099	390.000±90.185	332.500±127.377	620.000±337.046	570.000±315.595	487.500 ± 352.077	2030 mg/L
TSS (mg/L)	0.800 ± 129.099	1.125 ± 0.597	0.775 ± 0.206	0.575 ± 0.386	0.475 ± 0.206	0.500 ± 0.100	30 mg/L
TDS (mg/L)	449.200 ± 129.048	388.875±90.109	331.725±127.186	619.425±337.123	569.525±315.725	486.950 ± 351.980	2000 mg/L

NOTE: TS = Total Solids TSS = Total Suspended Solids TDS= Total Dissolved Solids BDL = Bellow Detection Limit

Table 4.15 shows the mean levels of the physico-chemical properties of the effluents from Golden and RIMCO in the dry season (October- Jan). It was observed that the mean total hardness obtained from these effluents followed the reverse trend as was the case in Table 4.14. The highest mean hardness was obtained from the effluent sample collected from 30 meters away from the points of discharge of the effluents (P_3)in both Golden and RIMCO industries. The trend was P_3>P_2>P_1. Mean hardness obtained from the two effluents were higher than the value recommended by the Federal Ministry of Environment (FMEnv), (1991) for industrial effluent limit.

pH values decreased from P_1 to P_3 from the effluent sample from RIMCO but did not follow this pattern in Golden effluent as P_3 recorded the highest level of pH compared to P_2 and P_1. Total dissolved solids were highest at P_1 in the two effluents and least at P_3.

Despite the variations obtained in the physico-chemical properties of the effluents at the different sampling points in both season, the pH values were lower in the rainy season than in the dry season at almost all the points of collection of the effluents. This could be as a result of acid rain in the area which instead of diluting the effluents, increased the acidity of the effluents, hence lowering the pH in the rainy season than in the dry season.

In the same way, total solids (TS) and total dissolved solids (TDS) obtained from these effluents were higher in the rainy season at all the points of discharge of the effluents than values obtained in the dry season. This could probably be as a result of flood run off from the surrounding areas which mixed with the effluent pathways, thus increasing the concentrations of these parameters in the rainy season than in the dry season.

4.5 Pooled Mean Levels of the Physico-Chemical Parameters

The results of the pooled mean levels of the physico-chemical parameters of the effluent samples are presented in Tables 4.16 (rainy season), 4.17 (dry season) and Figures 4.17 to 4.28 respectively.

Table 4.16: Pooled Mean levels of the Physico-Chemical Parameters of the Effluents in the rainy season (June – September)

Parameters Tested	Effluent Samples						
	Life Breweries Onitsha	**Savana Drinks**	**KP Beverages Ogidi**	**Obisco Beverages Ogidi**	**Golden Oil Osha**	**RIMCO Nnewi**	**FMEnv (1991) Effluent Limit**
Acidity (mg/L)	0.324 ± 0.061	0.249 ±0.112	0.102± 0.064	0.108± 0.056	0.379± 0.056	0.174± 0.056	NA
Hardness (mg/L)	173.333± 206.038	BDL	260.000± 118.956	455.143±134.883	226.000±252.244	423.667±145.691	100mg/L
Chloride Content (mg/l)	3.727± 1.689	4.473± 2.925	7.289± 1.689	8.449±1.689	6.622± 1.689	3.313± 1.689	200mg/L
Hydroxyl Content (mg/L)	104.267± 17.038	BDL	BDL	36.267±17.038	BDL	BDL	NA
Bicarbonate Content (mg/L)	1840.000±300.819	BDL	BDL	620.000±300.819	BDL	BDL	NA
Alkalinity (mg/L)	306.667+ 155.820	BDL	BDL	86.667±155.820	BDL	BDL	NA
pH	4.583± 0.414	2.650± 0.718	5.508± 0.414	5.625± 0.414	3.200± 0.414	2.908± 0.414	6 – 9
Nitrate Concentration (mg/L)	1.434± 0.353	1.050± 0.611	1.004± 0.353	4.166± 0.353	1.204± 0.353	1.333± 0.353	50mg/L
Sulphate Concentration (mg/L)	49.500± 9.346	84.917± 16.188	87.917± 9.346	53.333± 9.346	47.875± 9.346	41.875± 9.346	250 mg/L
TS (mg/L)	1191.667±103.957	475.000±180.059	1175.000±103.957	891.667±103.957	725.000±103.957	533.333±103.957	2030 mg/L
TSS (mg/L)	0.354± 0.069	0.200± 0.120	0.346±0.046	0.383± 0.069	0.275± 0.069	0.400± 0.069	30 mg/L
TDS (mg/L)	1191.313±103.916	474.800±179.988	1174.654±103.916	891.283±103.916	724.725±103.916	532.933±103.916	2000 mg/L

NOTE: TS = Total Solids TSS = Total Suspended Solids TDS= Total Dissolved Solids BDL = Bellow Detection Limit

Table 4.16 shows the mean levels of the physiochemical properties of the effluent samples from the various food industries monitored in the rainy season. From the Table, it was observed that the physicochemical parameters monitored showed marked variation from one effluent sample to the other. For instance, total mean value of pH of the discharged effluents was lowest in Savana effluent (2.650 ± 0.718). This value was closely followed by the values obtained from RIMCO effluent (2.908 ± 0.414) and Golden effluent sample (3.200 ± 0.414). The pH of these effluents were highly acidic in this season and could impair the activities of soil microbes and even aquatic lives if discharged into the environment without proper treatment.

The mean concentrations of pH obtained in the rainy season from all the effluents were lower than the values obtained in the dry season (Table 4.17). This could be as a result of acid rain which mixed with the effluents, hence leading to low pH values. Values of pH obtained from all the effluent samples monitored (rainy season) were lower than the permissible industrial effluent limitation guideline set by the Federal Ministry of Environment, (1991). Moreover, the total mean levels of sulphates, total solids and total dissolved solids were higher in the rainy season in all the effluent samples monitored than the values obtained for these parameters in the dry season. This could be as a result of flood run off which mixed with the effluent pathways, hence increased the turbidity of the effluents in this season (Table 4.16). However, the mean concentration of sulphates, Nitrates, total solids and total dissolved solids obtained from this work were still lower than the values recommended by the Federal Ministry of Environment, (1991) for industrial effluent limit. This showed that these parameters contributed little to the pollution status of these effluents.

This notwithstanding, hardness levels obtained from these effluent samples (apart from Savana effluent) recorded values that were higher than the value recommended by the Federal Ministry of Environment (FMEnv), (1991) for effluent limitation guideline.

Table 4.17: Pooled Mean levels of the Physico-Chemical Parameters of the Effluents in the dry season (October – January)

Parameters Tested	**Effluent Samples**						
	Life Breweries Onitsha	**Savana Drinks**	**KP Beverages Ogidi**	**Obisco Beverages Ogidi**	**Golden Oil Osha**	**RIMCO Nnewi**	**FMEnv (1991)**
Acidity (mg/L)	0.174± 0.058	0.169± 0.097	0.256± 0.064	0.179± 0.064	0.364± 0.056	0.351± 0.056	NA
Hardness (mg/L)	106.933± 103.019	107.000 ± 178.434	87.333± 103.019	242.733±103.109	516.667± 0.056	410.833± 103.019	100 mg/L
Chloride Content (mg/L)	7.124± 1689	5.467± 2.925	8.780± 1.689	8.118± 1.689	12.591± 1.689	3.313± 1.689	200 mg/L
Hydroxyl Content (mg/L)	61.200± 17.038	BDL	41.867 ± 12.048	37.867± 9.837	34.000± 17.036	17.000± 12.048	NA
Bicarbonate Content (mg/L)	1080.000± 300.819	BDL	740.000± 212.711	660.000±173.678	600.000±300.819	300.000± 212.711	NA
Alkalinity (mg/L)	546.667± 155.820	BDL	123.333± 110.181	331.111± 89.963	100.000±155.820	50.000± 110.181	NA
pH	8.033± 0.414	7.257± 0.718	6.600± 0.414	6.017± 0.414	4.817± 0.414	5.003± 0.414	6-9
Nitrate Concentration (mg/L)	1.000± 0.353	1.525± 0.611	2.050± 0.353	2.135± 0.353	1.896± 0.353	0.683± 0.353	50 mg/L
Sulphate Concentration (mg/L)	14.250± 9.346	13.000± 16.188	10.7792± 9.346	8.083± 9.346	7.500± 9.346	8.458± 9.346	250 mg/L
TS (mg/L)	512.500± 103.957	275.000 ± 180.059	408.333± 103.957	487.500±103.957	390.833± 103.957	559.167± 103.957	2030 mg/L
TSS (mg/L)	0.675± 0.069	0.700± 0.120	0.567± 0.069	0.725± 0.069	0.900± 0.069	0.567± 0.069	30 mg/L
TDS (mg/L)	511.825± 103.916	274.300± 179.988	407.767± 103.916	486.025±103.916	389.933± 103.916	558.600± 103.916	2000 mg/L

NOTE: TS = Total Solids TSS = Total Suspended Solids TDS= Total Dissolved Solids BDL = Bellow Detection Limit

The pH levels of the effluent samples were higher in the dry season than the pH values obtained in the rainy season from all the effluent samples monitored. Life, Savana, KP and Obisco effluents recorded pH values that were alkaline and close to neutrality, hence were within the limit allowed by the Federal Ministry of Environment (FMEnv), (1991) for industrial effluent limit, but values of pH obtained from Golden and RIMCO effluents in this season were still acidic and were lower than the Federal Ministry of Environment (FMEnv), (1991) limit. This confirmed that these effluents from Golden and RIMCO are highly acidic and will be toxic to soil, water and aquatic lives and human beings of discharged into the environment without proper treatment.

Again, the hardness values obtained from the effluent samples (except KP effluent) were higher than the hardness level recommended by the Federal Ministry of Environment (FMEnv), (1991) for industrial effluent limit. Total mean suspended solids were higher in the dry season (Table 4.17) than the values obtained for this parameter in the rainy season (Table 4.16) in all the effluent samples monitored. However, these values were lower than the limit prescribed by the Federal Ministry of Environment (FMEnv), (1991) for industrial effluent to be discharged into the environment.

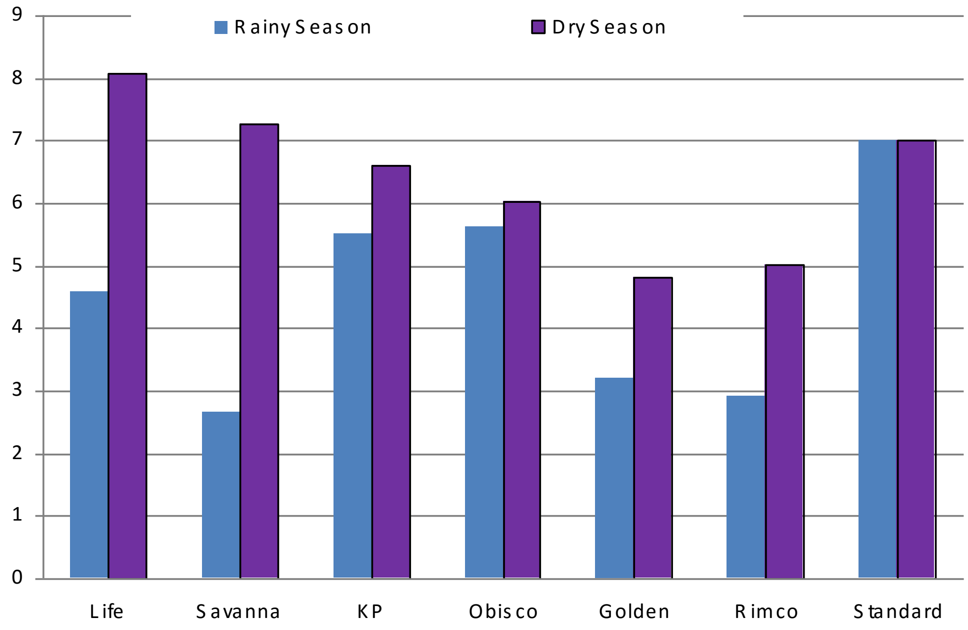


Fig. 4.17: pH Value levels by season and locations

Figure 4.17 showed that pH in rainy season was highest in effluent from Obisco beverage, Ogidi and least in effluent from Savana. Life Breweries, Onitsha recorded the highest pH level in the dry season (8.083 + 0.414) while Golden oil had the least value (4.817 + 0.414) (Tables 4.16 and 4.17).

Lower pH values would increase the acidity of the receiving streams, a situation that is deleterious to aquatic lives and even humans when sea foods such as oyster shell, shrimps, fish and water snails from such streams are consumed (Chukwu, 2008). Ram, et al., (2011) reported that most of the chemical reactions in aquatic environment are controlled by any change in pH values of the ecosystem. They also stated that the toxicity of heavy metals get enhanced at particular pH, thus any pH either highly acidic or alkaline would kill marine forms.

The low pH values of the waste water from RIMCO and Golden oil (in both seasons) might be as a result of free fatty acids from the oil droplets in the wastewater. This is evident in the results of organic pollutants shown on Tables 4.36 – 4.38 (Golden oil) and RIMCO (Tables 4.39 – 4.41). These could be concentrated and used for soap making instead of being discharged indiscriminately into receiving waterbody as these fats, according to Ene; (1994) would inhibit the transfer of oxygen from the atmosphere into the waterbody. Higher pH values, according to Chukwu, (2008) could also encourage some sea weeds such as water hyacinth to grow and multiply.

However, statistical analysis showed that the pH values of the wastewaters differ significantly ($P<0.05$) between rainy and dry seasons. Lower values were obtained in the rainy season than in the dry season. This could probably be as a result of acid rain which mixed with the effluents leading to increased acidity of the effluents or surface runoff of fertilizers from farmland which mixed with the effluents in their path ways leading to increased acidity of the effluents thus, reduced pH. Industries studied also showed marked significant difference ($P<0.05$) in the mean values of their pH. The industries that differed in the level of pH in their effluents were Life and Savana (p – value: 0.021), Life and Golden (p – value: 0.000), Life and RIMCO (p – value: 0.000), KP and Golden (p – value: 0.000), KP and RIMCO (p – value: 0.000), Obsico and Golden (p – value: 0.000), Obisco and RIMCO (p – value: 0.000) (Appendix 5a).

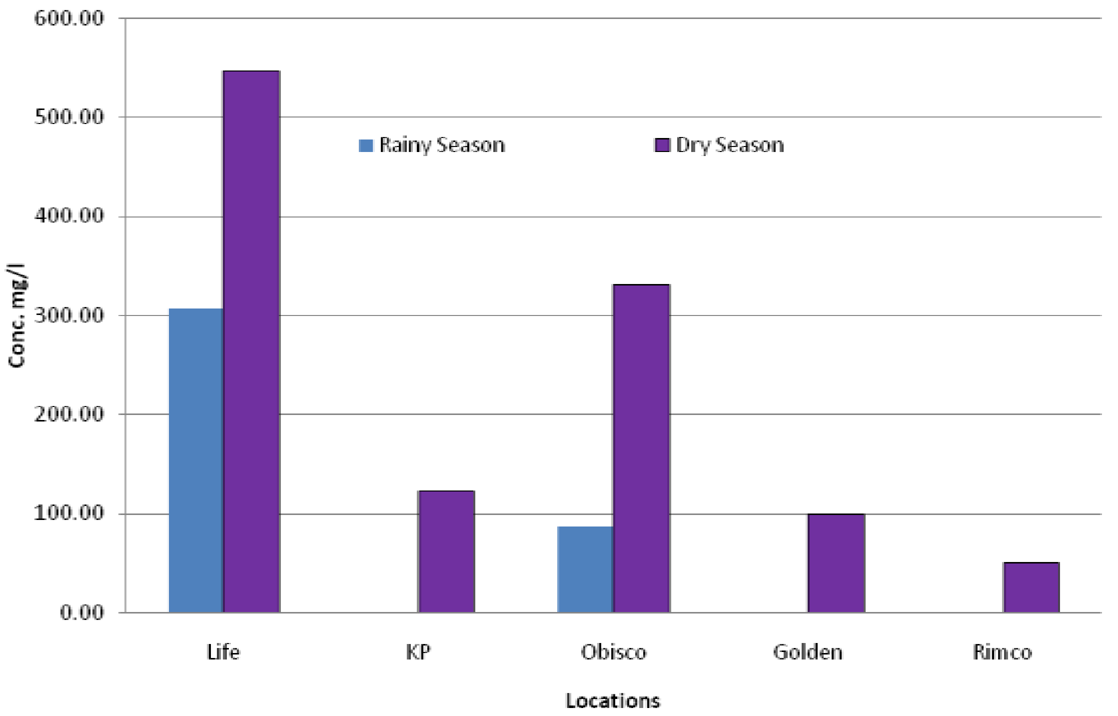


Fig. 4.18: Alkalinity levels by season and locations

The alkalinity levels were much higher in the dry season than in the rainy season (Tables 4.16 and 4.17). For instance, Life breweries recorded total mean alkalinity level of 546.667 ± 155.820mg/l in the dry season compared to the value (306.667 ± 155.82mg/l) obtained in the rainy season. Dry season alkalinity level obtained for life effluent was above the value (500mg/l) recommended by the World Health Organization (WHO), (1989) for drinking water. Alkalinity is an estimate of the ability of water to resist change in pH upon addition of acid. It is caused mainly by the presence of OH, CO_3, and HCO_3 ions. High concentration of alkalinity, especially that of sodium carbonate can give rise to taste problem.

Irrespective of the high levels of alkalinity observed in the dry season compared to the rainy season in these effluents, statistical analysis showed that there was no significant difference (P>0.05) between the two seasons as regards the alkalinity levels of the effluents. This was also the case in the level of alkalinity among the different industries investigated (Appendix 5b).

In the rainy season, Alkalinity was not detected from the effluent samples collected from Savana, KP, Golden Oil and RIMCO. It was below the detection limit of the instrument. This was against the values obtained for the alkalnity levels (BDL, 123.333 ± 110.181mg/L 100.000 ± 156.820mg/L, 50.000 ± 110.181mg/L) for the same industires in the dry season respectively.

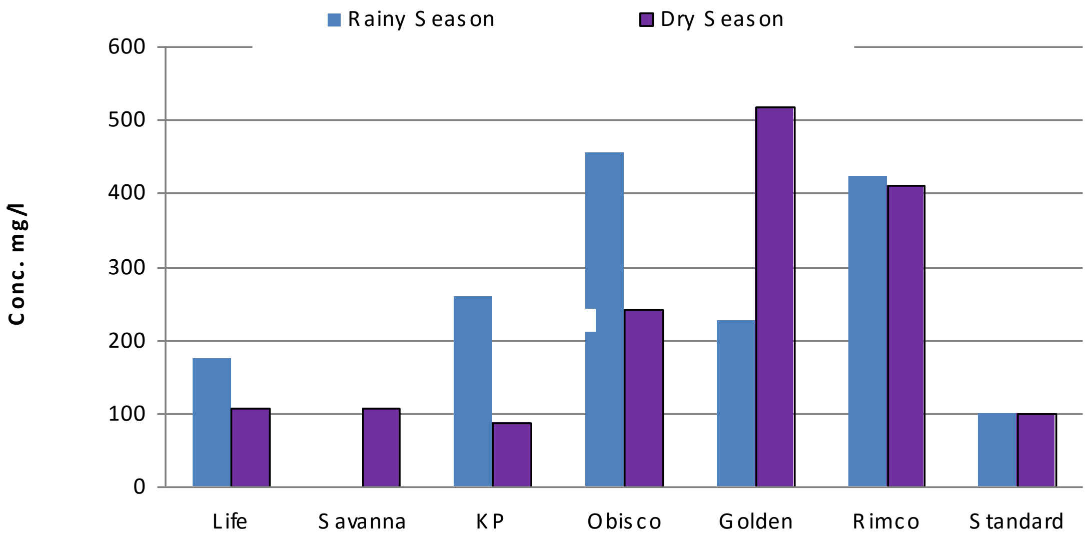


Fig. 4.19: Total Hardness levels by season and locations

Fig 4.19 showed the variation of the mean levels of hardness obtained from the effluent samples of the different food processing industries monitored in both seasons.

Hardness levels obtained in the effluent samples were relatively high in both seasons. The least value was recorded in the Savana effluents for the rainy season (BDL) while Obisco beverage, Ogidi, recorded the highest value in the same season. Values obtained in the dry season showed that KP effluents had the least value of mean hardness (87.333 ± 103.019mg/L) while Golden effluents had the highest value (516.667 ± 103.019mg/L) in the same season (Table 4.17). Apart from Savana effluents (BDL, rainy season) and KP effluents (87.333 ± 103.019mg/L, dry season), hardness levels obtained in the effluents from all other food industries studied were higher than the value (100mg/L) recommended by the Federal Ministry of Environment (FMEnv, 1991) for industrial effluent limit.

Statistically, there was no significant difference (P>0.05) in the hardness levels of the effluents between rainy and dry season. Again, hardness levels showed no significant difference in the effluent samples among the food industries apart from Life and Golden (p - value 0.009), KP and Golden (p - value 0.013), Life and RIMCO (p - value 0.000), KP and RIMCO (p - value 0.03) respectively (Appendix 5c).

Hardness is predominantly caused by cations such as calcium and magnesium. Alao *et al.*, (2010) reported that people with kidney and bladder stones should avoid high content of calcium and magnesium in water. Thus, the high level of hardness observed in these effluents would be detrimental to aquatic life and even human beings if they are discharged directly into receiving waterbody without treatment. Effort should be made by these food industries to soften their waste water before discharging them to nearby waterbody.

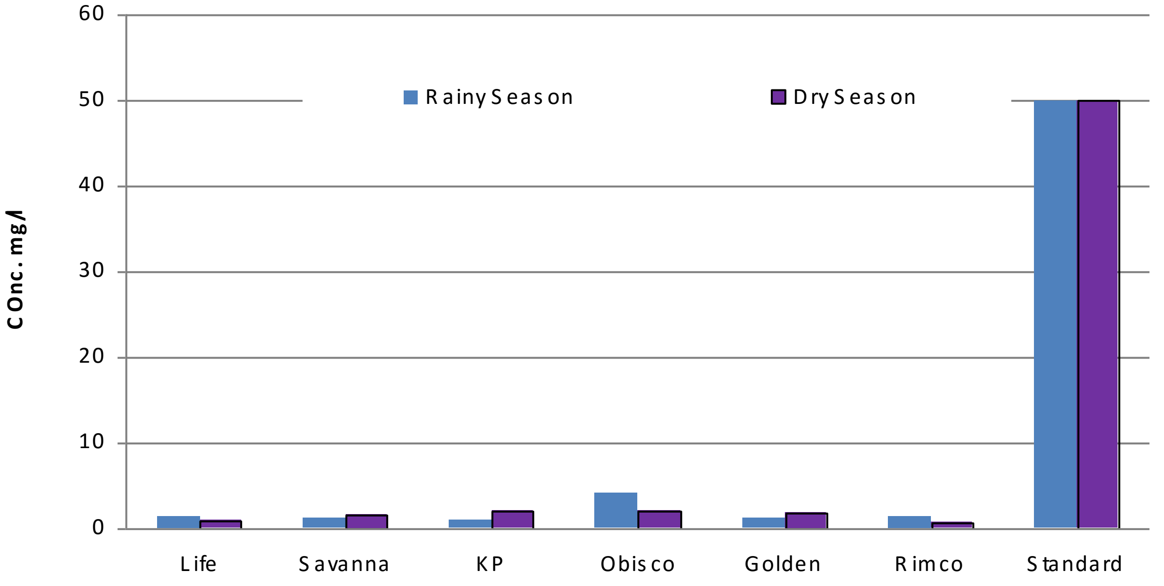


Fig. 4.20: Nitrate Content levels by season and locations

Figure 4.20 showed the Nitrate concnetrations of the different effluent samples monitored in both rainy and dry season.

Nitrate determination helps in the assessment of the character and degree of oxidation in surface waters and in biological processes (ISO, 1990). The mean concentrations of nitrate (Tables 4.16 and 4.17) obtained in the two seasons were highest in Obisco effluents (4.166 ± 0.353mg/l, rainy season) and 2.135 ± 0.353mg/L, (dry season) respectively, while the least value was obtained in RIMCO effluent in dry season and KP effluent in rainy season. Nevertheless, the mean levels of nitrate obtained in all the food industries studied were far below the allowable limit (50.00mg/l) recommended by FMEnv, (1991) for industrial effluent wastewaters to be discharged into receiving waterbody. Nitrate represents the final product of the biochemical oxidation of ammonia and if washed into the sea, leads to the growth of water hyacinth which reduces or undermines navigation on water ways. Moreover, the marine plants that use the nitrates are encouraged to grow and when they die, need a lot of oxygen for their biodegradation, this oxygen comes from water, subsequently reducing the oxygen available for the survival of aquatic organisms (Anser and Khad, 2005).

Statistical analysis showed that there was no significant difference ($P>0.05$) in the mean nitrate levels of effluent samples between rainy and dry seasons, though the industries showed significant difference ($P<0.05$) in the mean concentrations of nitrate among their waste waters. The industries that differed were life and Obisco, (p – value: 0.000) Savana and Obisco, (p – value: 0.000) KP and Obisco, (p – value: 0.000) Obisco and RIMCO, (p – value: 0.000) Obisco and Golden (p – value: 0.000) respectively (Appendix 5f).

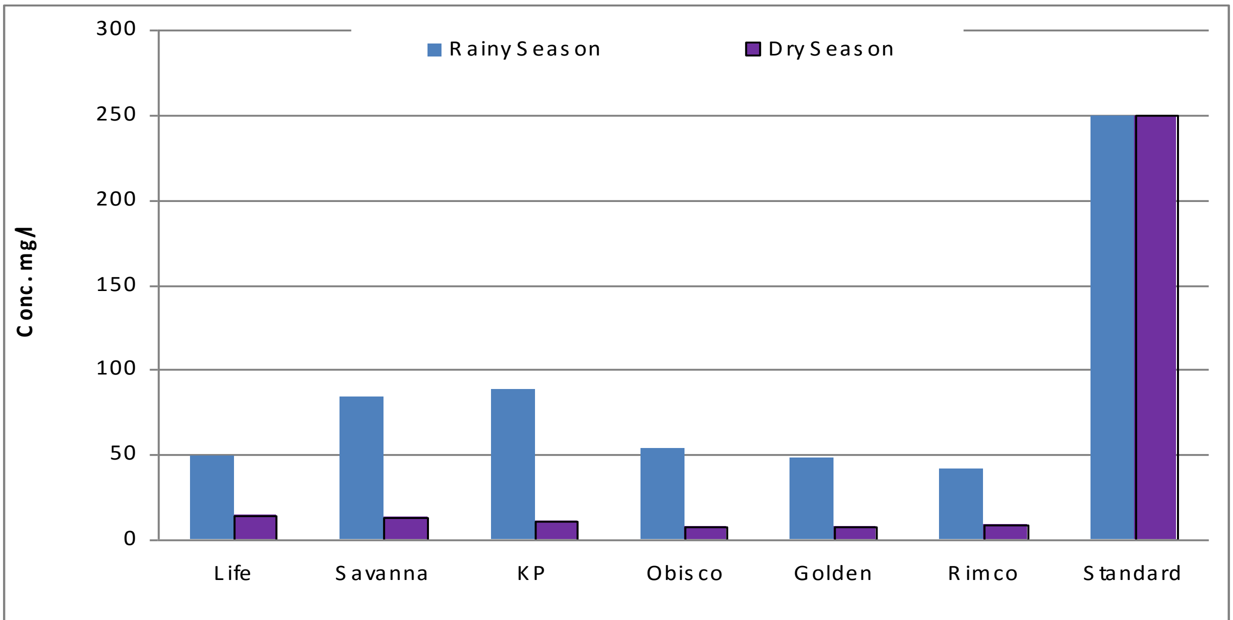


Fig. 4.21: Sulphate Content levels by season and locations

Sulphate concentrations were higher in the rainy season than dry season in all the effluent samples studied. This was in line with the findings of Phiri *et al.*, (2005). In the rainy season, sulphate levels ranged from a minimum of 41.875 + 9.346mg/L (Obisco) to a maximum of 87.917 + 9.346mg/L (KP), while in the dry season, Life breweries recorded the highest value of sulphate in its effluent and Golden, the least value in the same season (Table 4.17). Sulphate concentrations, though higher in the rainy season than in the dry season in all the effluent samples studied, were still far below the FMENV, (1991) allowable limit for industrial effluents. Nevertheless, there was significant seasonal difference ($P<0.05$) in the mean levels of sulphate in the effluent samples between rainy and dry seasons. (Appendix 5h). Sulphate levels were significantly higher in the rainy season than in the dry season probably due to run off of fertilizers from farm lands which mixed with the effluents increasing their levels in the rainy season. On the other hand, there was no significant difference ($P>0.05$) in the mean sulphate levels of effluents among the food industries, though KP differed slightly from Obisco, (p – value 0.046) Golden (p – value 0.021) and RIMCO (p – value 0.011) in the level of sulphate in its effluent samples.

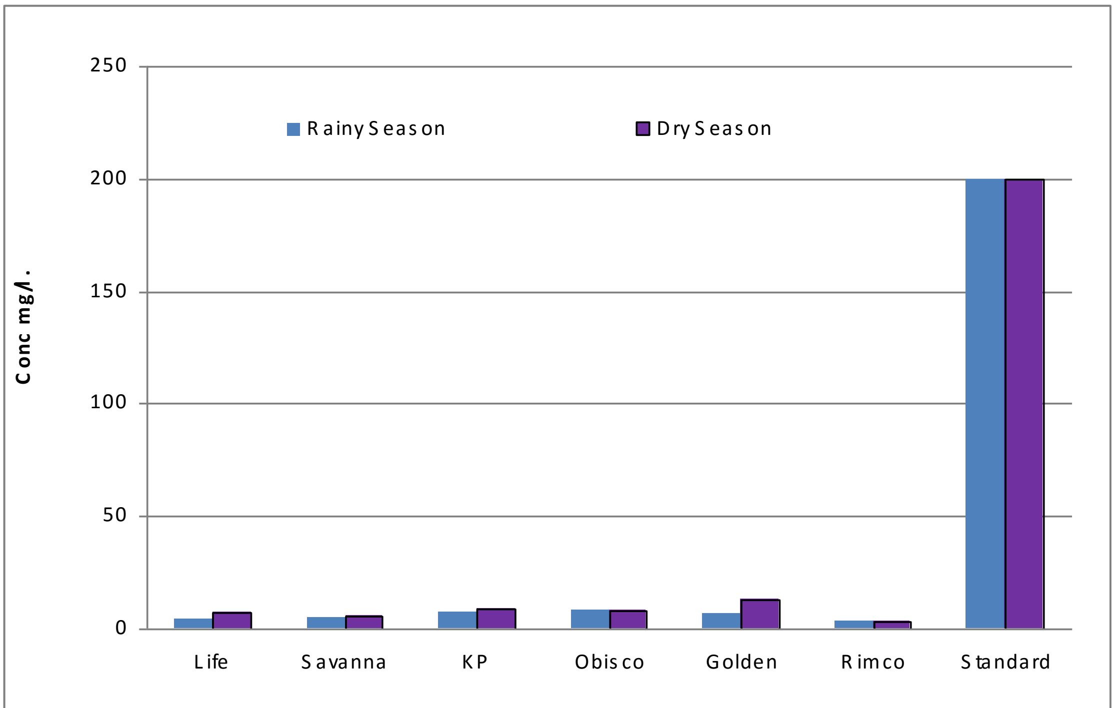


Fig. 4.22: Chloride Content levels by season and locations

Dry season mean concentrations of chloride was highest in the effluent samples from Golden and least in the effluent samples from RIMCO (Table 4.17). The highest value in the rainy season was recorded by effluent sample from Obisco while RIMCO again gave the least value of chloride in their effluent samples in the same season. With the exception of effluents from RIMCO with mean chloride concentrations of 3.313 ± 1.698mg/L, both rainy and dry seasons), other effluent recorded higher chloride concentrations in the dry season than in the rainy season.

This was in line with the findings of Fakayode, (2005) and Phiri *et al*., (2005). Mean chloride levels obtained in this work were below the FMEnv, (1991) allowable limit for industrial effluents. This confirmed that chloride composition of the effluents had little contribution to the pollution state of these industrial effluents.

Bhujangaiah and Nayak; (2005) reported that excessive chloride in potable water was not particularly harmful and the criteria set for this anion are based primarily on palatability and its potentially high corrosiveness. Chloride in excess imparts a salty taste to water and people who are not accustomed to high chlorides, according to Ram et al., (2011) might be subjected to laxative effects. APHA, (1980) also reported that a high chloride content might harm metallic pipes and structures as well as growing plants.

In as much as chloride levels obtained in this work were higher in the dry season than in the rainy season, statistical analysis showed that there was no significant difference ($P>0.05$) in the mean chloride concentrations of the effluents between rainy and dry seasons, though industries differed significantly ($P<0.05$) in the mean chloride contents of the wastewater especially between Life and Golden (p – value: 0.015); KP and RIMCO (p – value: 0.006), Obisco and RIMCO (p – value: 0.004), Golden and RIMCO (p – value: 0.000) (Appendix 5g).

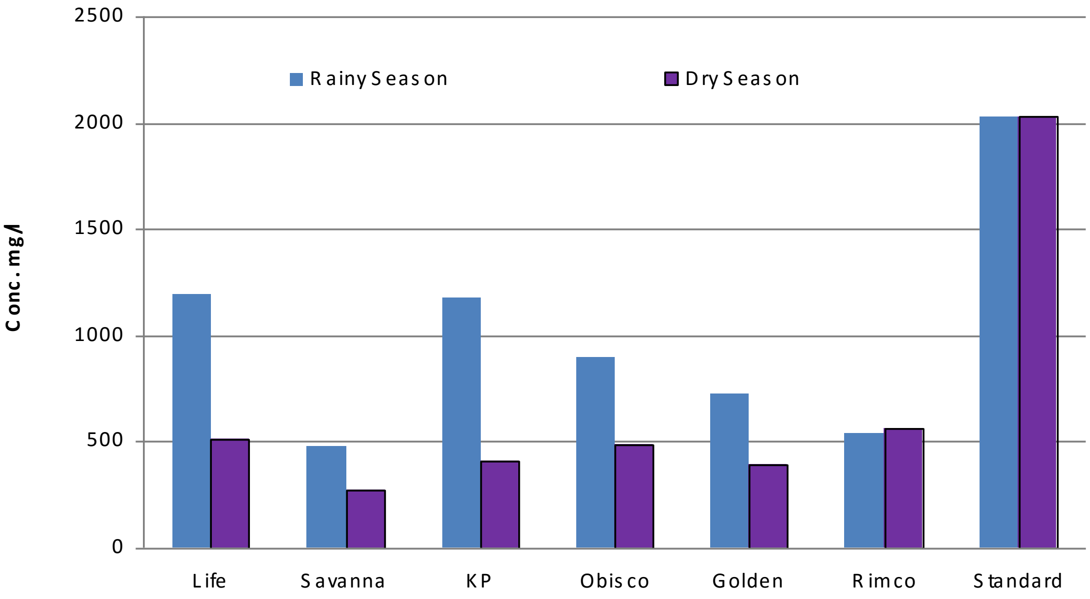


Fig. 4.23: Total Solids levels by season and locations

The total solids (TS) of the effluent from Life breweries was the highest in the rainy season, while Savana effluent recorded the least value of mean TS in the same season. In the dry season, RIMCO had the highest mean TS value while Savana again had the least value. Total solids levels were higher in the rainy season than in the dry season in the effluent samples from all the food industries investigated (Tables 4.16 and 4.17). Total solids contribute to high turbidity of water bodies into which they are discharged. In both cases, the TS contents in the effluent samples studied were below the value recommended by FMEnv, (1991), for industrial effluent limit but higher than the value (500mg/L) recommended by WHO, (1989) for drinking water.

The test of between subject effects and multiple comparison tests of the Total solids concentrations of the effluent samples from the food industries studied in rainy and dry season and also how the industries differed in the levels of total solids among their effluents were shown in Appendix 5.

The total solids concentrations in the rainy season varied significantly ($P<0.05$) from that of the dry season. There was a significant increase in the mean total solids concentration of the effluents in the rainy season compared to that of dry season. Again, the different food industries studied showed marked significant difference ($P<0.05$) in the TS level of their effluents. Variation occurred between Life and Savana (p – value: 0.002), Life and Golden (p – value: 0.005), Life and RIMCO (p – value: 0.004), Savana and KP (p – value: 0.005), Savana and Obisco (p – value: 0.034), KP and Golden (p – value: 0.026), KP and RIMCO (p – value: 0.020) respectively (Appendix 5i).

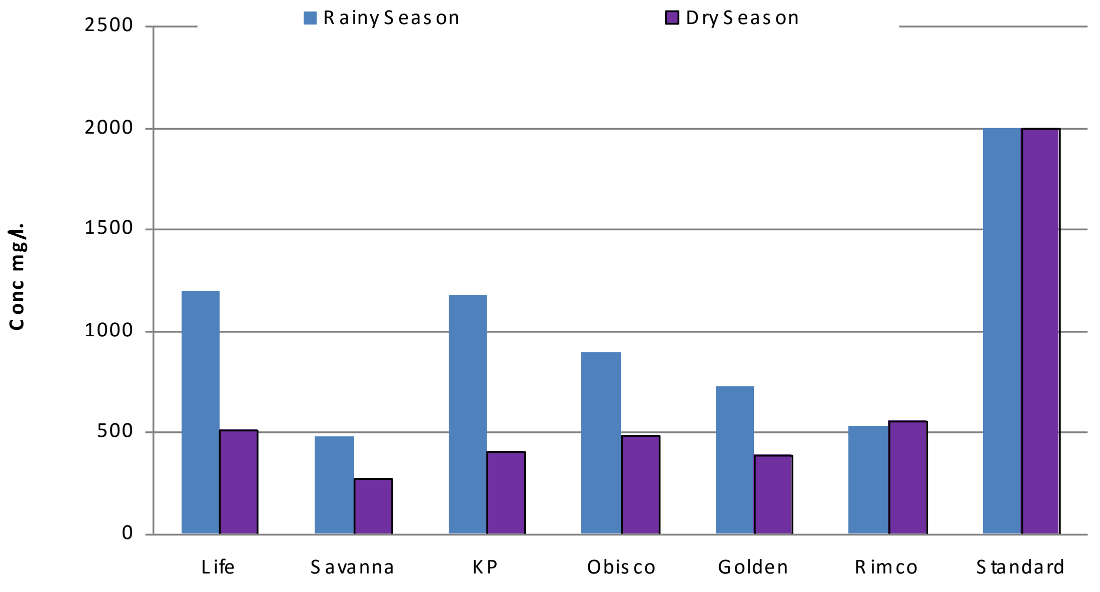


Fig. 4.24: Total Dissolved Solid levels by season and locations

The mean TDS values were higher in all the effluent samples in the rainy season than in the dry season (except RIMCO), though values obtained were lower than the FMEWV, (1991) industrial effluent limits. A low level of TDS implied that the sediments are of small size which according to Chukwu (2008) was more dangerous because the sediments could easily hamper respiration of sea animals by blocking the respiratory pores. This called for proper sedimentation process if the quality of the wastewater was to be improved since smaller sediments settled more slowly than bigger ones. A high value of TDS lead to nutrient enrichment or entrophication (Chukwu, 2008) of receiving water bodies.

There was significant difference ($P<0.05$) in the mean concentrations of TDS in the waste water samples between rainy and dry season. TDS was higher in the rainy season than in the dry season in all the effluent samples monitored. This was also the case among the various industries investigated. This difference was seen between Life and Golden, Life and RIMCO, Life and Savana, Savana and KP, Savana and Obisco, KP and Golden, KP and RIMCO respectively (Appendix 5k).

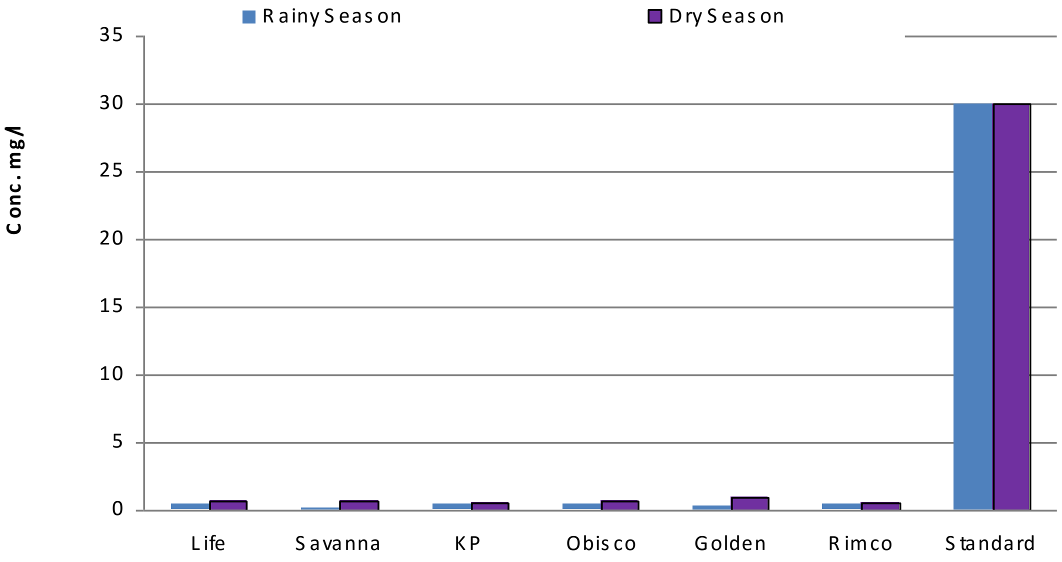


Fig. 4.25: Total Suspended Solids levels by season and locations

Total Suspended Solids (TSS) are higher in the dry season than in the rainy season in the effluent samples from all the food industries studied (Table 4.17), though values obtained were below the FMEnv, (1991) industrial effluent limit of 30.00mg/l. This was in line with the findings of Aloa et al., (2010). The low value could be explained by the fact that as the wastewater travels along the effluent pathway, they permeate the ground and the solid materials would be filtered out. Alao, *et al.*, (2010) reported that untreated effluent typically contains TSS in the range of 10 – 60mg/l, but this value was higher than values obtained for TSS in this study for all the effluent samples. Water high in suspended solids might be aesthetically unsatisfactory for bathing. Again, the effect of the presence of suspended solids is the turbidity due to silts and organic matter. Increase in turbidity could be considered a type of pollution in that it affected the biotic balance.

Statistical analysis showed that there was significant difference ($P<0.05$) in the mean concentrations of TSS of the effluent samples between rainy and dry seasons. TSS was significantly higher in the dry season than in the rainy season and was in line with the findings of Phiri, et al., (2005). Nevertheless, the level of this parameter did not differ significantly ($P>0.05$) among the different effluent samples studied.

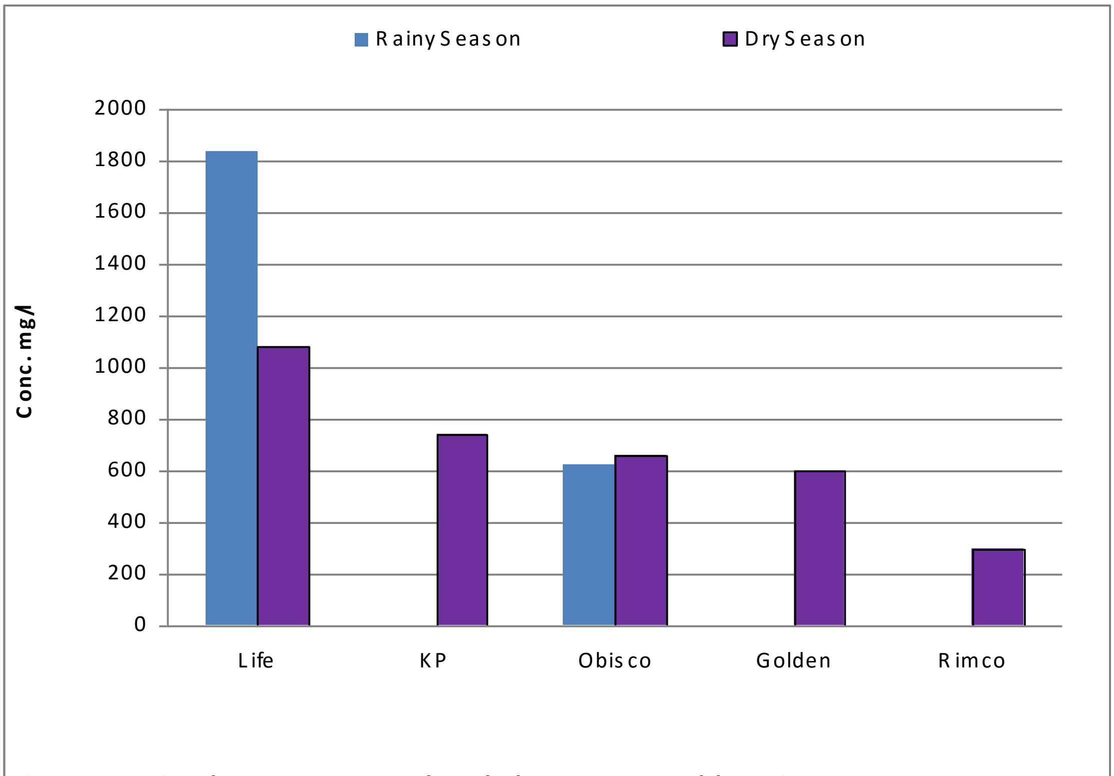


Fig:. 4.26: Bicarbonate Content levels by season and locations

Figure 4.26 showed the Bicarbonate levels of the different effluent samples from the food industries studied in both rainy and dry seasons. In the rainy season, Bicarbonate were not detected in the effluent samples from savanna, KP, Golden and RIMCO industries or rather, it was below the detection limit of the instrument. Highest concentration of Bicarbonate was recorded in the effluent sample from Life breweries, Onitsha in the rainy season. In the dry season, the levels of this parameter were high in all the effluent samples (except Savana) studied. The trend of bicarbonate content in the effluent samples in the dry season was Life > KP > Obisco > Golden > RIMCO.

Appendix 5e showed that there was no significant difference ($p > 0.05$) in the levels of Bicarbonate contents between the rainy and dry season in the effluent samples of the food industries studied. However, there was significant difference ($p < 0.05$) in the mean concentrations of this parameter among the effluent samples of the different food industries studied. This difference was recorded between the effluent samples from Life and KP (p – value: 0.024), Life and Obisco (p – value: 0.005), Life and Golden (p – value: 0.028), Life and RIMCO (p – value: 0.001).

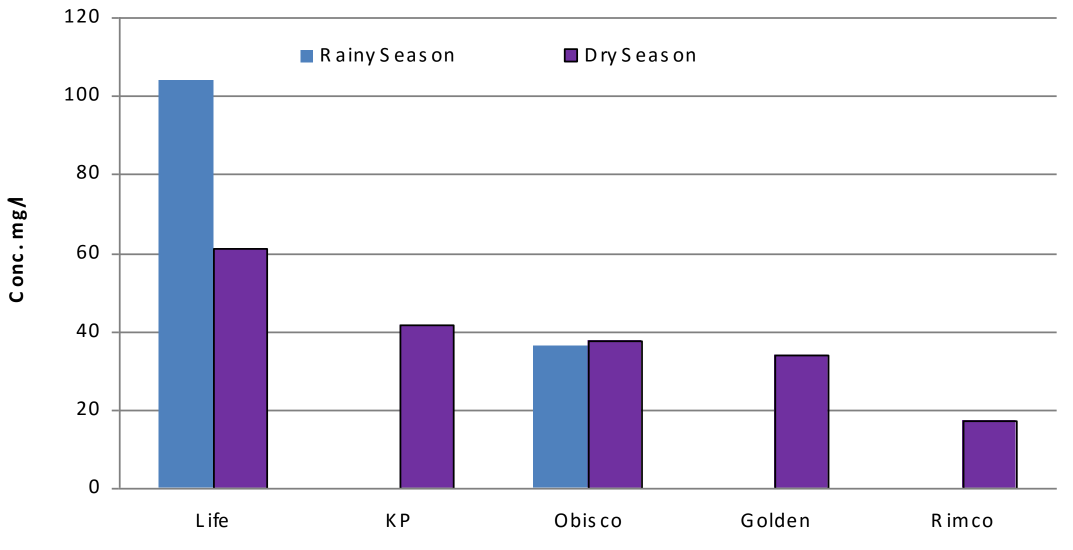


Fig. 4.27: Hydroxyl Content levels by season and locations

In Figure 4.27, Life breweries, recorded the highest mean concentrations of hydroxyl content in both seasons. This parameter was not detected in the effluent samples from Savana (Both seasons), KP, Golden and RIMCO (rainy season only). It was below the detection limit of the instrument in the rainy season. The least value of hydroxyl content was obtained in the effluent sampe from RIMCO effluent in the dry season.

The ANOVA Table (Appendix 5d) showed that the mean concentrations of Hydroxyl contents in the effluent samples did not differ singificantly ($p > 0.05$) between rainy and dry seasons. However, there was significant difference ($p<0.05$) in the levels of this parameter among the effluent samples from the different food processing industries monitored. This difference was seen between Life and KP (p – value: 0.024), Life and Obisco (p – value: 0.005), Life and Golden (p – value: 0.028), Life and RIMCO (p – value: 0.001) respectively.

The hydroxyl and bicarbonate contents of the effluent wastewaters did not differ significantly ($P>0.05$) in the two seasons, but differed highly ($P<0.05$) among the effluents from different industries studied. In both cases, differences in the concentrations of the two parameters were seen between Life and KP; Life and Obisco, Life and Golden, Life and RIMCO respectively. However, there was neither FMEnv, (1991) industrial effluent limit nor WHO standard for drinking water for these two parameters.

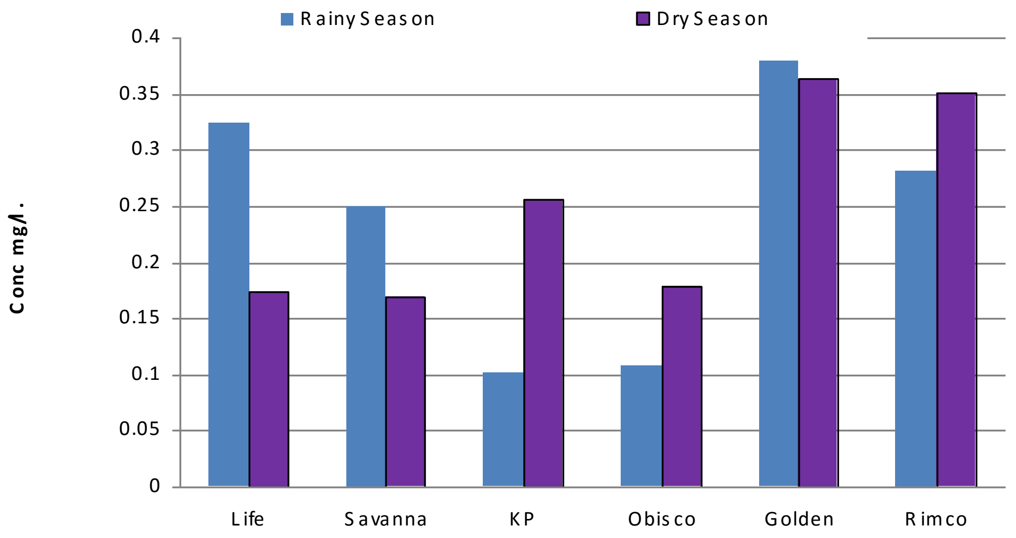


Fig. 4.28: Acidity levels by season and locations

Figure 4.28 showed that the level of Acidity in the effluent samples was highest in the effluent samples from Golden Vegetable Oil, Onitsha in both seasons. The levels of acidity in the effluent samples from Golden, Life and Savana were higher in the rainy season than the value obtained for this parameter in the dry season for the same industries. This confirmed the result of the pH levels of the effluents which were low in the rainy season than in the dry season. This increase in the levels of acidity in the rainy season in these effluent samples could be attributed to acid rain or run off of fertilizers from surrounding farm lands which mixed with the effluents in their pathways, hence reduction in pH levels and subsequent increase in the levels of acidity of these effluents.

The ANOVA Table of between subjects effects for Acidity level of the effluent samples between the rainy and dry season period was shown in Appendix 5L. From this test, it was observed that there was no significant difference ($p > 0.05$) in the levels of acidity in the effluent samples between rainy and dry seasons. Nevertheless, the multiple comparison tests showed that there was significant difference ($p < 0.05$) in the level of acidity among the effluent samples of the different food processing industries studied, especially between Life and Golden (p – value: 0.031), Savana and Golden (p – value: 0.046), KP and Golden (p – value: 0.002), KP and RIMCO (p – value: 0.025), Obisco and Golden (p – value: 0.000), Obisco and RIMCO (p – value: 0.003), Obisco and Life (p – value: 0.031) among others (Appendix 5l).

Generally, this study has shown that apart from pH and hardness levels, other parameters investigated were either within or below the standard set by the Federal Ministry of Environment for effluent composition or the World Health Organisation standard for drinking water. Although the values in some cases were lower than the allowable limits, the continued discharge of the effluents into the environment or receiving waterbodies without treatment might result in severe accumulation of the contaminants which might in turn affect the lives of the people. Thus, careless disposal/discharge of the wastes should be discouraged and if possible, there was need for industries to install a treatment plant for all the industrial wastes so that they are properly treated before being discharged into the environment.

4.6 Results of Pollution Index of the Physicochemical Parameters:

The pollution index of the physicochemical characteristics of the effluents were presented in Tables 4.18.

Table 4.18: Pollution Index of the Physicochemical Parameters of the Effluents.

Dry Season

	Alkalinity	**Total Hardness**	**TDS**	**TSS**	**TS**	**Sulphate**	**Nitrate**	**pH**	**Chloride**	**Pollution Index**
Life	306.67	173.33	1191.31	.3542	1191.67	49.50	1.43	4.58	3.73	0.49
Savanna			474.80	.2000	475.00	84.25	1.05	2.65	4.47	0.14
KP		260.00	1174.65	.3458	1175.00	87.92	1.00	5.51	7.29	0.55
Obisco	86.67	455.14	891.28	.3833	891.67	53.33	4.17	5.63	8.45	0.75
Golden		226.00	724.73	.2750	725.00	47.58	1.20	3.20	6.62	0.41
RIMCO		423.67	532.93	.4000	533.33	41.86	1.33	2.91	3.31	0.60
Rainy Season										
Life	546.67	106.93	511.82	.6750	512.50	14.25	1.00	8.08	7.12	0.44
Savanna		107.00	274.30	.7000	275.00	13.00	1.53	7.26	5.47	0.31
KP	123.33	87.33	407.77	.5667	408.33	10.79	2.05	6.60	8.78	0.29
Obisco	331.11	242.73	486.03	.7250	487.50	8.08	2.14	6.02	8.12	0.51
Golden	100.00	516.67	389.93	.9000	390.83	7.50	1.90	4.82	12.60	0.73
RIMCO	50.00	410.83	558.60	.5667	559.17	8.46	0.68	5.03	3.31	0.62
Total										
Life	426.67	120.21	851.57	.5146	852.08	31.88	1.22	6.33	5.43	0.44
Savanna		107.00	374.55	.4500	375.00	48.63	1.29	4.96	4.97	0.30
KP	123.33	161.33	791.21	.4563	791.67	49.35	1.53	6.05	8.03	0.42
Obisco	270.00	320.99	688.65	.5542	689.58	30.71	3.15	5.82	8.28	0.61
Golden	100.00	475.14	557.33	.5875	557.92	27.54	1.55	4.01	9.61	0.70
RIMCO	50.00	415.11	545.77	.4833	546.25	25.17	1.01	3.97	3.31	0.61

Pollution index (Pi) showed the relative pollution contributed by each physicochemical parameters. Pollution index of more than one (1.000) showed that the average concentration of each of the physico-chemical parameters were above the allowable limits, while indics less than one (<1.000) indicated no pollution from the said parameters.

Table 4.18 showed the pollution index of the physicochemical parameters of the effluents. In the rainy season, result of the index showed that Golden effluent had the highest pollution index (0.73368) while the least index was recorded by KP effluent (0.2905) in the same season. Similarly, it was observed that Obisco effluent sample had the highest index value (0.7516) in the dry season and Savana effluent the least value in the same season (Table 4.18).

Values of the pollution index obtained in both seasons showed that the highest index was recorded by Golden effluent (0.6984), while Savana effluent was the least polluted in terms of the physicochemical parameters monitored (Table 4.18). The trend of pollution from the physicochemical parameters of the effluents investigated was Golden > RIMCO > Obisco > Life > KP > Savana. This trend, not withstanding, values obtained for the pollution index of the physicochemical parameters of all the effluent samples monitored were less than one (<1.000).

This showed that the physicochemical parameters of the effluents contributed little to the pollution profile of the effluents in all the food processing industries monitored since index values obtained were less than one (Table 4.18). Nevertheless, the continued discharge of the effluents in the environment might result in severe accumulation of these pollutants into toxic levels that might affect crop yield, aquatic ecosystem and human health.

4.7 Microbial Results

The result of the presumptive coliform count of the effluent samples for both rainy and dry seasons are shown in Table 4.19 while the Most Probable Number (MPN) of organisms are presented in Tables 4.20 – 4.22 (rainy season) and 4.23 – 4.25 (dry season).

Table 4.19: Presumptive Test Results of Effluent Samples in both Seasons

		Rainy Season				Dry Season					
		Volume of Effluents Used				Volume of Effluents Used					
Food Industry	**Point of Collection of Effluent**	**10ml**	**1ml**	**0.1ml**	**Probable Number of Coliform Bacilli in 100ml of Effluent**	**10ml**	**1ml**	**0.1ml**	**Probable Number of Coliform Bacilli in 100ml of Effluent**	**FMENV, 1991 Effluent Limit**	**WHO Limit in Drinking Water**
Life Breweries Onitsha	P_1	4/5	3/5	2/5	50	3/5	1/5	2/5	26	Daily Average of 500MPN in 100ml of Effluent	Less than 3MPN in 100ml of Water
	$P_{2\&3}$	4/5	3/5	2/5	113	4/5	3/5	2/5	54		
Savana	P_1	4/5	2/5	2/5	65	3/5	2/5	2/5	26		
Kp Beverages Ogidi	P_1	4/5	2/5	2/5	31	3/5	2/5	2/5	25		
	$P_{2\&3}$	4/5	3/5	2/5	78	4/5	1/5	1/5	61		
Obisco Beverages Ogidi	P_1	5/5	2/5	2/5	100	4/5	1/5	2/5	23		
	$P_{2\&3}$	2/5	2/5	3/5	132	4/5	2/5	2/5	51		
Golden Oil Onitsha	P_1	5/5	1/5	1/5	73	4/5	2/5	1/5	36		
	$P_{2\&3}$	5/5	2/5	2/5	117	4/5	1/5	2/5	22		
RIMCO Nnewi	P_1	4/5	2/5	2/5	62	3/5	2/5	2/5	26		
	$P_{2\&3}$	5/5	2/5	2/5	93	4/5	3/5	2/5	43		

NB: The numerators are the number of tubes with positive organisms while the denominators showed the number of inoculated tubes.

Table 4.19 shows the presumptive test results of the effluent samples in both seasons with the different points of collection of the effluents. Usually, the result obtained from presumptive test determines whether the rest of the examination will be carried out or not (differential and confirmatory/completed tests). The numerators in Table 4.19 showed the positive tubes while the denominators indicated the number of inoculated tubes. From the Table, it was observed that all the effluent samples from food industries studied showed positive presumptive test in both rainy and dry season respectively. This was as a result of the presence of lactose fermenting organisms in these effluent samples. The rainy season counts were higher than that of dry season at all the points.

The highest probable number of coliform organisms was obtained in the effluent sample from Obisco beverage, Ogidi (rainy season) at P_2 and P_3 (132MPN) while the least probable number of coliform organisms was recorded in the effluent sample from KP beverages, Ogidi (P_1) (31 MPN) (Table 4.19).

Though the Most Probable Number (MPN) of coliform organisms were higher in the rainy season than in the dry season in all the effluent samples monitored, these values were still below the limit (500MPN) allowed by the Federal Ministry of Environment (FMEnv), (1991) in industrial effluent to be discharged into receiving water body but higher than the standard set by the World Health Organization (1989) in drinking water.

Samples that showed positive presumptive test were tested for the presence of *Escherichia coli*. The pure cultures of the bacterial isolates were subjected to various morphological and biochemical characterization tests to determine the identity of the bacteria isolates.

Table 4.20: Differential/Confirmatory Test Result of Effluents for Rainy Season

Food Industry	Test Performed	Vol. of Effluents Used			Gram staining Reaction	Growth in EMBA	Growth in Nutrient Agar	Suspected Organisms	MPN Index Organism
		10ml	Iml	0.Iml					
Life Brew (PI) Onitsha	Growth in BGB Broth	0/5	0/5	0/5	1. Gram –ve non-sporing rods. 2. Gram +ve sporing large rods, straight or curved.	Large brown centered colonies mucoid, gummy & pinkish appearance.	Round, 3-5mm in diam, raised, dull, grayish white opaque colonies with entire edge and finely granular surface.	1. *Enterobacter aerogenes* 2. *Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	3/5	3/5	2/5					
	Citrate Utilization Test	3/5	3/5	2/5					
	Catalase Test.	5/5	5/5	5/5					
P2&3	Growth in BGB Broth	0/5	0/5	0/5	1. Gram –ve non-sporing rods. 2. Gram +ve sporing large rods, straight or curved.	Large brown centered colonies mucoid, gummy & pinkish appearance.	Round, 3-5mm in diam, raised, dull, grayish white opaque colonies with entire edge and finely granular surface.	1. *Enterobacter aerogenes* 2. *Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	4/5	3/5					
	Citrate Utilization Test	3/5	3/5	2/5					
	Catalase Test.	4/5	4/5	3/5					
Savana P_I	Growth in BGB Broth	4/5	3/5	2/5	1. Gram –ve non-sporing rods. 2. Gram +ve sporing large rods, straight or curved.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3-5mm in diam, raised, dull, grayish white opaque colonies with entire edge and finely granular surface.	1. *E. coli* 2. *Bacillus cereus*	33
	Indole at 44°c	4/5	3/5	2/5					
	Methyl Red Test	3/5	2/5	2/5					
	Voges-Proskaur Test	2/5	3/5	3/5					
	Citrate Utilization Test	2/5	3/5	3/5					
	Catalase Test.	5/5	5/5	5/5					

Note: -ve = Negative, +ve = Positive

Numerator: Number of tubes with positive organisms Denominator: Number of negative tubes

P_1: Point of discharge of effluents P_2: 15 meters away from point of discharge

P_3 = 30 meters away from point of discharge.

Table 4.20 shows the differential/confirmatory test results of the effluents from Life and Savana for rainy season count period. It was observed from the Table that after subjecting the positive tubes (from the presumptive tests) to various morphological and biochemical characterization tests, that Life effluents at different points of discharge showed no evidence of coliform organism while effluent from Savana recorded 33 Most Probable Number (33MPN/100mg) of *Escherichia coli* organisms. This count from Savana effluent was lower than the value (500 MPN/100ml) recommended by the Federal Ministry of Environment (FMEnv), (1991) for industrial effluent.

The presence of *E.coli* in Savana effluent showed that the effluent was contaminated with feacal matter which could lead to water borne diseases if the water bodies used as dumping site are used for drinking purposes or for cooking among others.

Table 4.21: Differential/Confirmatory Test Result of Effluents for Rainy Season

Food Industry	**Test Performed**	**Vol. of Effluents Used**			**Gram staining Reaction**	**Growth in EMBA**	**Growth in Nutrient Agar**	**Suspected Organisms**	**MPN Index Organism**
		10ml	**1ml**	**0.1ml**					
KP Beverage Ogidi (P_1)	Growth in BGB Broth	3/5	2/5	1/5	1. Gram –ve non-sporing rods. 2. Gram +ve sporing large rods, straight or curved.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3-5mm in diam, raised, dull, grayish white opaque colonies with entire edge and finely granular surface.	1. *E. coli* 2. *Bacillus cereus*	9
	Indole at 44°c	3/5	2/5	1/5					
	Methyl Red Test	3/5	2/5	1/5					
	Voges-Proskaur Test	2/5	3/5	4/5					
	Citrate Utilization Test	2/5	3/5	4/5					
	Catalase Test.	5/5	5/5	5/5					
P2&3	Growth in BGB Broth	4/5	2/5	2/5	1. Gram –ve non-sporing rods. 2. Gram +ve sporing large rods, straight or curved.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3-5mm in diam, raised, dull, grayish white opaque colonies with entire edge and finely granular surface.	1. *E. coli* 2. *Bacillus cereus*	17
	Indole at 44°c	4/5	2/5	2/5					
	Methyl Red Test	4/5	2/5	2/5					
	Voges-Proskaur Test	1/5	3/5	3/5					
	Citrate Utilization Test	1/5	3/5	3/5					
	Catalase Test.	5/5	5/5	5/5					
Obisco Beverage Ogidi (P_I)	Growth in BGB Broth	3/5	2/5	2/5	1. Gram –ve non-sporing rods. 2. Gram +ve sporing large rods, straight or curved.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3-5mm in diam, raised, dull, grayish white opaque colonies with entire edge and finely granular surface.	1. *E. coli* 2. *Bacillus cereus*	22
	Indole at 44°c	3/5	2/5	2/5					
	Methyl Red Test	3/5	2/5	2/5					
	Voges-Proskaur Test	2/5	3/5	3/5					
	Citrate Utilization Test	2/5	3/5	3/5					
	Catalase Test.	5/5	5/5	5/5					
P2&3	Growth in BGB Broth	4/5	2/5	2/5	1. Gram –ve non-sporing rods. 2. Gram +ve sporing large rods, straight or curved.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3-5mm in diam, raised, dull, grayish white opaque colonies with entire edge and finely granular surface.	1. *E. coli* 2. *Bacillus cereus*	30
	Indole at 44°c	4/5	2/5	2/5					
	Methyl Red Test	4/5	2/5	2/5					
	Voges-Proskaur Test	1/5	3/5	3/5					
	Citrate Utilization Test	1/5	3/5	3/5					
	Catalase Test.	5/5	5/5	5/5					

Note: -ve = Negative, +ve = Positive
Numerator: Number of tubes with positive organisms Denominator: Number of negative tubes
P_1: Point of discharge of effluents P_2: 15 meters away from point of discharge P_3 = 30 meters away from point of discharge.

Table 4.21 shows that Kingsize Pharmaceutical (KP) effluent recorded 9MPN/100ml of *Esherichia coli* organism at the point of discharge of the effluent (P_1) in the rainy season compared to the count obtained at P_2 and P_3 (17MPN/100ml) in the same season. In the case of Obisco effluent sample, it was also observed that high count of *E coli* organism was recorded at P_2 and P_3 (30MPN/100ml) compared to the number obtained at the point of discharge of the effluent P_1(22MPN/100ml). This showed that *E. coli* accumulation was higher at P_2 and P_3 than the counts obtained at P_1 from the two effluent samples.

The higher counts obtained from the effluent samples at P_2 and P_3 compared to P_1 could be as a result of flow velocity factor and consequently boundary effects which hindered further movement of the organisms in the effluents at P_2 and P_3, thus increasing their concentrations at P_2 and P_3 compared to the count obtained at P_1.

Table 4.22: Differential/Confirmatory Test Result of Effluents for Rainy Season

Food Industry	Test Performed	Vol. of Effluents Used			Gram staining Reaction	Growth in EMBA	Growth in Nutrient Agar	Suspected Organisms	MPN Index Organism
		10ml	1ml	0.1ml					
Golden Oil Onitsha P_I	Growth in BGB Broth	0/5	0/5	0/5	Gram +ve sporing large rods, straight or curved		Round, 3-5mm in diam, raised, dull, grayish white opaque colonies with entire edge and finely granular surface.	*Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	3/5	3/5					
	Citrate Utilization Test	0/5	0/5	0/5					
	Catalase Test.	4/5	5/5	3/5					
P2&3	Growth in BGB Broth	0/5	0/5	0/5	Gram +ve sporing large rods, straight or curved		Round, 3 – 5mm in diameter raised, dull grayish white opaque colonies with entire edge and finely granulas surface.	*Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	3/5	3/5					
	Citrate Utilization Test	0/5	0/5	0/5					
	Catalase Test.	4/5	3/5	2/5					
RIMCO P_I Nnewi	Growth in BGB Broth	0/5	0/5	0/5	1. Gram –ve non-sporing rods. 2. Gram +v sporing large rods, straight or curved.	Large, brown centered colonies, mucoid, gummy & pinkish in appearance.	Same As Above.	1.*Enterobacter aerogenes* 2. *Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	3/5	2/5					
	Citrate Utilization Test	4/5	3/5	2/5					
	Catalase Test.	3/5	2/5	4/5					
RIMCO P2&3 Nnewi	Growth in BGB Broth	0/5	0/5	0/5	1. Gram –ve non-sporing rods. 2. Gram +v sporing large rods, straight or curved.	Large, brown centered colonies, mucoid, gummy & pinkish in appearance.	Same As Above.	1.*Enterobacter aerogenes* 2. *Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	3/5	4/5					
	Citrate Utilization Test	4/5	3/5	3/5					
	Catalase Test.	5/5	5/5	5/5					

Note: -ve = Negative, +ve = Positive

Numerator: Number of tubes with positive organisms Denominator: Number of negative tubes

P_1: Point of discharge of effluents P_2: 15 meters away from point of discharge

P_3 = 30 meters away from point of discharge.

The differential/confirmatory test results of the effluents from Golden vegetable oil, Onitsha and Resource Improvement and Manufacturing Company (RIMCO) in the rainy season was presented in Table 4.22. From the Table, it was observed that there was no evidence of *Esherichia coli (E. coli)* organism in the effluent samples from both food industries at the various points of collection in the rainy season. However, other organisms that were isolated are *Bacillus cereus* and *Enterobacter aerogenes*. This showed that contamination of the effluents from these two industries was primarily from the surrounding soil and vegetation since *E.coli* was not detected whose presence indicate feacal matter contamination.

Table 4.23: Differential/Confirmatory Test Result of Effluents for Dry Season

Food Industry	Test Performed	Vol. of Effluents Used			Gram staining Reaction	Growth in EMBA	Growth in Nutrient Agar	Suspected Organisms	MPN Index Organism
		10ml	Iml	0.Iml					
Life Brew Onitsha (P_I)	Growth in BGB Broth	0/5	0/5	0/5	1. Gram +ve sporing large rods, straight or curved. 2. Gram –ve non-sporing rods.	Large brown centered colonies mucoid, gummy & pinkish in appearance.	Round, 3-5mm in diam, raised, dull opaque colonies with entire edge and finely granular surface.	1. *Enterobacter aerogenes* 2. *Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	4/5	3/5					
	Citrate Utilization Test	4/5	4/5	3/5					
	Catalase Test.	5/5	5/5	5/5					
P2&3	Growth in BGB Broth	0/5	0/5	0/5	1. Gram +ve sporing large rods, straight or curved. 2. Gram –ve non-sporing rods.	Large brown centered colonies mucoid, gummy & pinkish in appearance.	Round, 3-5mm in diam, raised, dull opaque colonies with entire edge and finely granular surface.	1. *Enterobacter aerogenes* 2. *Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	4/5	3/5					
	Citrate Utilization Test	4/5	4/5	3/5					
	Catalase Test.	5/5	5/5	5/5					
Savana P_I	Growth in BGB Broth	0/5	0/5	0/5	1. Gram +ve sporing large rods, straight or curved. 2. Gram –ve non-sporing rods.	Large brown centered colonies mucoid, gummy & pinkish in appearance.	Round, 3-5mm in diam, raised, dull opaque colonies with entire edge and finely granular surface.	1. *Enterobacter aerogenes* 2. *Bacillus cereus*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	4/5	3/5					
	Citrate Utilization Test	4/5	3/5	3/5					
	Catalase Test.	5/5	5/5	5/5					

Note: -ve = Negative, +ve = Positive

Numerator: Number of tubes with positive organisms

Denominator: Number of negative tubes

P_1: Point of discharge of effluents

P_2: 15 meters away from point of discharge

P_3 = 30 meters away from point of discharge.

Table 4.23 shows the result of the differential/confirmatory test of effluent samples from life Breweries and Savana drink in the dry season. It was observed from the Table that there was no evidence of *E.coli* organism in the effluent sample from life Breweries at all the points of collection of the effluents. This was also the case in the rainy season (Table 4.20) at the points of collection of the effluent. However, Savana effluent samples with MPN count of 33 in the rainy season (Table 4.20) was observed to show no evidence of *E. coli* count in the dry season. This could be as a result of high humidity observed during the rainy season which favoured the growth and reproduction of these micro organisms in the rainy season than in the dry season.

Table 4.24: Differential/Confirmatory Test Result of Effluents for Dry Season

Food Industry	Test Performed	Vol. of Effluents Used			Gram staining Reaction	Growth in EMBA	Growth in Nutrient Agar	Suspected Organisms	MPN Index Organism
		10ml	1ml	0.1ml					
KP Beverages Ogidi P_I	Growth in BGB Broth	0/5	0/5	0/5	1. Gram –ve non- sporing rods 2. Gram +ve sporing large rods straight or curved.	Large brown centered colonies mucoid, gummy & pinkish in appearance.	Round, 3-5mm in diam, raised, dull opaque colonies with entire edge and finely granular surface.	1. *Bacillus cereus* 2. *Enterobacter Aerogenes*	
	Indoleatf 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	4/5	3/5					
	Citrate Utilization Test	4/5	3/5	4/5					
	Catalase Test.	5/5	5/5	5/5					
P2&3	Growth in BGB Broth	0/5	0/5	0/5	1. Gram –ve non- sporing rods 2. Gram +ve sporing large rods straight or curved.	Large brown centered colonies mucoid, gummy & pinkish in appearance.	Round, 3-5mm in diam, raised, dull opaque colonies with entire edge and finely granular surface.	1. *Bacillus cereus* 2. *Enterobacter Aerogenes*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	4/5	4/5					
	Citrate Utilization Test	4/5	4/5	3/5					
	Catalase Test.	5/5	5/5	5/5					
Obisco Beverages Ogidi (P_I)	Growth in BGB Broth	3/5	2/5	2/5	1. Gram –ve non-sporing rods. 2. Gram +v sporing large rods, straight or curved.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3 – 5mm in diameter raised, dull grayish white opaque colonies with entire edge and finely granular surface.	*1. E. coli.* 2. *Bacillus cercus*	20
	Indole at 44°c	3/5	2/5	2/5					
	Methyl Red Test	3/5	2/5	2/5					
	Voges-Proskaur Test	2/5	3/5	3/5					
	Citrate Utilization Test	2/5	3/5	3/5					
	Catalase Test.	5/5	5/5	5/5					
P2&3	Growth in BGB Broth	4/5	2/5	2/5	1. Gram –ve non-sporing rods. 2. Gram +v sporing large rods, straight or curved.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3 – 5mm in diameter raised, dull grayish white opaque colonies with entire edge and finely granular surface.	1. *E. coli* 2. *Bacillus cereus*	30
	Indole at 44°c	4/5	2/5	2/5					
	Methyl Red Test	4/5	2/5	2/5					
	Voges-Proskaur Test	1/5	3/5	3/5					
	Citrate Utilization Test	1/5	3/5	3/5					
	Catalase Test.	5/5	5/5	5/5					

Note: -ve = Negative, +ve = Positive

Numerator: Number of tubes with positive organisms Denominator: Number of negative tubes

P_1: Point of discharge of effluents P_2: 15 meters away from point of discharge

P_3 = 30 meters away from point of discharge.

The differential/confirmatory results of the effluents from KP and Obisco beverages Ogidi in the dry season was presented in Table 4.24. The Table showed that KP effluent had no evidence of *E. coli* organism at the different points of collection in this season unlike what was obtained in the rainy season (Table 4.21). Higher counts of *E. coli* organisms in the rainy season compared to the dry season could be as a result of the explanation offered in Table 4.23 for effluent sample from Savana drink, Onitsha.

Nevertheless, the effluent sample from Obisco beverage, Ogidi had 20 cells/100ml of *E. coli* organism at P_1 compared to 22 Cells/100ml obtained in the rainy season at the same point. This showed a reduction in the number of *E. coli* organism from the point of discharge of the effluent from 22cells in the rainy season to 20 cells in the dry season probably because of reduction in atmospheric humidity observed in the dry season.

Table 4.25: Differential /Confirmatory Test Result of Effluents for Dry Season

Food Industry	Test Performed	Vol. of Effluents Used			Gram staining Reaction	Growth in EMBA	Growth in Nutrient Agar	Suspected Organisms	MPN Index Org
		10ml	1ml	0.1ml					
Golden Vegetable Oil Osha (P_I)	Growth in BGB Broth	3/5	2/5	1/5	1. Gram –ve non-sporing rods.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3 – 5mm in diameter raised, dull grayish white opaque colonies with entire edge and finely granular surface.	1. *E. coli*	17
	Indole at 44°c	3/5	2/5	1/5					
	Methyl Red Test	3/5	2/5	1/5				2. *Bacillus cereus*	
	Voges-Proskaur Test	2/5	3/5	4/5	2. Gram +v sporing large rods, straight or curved.				
	Citrate Utilization Test	2/5	3/5	4/5					
	Catalase Test.	5/5	5/5	5/5					
P2&3	Growth in BGB Broth	4/5	3/5	1/5	1. Gram –ve non-sporing rods.	Large, dark-centered colonies with metallic sheen in reflected light.	Round, 3 – 5mm in diameter raised, dull grayish white opaque colonies with entire edge and finely granular surface.	1. *E. coli*	35
	Indole at 44°c	4/5	3/5	1/5					
	Methyl Red Test	4/5	3/5	1/5					
	Voges-Proskaur Test	1/5	2/5	4/5	2. Gram +v sporing large rods, straight or curved.			2. *Bacillus cereus*	
	Citrate Utilization Test	1/5	2/5	4/5					
	Catalase Test.	5/5	5/5	5/5					
RIMCO Nnewi (P_I)	Growth in BGB Broth	0/5	0/5	0/5	1. Gram –ve non-sporing rods.	Large, brown centered colonies, mucoid, gummy & pinkish in appearance.	Same As Above.	1.*Enterobacter aerogenes*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	4/5	3/5	2. Gram +v sporing large rods, straight or curved.			2. *Bacillus cereus*	
	Citrate Utilization Test	4/5	4/5	4/5					
	Catalase Test.	5/5	5/5	5/5					
RIMCO Nnewi (P2&3)	Growth in BGB Broth	0/5	0/5	0/5	1. Gram –ve non-sporing rods.	Large, brown centered colonies, mucoid, gummy & pinkish in appearance.	Same As Above.	1.*Enterobacter aerogenes*	
	Indole at 44°c	0/5	0/5	0/5					
	Methyl Red Test	0/5	0/5	0/5					
	Voges-Proskaur Test	4/5	4/5	3/5	2. Gram +v sporing large rods, straight or curved.			2. *Bacillus cereus*	
	Citrate Utilization Test	4/5	4/5	4/5					
	Catalase Test.	5/5	5/5	5/5					

Note: -ve = Negative, +ve = Positive

Numerator: Number of tubes with positive organisms Denominator: Number of negative tubes

P_1: Point of discharge of effluents P_2: 15 meters away from point of discharge P_3 = 30 meters away from point of discharge.

Table 4.25 shows the confirmatory test results of the effluent samples from Golden and RIMCO in the dry season. The Table showed that Golden effluent without *E. coli* count in the rainy season, recorded *E. coli* organism of 17MPN/100ml at the point of discharge (P_1) of the effluent and 35MPN/100ml of *E. coli* organism at P_2 and P_3. In the case of RIMCO effluent sample, no evidence of *E. coli* organism was observed as was the case in the rainy season though other coliforms like *Enterobacter aerogens* and *Bacillus cereus* were isolated.

Nevertheless, counts of *E. coli* organisms obtained from these effluents were lower than the value (500MPN/100ml) recommended by FMEnv, (1991) for industrial effluent limit though higher than the standard set by the World Health Organization (WHO), (1989) for drinking water.

The presence of *E. coli* generally suggests that the effluents might have been contaminated with feaces either of human or animal origin. This was in line with the findings of Banwo, (2006) who reported that the presence of bushes around the industries might have resulted in animals roaming about these industries at night to drink from wastewaters thereby passing out feaces on the process. Moreover, Benka-Coker and Ojior, (1995) associated human health with the possibility of accumulation of enteric microorganisms by aquatic organisms. Thus, the presence of coliform organisms, especially *Escherichia coli* might be deleterious to humans if effluents from these industries are discharged into a body of water without treatment. Coliform accumulation or build up was greater at points 2 and 3 (Tables 4.20 and 4.21) than point 1. This could be as a result of flow velocity factors which was expected to be lower at points 2 and 3 than point 1 as a result of boundary effect. Thus, the higher the flow velocity factor, the less the accumulation of the organisms. Organisms isolated from the effluent samples in both rainy and dry seasons are *Escherichia coli, Bacillus* *cereus* and *Enterobacter aerogens*. The presence of these micro-organisms (coliforms) in the effluents of the food processing industries studied could lead to risk of waterborne diseases if discharged into receiving water bodies without proper treatment. Such water borne diseases include hepatitis, cholera, typhoid, diarrhea and stomach cramps among others.

4.8 Result of the Organic Pollutants

The result of the organic pollutants identified by the GC – MS analysis were shown in Tables 4.26 – 4.41 while the GC – MS spectra of the effluents were presented in appendix 6.

Table 4.26: Organic Pollutants by GC – MS in Effluent from Life Breweries, Onitsha (P_1)

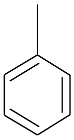
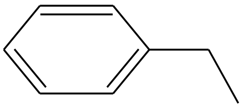
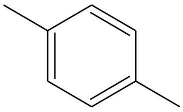
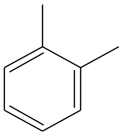
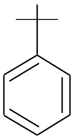
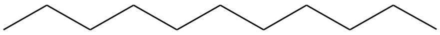
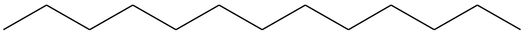
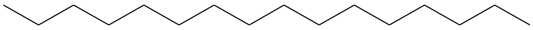
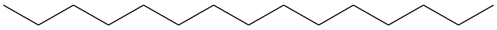
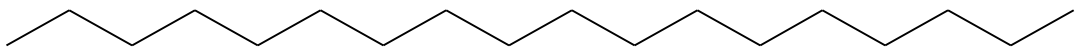
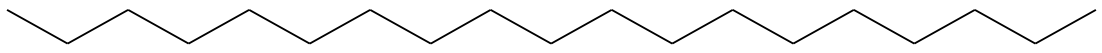
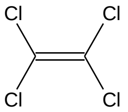
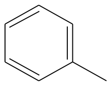
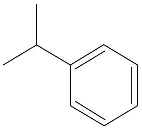
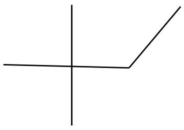
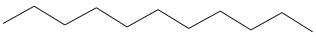
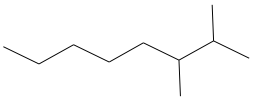
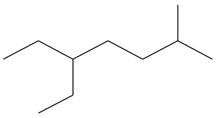
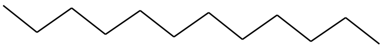
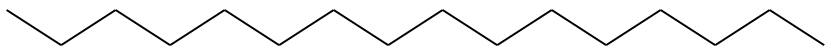
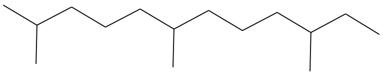
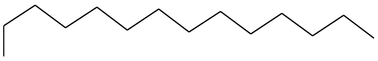
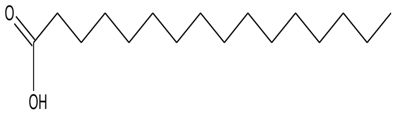
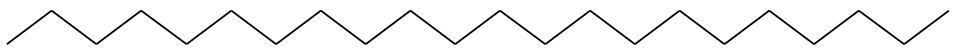
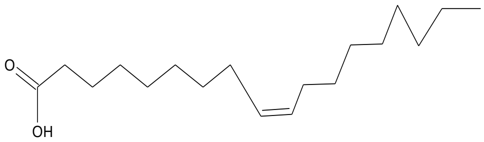
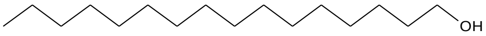
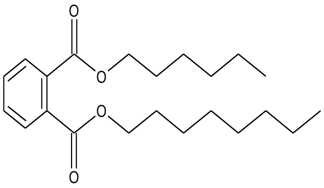
M.W	Formular	Structure	Name
92	C_7H_8		Toluene
106	C_8H_{10}		Ethyl Benzene
106	C_8H_{10}		P-xylene
106	C_8H_{10}		O-xylene
134	$C_{10}H_{14}$		Dimethylethylbenzene
156	$C_{11}H_{24}$		Undecane
170	$C_{12}H_{26}$		Dodecane
184	$C_{13}H_{28}$		Tridecane
226	$C_{16}H_{34}$		Hexadecane
212	$C_{15}H_{32}$		Pentadecane
198	$C_{14}H_{30}$		Tetradecane
254	$C_{18}H_{38}$		Octadecane
268	$C_{19}H_{40}$		Nonadecane

Table 4.26 shows the major organic compounds found in the effluent samples from the point of discharge (P_1) of the wastewater in Life breweries, Onitsha. These organics were the alkylbenzenes and alkane compounds. The source of these might be from the laboratory analar reagents used in the industry or from soil and air pollution of the surrounding petroleum resource industries.

These alkylbenzenes could react in the environment to form Poly Aromatic Hydrocarbons (PAHS) and become toxicants to receiving water bodies and soils.

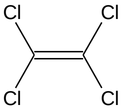
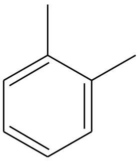
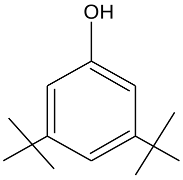
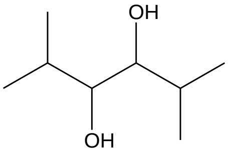
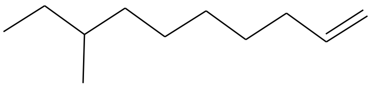
Table 4.27: Organic Pollutants by GC – MS in Effluent from Life Breweries, Onitsha (P_2)

M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		P-xylene
120	C_9H_{12}		Benzene, (1-methyl)-
86	C_6H_{14}		2,2-dimethyl-butane,
156	$C_{11}H_{24}$		Undecane
142	$C_{10}H_{22}$		2,3 dimethyl-octane
142	$C_{10}H_{22}$		5-ethyl-2-methylheptane
170	$C_{12}H_{26}$		Dodecane
226	$C_{16}H_{34}$		Hexadecane
212	$C_{15}H_{32}$		2,6,10-Trimethyldodecane
182	$C_{13}H_{26}$		1-Tridecane
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
308	$C_{22}H_{44}$		1-Docosene

282	$C_{18}H_{34}O_2$		Oleic Acid
242	$C_{16}H_{34}O$		1-Hexadecanol
390	$C_{24}H_{38}O_4$		Di-n-octyl phthalate

The major organics found in the effluent samples (P_2) were alkylbenzenes, alkanes, alkanols, alkanoic acids and benzyl-phthalates. The phthalates may react to form polyaromatics which are hard to biodegrade in the environment. These might accumulate to form toxins to both soil and receiving water bodies, hence to fish and other aquatic organisms.

Table 4.28: Organic Pollutants by GC – MS in Effluent from Life Breweries, Onitsha (P_3)

M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		O-Xylene
206	$C_{14}H_{22}O$		3,5-Di-t-butylphenol
146	$C_8H_{18}O_2$		2,5-dimethylhexanediol
154	$C_{11}H_{22}$		8-methyl-1-decene

The major organic pollutants at the 30 meters away from the point of discharge (P_3) were o-xylene, and phenolic compounds. These compounds are easily biodegradable but might pose problem in the environment as earlier stated in Tables 3.26 and 3.27.

Table 4.29: Organic Pollutants by GC – MS in Savana Effluent

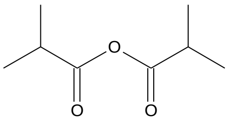
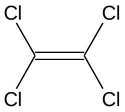
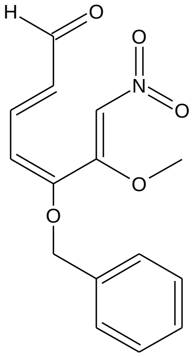
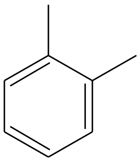
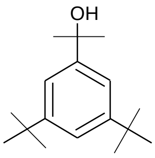
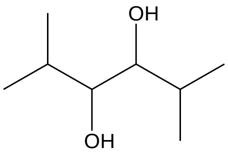
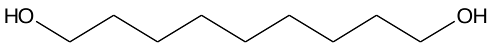
M.W	Formular	Structure	Name
158	$C_8H_{14}O_3$		2-methyl propanoic acid anhydride
164	C_2Cl_4		Tetrachloroethylene
287	$C_{15}H_{13}NO_5$		Benzonitrate
106	C_8H_{10}		O-xylene
206	$C_{14}H_{22}O$		3,5-Di-tert-butylphenol
146	$C_8H_{18}O_2$		2,5-dymethyl-hexanediol
160	$C_9H_{20}O_2$		1,9-Nonanediol

Table 4.29 shows the organic pollutants found in the effluent samples from Savana at the point of discharge (P_1) of the waste water. The major organic components here were Benzonitrates, O-xylene, phenolic compounds and diols.

Reactivity of the Benzonitrates in the environment might form Polyaromatic compounds that are not biodegradable in the environment leading to their accumulation and formation of toxins that are harmful to the soil, water and aquatic organisms.

Table 4.30: Organic Pollutants by GC – MS in Effluent from KP Beverages, Ogidi (P_1)

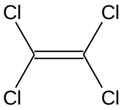
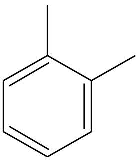
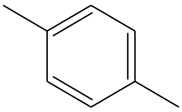
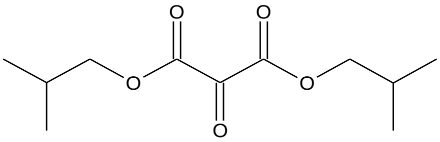
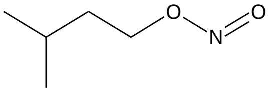
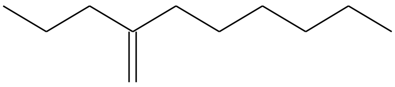
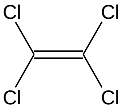
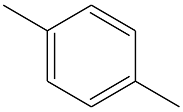
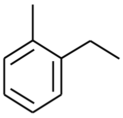
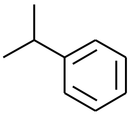
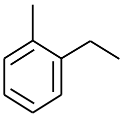
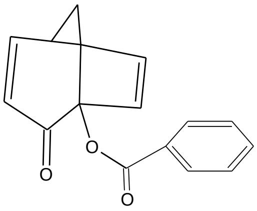
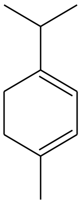
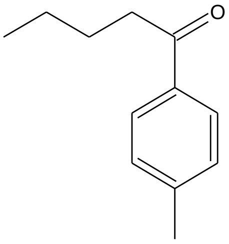
M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		O - xylene
106	C_8H_{10}		P - xylene
230	$C_{11}H_{18}O_5$		Propanedioic acid
117	$C_5H_{11}NO_2$		Nitrous acid
154	$C_{11}H_{22}$		4-methylene-decane

Table 4.30 shows the major organics found in the effluent samples from KP beverages, Ogidi at the point of discharge of the effluent (P_1). These organics include substituted benzene compounds and alkanoic acids. These organic compounds are easily biodegrable but might pose problem to the soil microbes and aquatic life if discharged into receiving water body without proper treatment.

Table 4.31: Organic Pollutants by GC – MS in Effluent from KP Beverages, Ogidi (P_2)

M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		P-xylene
120	C_9H_{12}		1-Ethyl-2-methyl benzene
120	C_9H_{12}		(1-methyl ethyl)benzene
120	C_9H_{12}		1-Ethyl-2-methyl benzene
254	$C_{16}H_{14}O_3$		2-Oxobicyclo(3,2,2)nona-3,6-dien-1-yl benzoate
134	$C_{10}H_{14}$		1,3,8-P-Menthatriene
176	$C_{12}H_{16}O$		1-(4-methyl phenyl)-1-pentanone

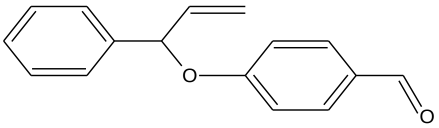
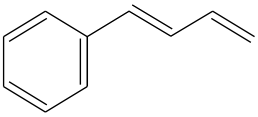
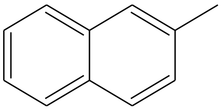
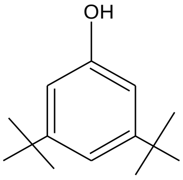
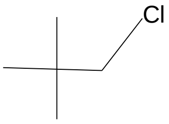
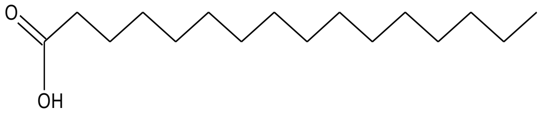
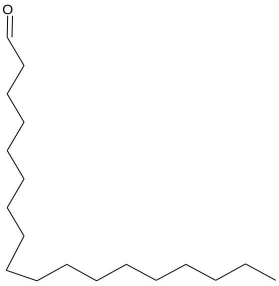
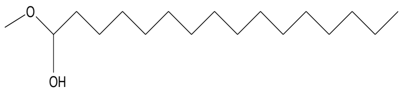
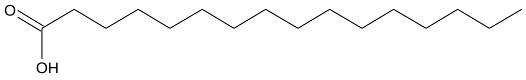
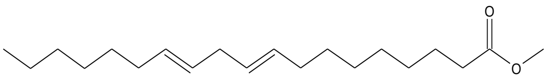
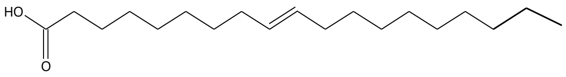
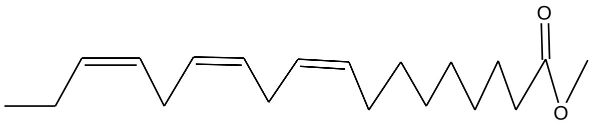
238	$C_{16}H_{14}O_2$		Benzaldehyde
128	$C_{10}H_8$		4-Phenylbut-3-ene-1-yne
142	$C_{11}H_{10}$		2-Methylnaphthalene
206	$C_{14}H_{22}O$		3,5-Di-tert-butylphenol
106	$C_5H_{11}Cl$		1-chloro-2,2-dimethyl propane
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
266	$C_{18}H_{34}O$		9-Octadecenal olealdehyde

Table 4.31 shows the major organic pollutants obtained in the effluent samples from KP beverages, Ogidi 15meters away from the point of discharge of the effluent (P_2). The organics were polyaromatic disubstituted benzene, substituted phenols, and alkanoic acids.

The 2-methylnaphthalene and 4-phenylbut-3-ene (presence of heavy metals) might form methyl compounds which have been reported as toxicants in water and aquatic animals (Goya, 1996).

Table 4.32: Organic Pollutants by GC – MS in Effluent from KP Beverages, Ogidi (P_3)

M.W	Formular	Structure	Name
270	$C_{17}H_{34}O_2$		Methyl ester, hexadecanoic acid
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
294	$C_{19}H_{34}O_2$		9,12-Octadecenoic acid
296	$C_{19}H_{36}O_2$		Methylester, 9-octadecenoic acid
292	$C_{19}H_{32}O_2$		Methylester 9,12,15-Octadecatrienoic acid

The major organics found in the effluent sample from KP beverages, Ogidi at (P_3) were mainly alkanoic acids which are easily biodegradable in the environment.

Nevertheless, care should be taken in discharging these effluents into any water body as the acidity of the receiving water body might increase leading to death of the aquatic organisms.

Table 4.33: Organic Pollutants by GC – MS in Effluent from OBISCO Beverages, Ogidi (P_1)

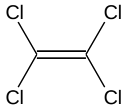
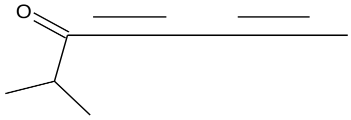
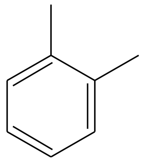
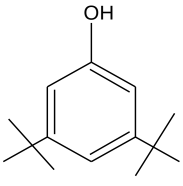
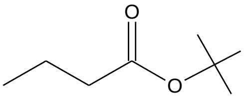
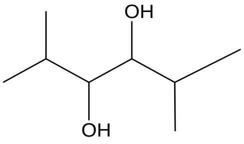
M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
134	$C_9H_{10}O$		Octadiyn-3-one
106	C_8H_{10}		O-xylene
206	$C_{14}H_{22}O$		3,5-di-tert-butylphenol
144	$C_8H_{16}O_2$		Tert.butyl butanoate
146	$C_8H_{18}O_2$		2,5-dimethyl hexanediol

Table 4.33 shows the organic pollutants obtained in the effluent sample from Obisco beverages, Ogidi at the point of discharge of the effluent (P_1). The major organics here were o-xylene, substituted phenol, diol and alkanoic acid. These compounds are easily bio-degradable but might pose problems (on continuous discharge) to soil microbes, plants and even aquatic organisms.

Table 4.34: Organic Pollutants by GC – MS in Effluent from OBISCO Beverages, Ogidi (P_2)

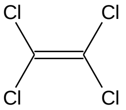
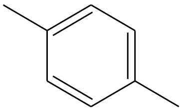
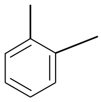
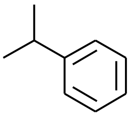
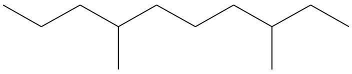
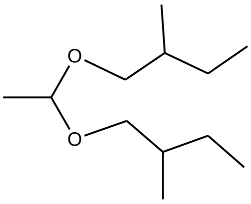
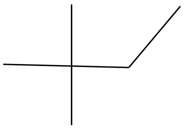
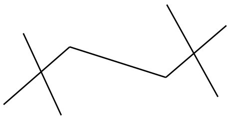
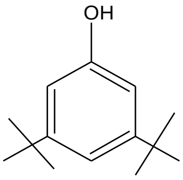
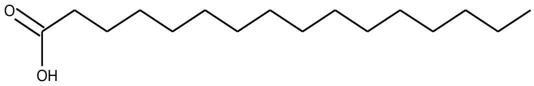
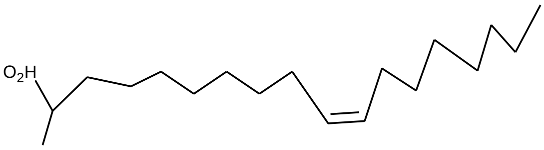
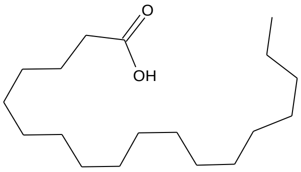
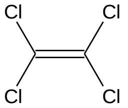
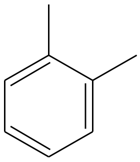
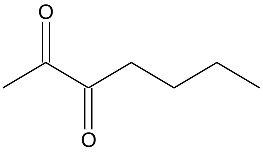
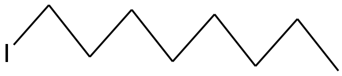
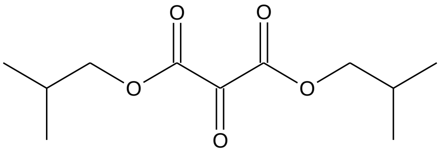
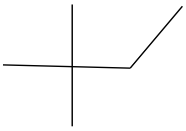
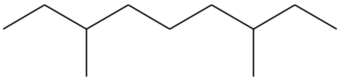
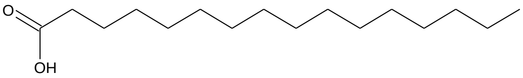
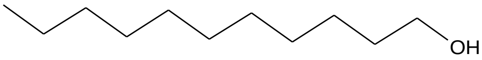
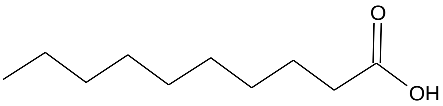
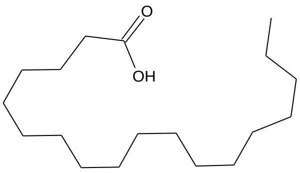
M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		P-xylene
106	C_8H_{10}		O-Xylene
120	C_9H_{12}		(1-methyl ethyl)benzene
170	$C_{12}H_{26}$		3,7 dimethyldecane
202	$C_{12}H_{26}O_2$		2-Methyl-1-[-1-(2-methylbutoxyl)ethoxy]butane
86	C_6H_{14}		2,2-dimethylbutane
142	$C_{10}H_{22}$		2,2,5,5, tert.methylhexane
206	$C_{14}H_{22}O$		3,5-di-tert-butylphenol
256	$C_{16}H_{32}O_2$		n-hexadecanoic acid

Table 4.34 continued

282	$C_{18}H_{34}O_2$		Oleic Acid
284	$C_{18}H_{36}O_2$		Octadecanoic acid

The major organic pollutants here were mainly substituted benzene compounds, alkanes, substituted phenols and of course alkanoic acids. Similarly, these organics are easily biodegradable but could still be dangerous to the soil microbes, plants and aquatic lives if allowed to accumulate over a period of time.

Table 4.35: Organic Pollutants by GC – MS in Effluent from OBISCO Beverages, Ogidi (P_3)

M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		O-xylene
128	$C_7H_{12}O_2$		2,3-Heptadione
240	$C_8H_{17}I$		Octyl Iodide
230	$C_{11}H_{18}O_5$		Oxo-bis(2-methylpropyl)ester
282	$C_{11}H_{23}I$		I-iodoundecane
86	C_6H_{14}		2,2-dimethylbutane
156	$C_{11}H_{24}$		3,7-dimethylnonane
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
172	$C_{11}H_{24}O$		1-Undecanol
172	$C_{10}H_{20}O_2$		n-Decanoic Acid
284	$C_{18}H_{36}O_2$		Octadecanoic adic

The major organic pollutants found in the effluents from Obisco beverage, Ogidi (P_3) were o-xylene, alkanols, alkanoic acids, alkanes. These organic compounds are easily biodegradable in the environment but could still pose some problem to the soil microbes and aquatic lives since they might accumulate to toxic level by continuous discharge of untreated effluent into the soil or receiving water bodies as discussed in Table 4.34.

Table 4.36: Organic Pollutants by GC – MS in Effluent from Golden Vegetable Oil, Onitsha (P_1)

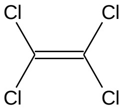
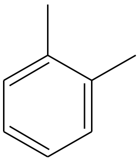
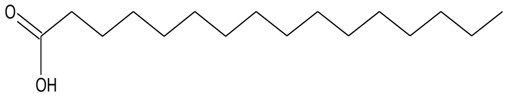
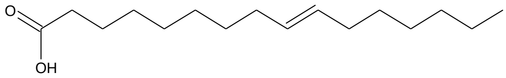
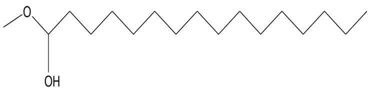
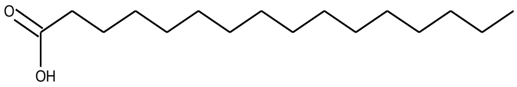
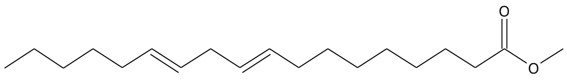
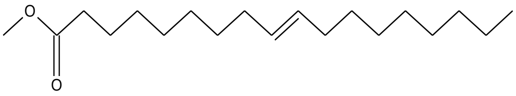
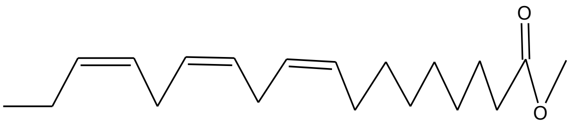
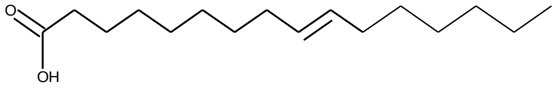
M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		0-xylene
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
254	$C_{16}H_{30}O_2$		9-Hexadecenoic acid

Table 4.36 shows that the major organics found in the effluent of Golden Vegetable Oil, Onitsha at the point of discharge (P_1). The organics were substituted benzene and alkanoic acids. The presence of alkanoic acids was evidence in the result of the mean concentration of pH obtained in this effluent which was low (acidic) in both seasons.

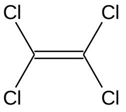
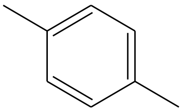
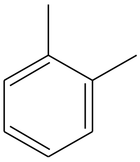
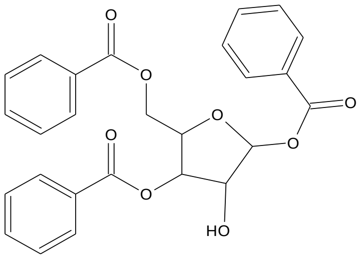
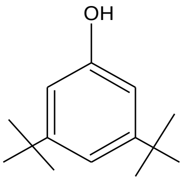
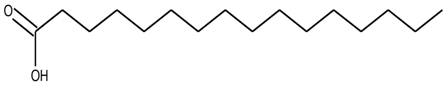
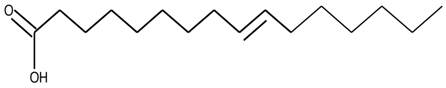
This effluent could be acidic to the receiving water body, hence endanger the aquatic lives and humans who consume fishes from the source.

Table 4.37: Organic Pollutants by GC – MS in Effluent from Golden Vegetable Oil, Onitsha (P_2)

M.W	Formular	Structure	Name
270	$C_{17}H_{34}O_2$		Hexadecanoic acid
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
294	$C_{19}H_{34}O_2$		9,12-Octadienoic acid
296	$C_{19}H_{36}O_2$		methyl ester 9-octadecenoic acid
292	$C_{19}H_{32}O_2$		9,12,15-Octadecatrienoic acid
254	$C_{16}H_{30}O_2$		9-Hexadecenoic acid

The major pollutants here (Table 4.37) were mainly alkanoic acids such as hexadecanoic acid, 9, 12-octadecanoic acids among others. This confirmed the low pH value obtained in the effluent sample from this industry in both seasons. The acidic nature of this effluent (low pH) would be deleterious to aquatic lives and even humans when sea food from such river are consumed (Chukwu, 2008).

Table 4.38: Organic Pollutants by GC – MS in Effluent from Golden Vegetable Oil, Onitsha (P_3)

M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		P-xylene
106	C_8H_{10}		O-Xylene
462	$C_{26}H_{22}O_8$		1,3,5-Tri-O-benzyl-alpha-ribofuranose
206	$C_{14}H_{22}O$		3,5-di-tert-butylphenol
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
254	$C_{16}H_{30}O_2$		9-Hexadecenoic acid

The major organics found in the effluent sample from Golden Vegetable Oil, Onitsha at 30 meters from the point of discharge (P_3) were mainly o-xylene, phenolic compounds and alkanoic acids.

These organics are easily biodegradable in the environment though could pose problems to the aquatic organisms.

The presence of alkanoic acids here also was evident in the low pH obtained in the effluent sample from this industry in both seasons (Tables 4.16 and 4.17) as previously discussed in physiochemical properties section.

Table 4.39: Organic Pollutants by GC – MS in RIMCO Effluent (P_1)

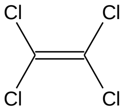
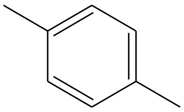
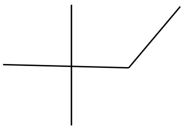
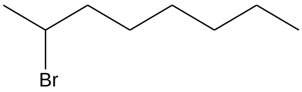
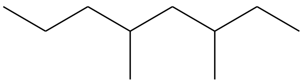
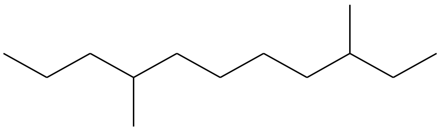
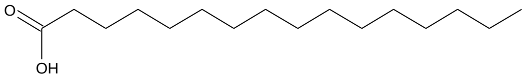
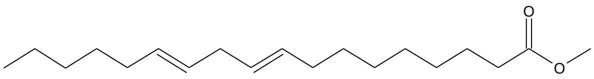
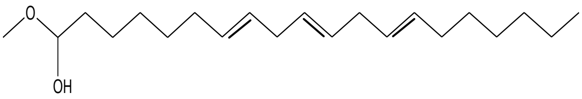
M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		P - xylene
86	C_6H_{14}		2,2-dymethyl-butane
192	$C_8H_{17}Br$		2-BromoOctane
142	$C_{10}H_{22}$		3,5-Dimethyloctane
184	$C_{13}H_{28}$		3,8-dimethylundecane
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
294	$C_{19}H_{34}O_2$		Methylester 9,12-Octadecenoic acid
320	$C_{21}H_{36}O_2$		7,10,13-Eicosatrienoic acid

Table 4.39 shows the organic pollutants obtained in RIMCO effluents from the point of discharge of the waste water (P_1). The major organics here were p-xylene, alkanes and alkanoic acids. These organic compounds are easily biodegradable in the environment but might still pose problem to the receiving water bodies and soil which might produce crops that are unhealthy.

Table 4.40: Organic Pollutants by GC – MS in RIMCO Effluent (P_2)

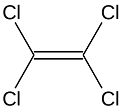
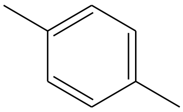
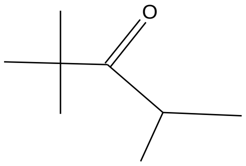
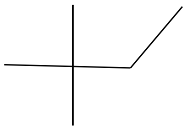
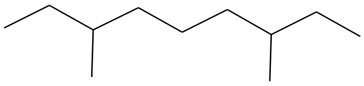
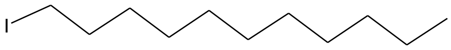
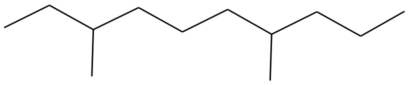
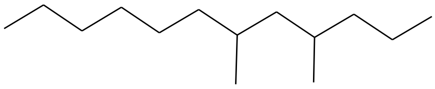
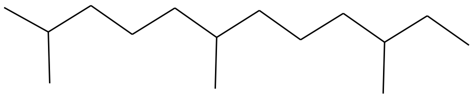
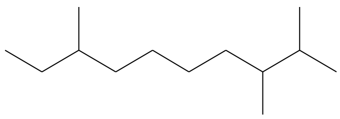
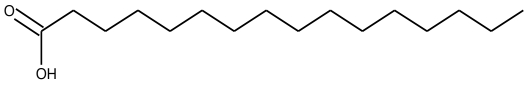
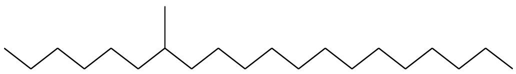
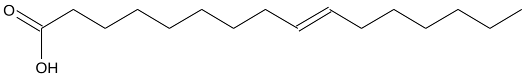
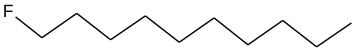
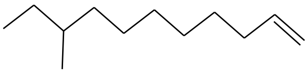
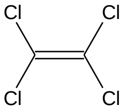
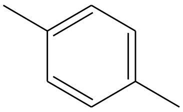
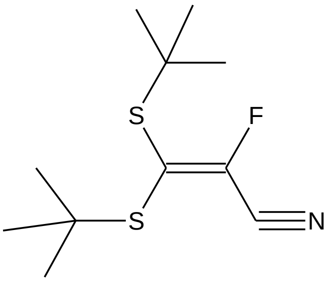
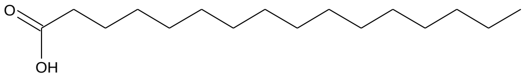
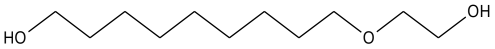
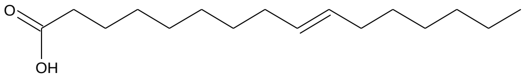
M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		P-xylene
128	$C_8H_{16}O$		2,2,4-Trimethyl-3-pentanone
86	C_6H_{14}		2,2-dimethylbutane
156	$C_{11}H_{24}$		3,7-dimethylnonane
282	$C_{11}H_{23}I$		1-Iodoundecane
170	$C_{12}H_{26}$		3,7-Dimethyldecane
198	$C_{14}H_{30}$		4,6-Dimethyldodecane
212	$C_{15}H_{32}$		2,6,10-Trimethyldodecane
184	$C_{13}H_{28}$		2,3,8-Trimethyldecane
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
280	$C_{20}H_{40}$		7-Eicosene

Table 4.40 continued

254	$C_{16}H_{30}O_2$		9-Hexadecceanoic acid
160	$C_{10}H_{21}F$		1-Fluorodecane
168	$C_{12}H_{24}$		9-methyl-1-undecene

The organics found in RIMCO effluents at 15meters away from the point of discharge of the wastewater (P_2) were alkyl benzenes, alkanoic acids and alkanes. These organic compounds are easily biodegradable in the environment but might pose some risk to the soil and aquatic organisms after much accumulation. The soil polluted by these organics might produce unhealthy crops leading to economic loss to the farmer.

Table 4.41: Organic Pollutants by GC – MS in RIMCO Effluent (P_3)

M.W	Formular	Structure	Name
164	C_2Cl_4		Tetrachloroethylene
106	C_8H_{10}		P-xylene
247	$C_{11}H_{18}FNS_2$		3,3-Bis-tert-butylsulfanyl-2-fluoro-acrylonitrile
256	$C_{16}H_{32}O_2$		n-Hexadecanoic acid
204	$C_{11}H_{24}O_3$		Nonamethylene glycol
254	$C_{16}H_{30}O_2$		9-Hexadececanoic acid

The organics found in RIMCO effluents at 30 meters from the point of discharge (P_3) were p-xylene, alkanoic acids, diol and 3, 3-bis-test-butyl sulfanyl-2-fluoro-acrylonitrile. These organic components can be degraded easily in the environment, but care should be taken in the discharge of the effluents as they might still pose problems to the aquatic environment and soil microbes.

The presence of alkanoic acid at all the points of discharge of the effluents in RIMCO industry is evident in the result of the pH value obtained in the effluents from this industry (Tables 4.16 and 4.17) in both rainy and dry seasons.

From the Tables (4.26 – 4.41), the organic pollutants were mainly substituted benzene compounds such as toluene, p – xylene, o – xylene, ethyl benzene, 1, 2 –xylene, 1, 4 – xylene, 1 – ethyl – 2 – methyl benzene and 3, 5 – di – t – butylphenol which is highly toxic in the environment. Others include hexadecanoic acid, tetrachloro ethylene, 4 – phenyl but – 3 – ene – 1 – yne; dimethyl ethyl benzene among others.

In KP effluent (P_2), 2 – methyl naphthalene was identified while Di – n – octyl phthalate was found only in effluent from Life breweries, Onitsha (P_2).

Polycyclic Aromatic Hydrocarbons (PAH) were not detected in all the effluent samples. They are persistent organic compounds and are combustion byproducts produced by unburned fuel, exhaust gases and vapour, lead compounds (from petrol additives) and hydrocarbon losses from fuel, lubrication and hydraulic systems.

Exposure to these organic pollutants can cause death and illnesses such as disruption of the endocrine, reproductive and immune systems; neurobehavioral disorders and cancers (Szabo and Loccisano, 2012). Moreover, Rogers and Kavlock, (1996), reported that organic pollutants are suspected human carcingens and disrupt the immune and endocrine systems.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Heavy metal levels in the effluent samples were higher in the dry season than in the rainy season probably as a result of dilution through precipitation or leaching away into the nearest stream or river through flood run off during the rainy season. Values obtained for heavy metals in this work were higher than the values recommended by the Federal Ministry of Environment for effluents to be discharged into the environment.

Nevertheless, two sample paired t-test showed that there was no significant difference ($p>0.05$) in the mean concentrations of Lead, Chromium, Arsenic, Cadmium and Zinc between the two seasons in all the effluent samples studied. Analysis of Variance also indicated that there were no significant difference ($p>0.05$) in the levels of Mercury, Iron, Lead, Chromium, Cadmium and Zinc when their levels were compared from one industry to the other.

Pollution Index (P_I) calculations to show the extent of pollution by these heavy metals showed that these effluents were highly polluted by these toxic heavy metals in both seasons. Pollution was higher in the dry season in all the effluent samples (except RIMCO) than in the rainy season. Generally, pollution in the industries was highest in Savana effluent and least in RIMCO effluent in both seasons. Pollution in the food industries ranged in the order: Savana>Life>Obisco>Golden>KP>RIMCO respectively.

This finding could mean that RIMCO management partially treats its wastewater (as they claimed to do) before discharge into the environment.

On the otherhand, values obtained for the physicochemical parameters were either within or below the allowable industrial effluent limit, except for pH and hardness levels (which failed to meet the Federal Ministry of Environment specifications). The pH levels were lowest in RIMCO and Golden effluents in the dry season which showed that these effluents were highly acidic and will be toxic to the soil, water, aquatic lives and humans when discharged into the environment. Hardness levels were highest in the effluent samples from Golden vegetable oil in the dry season which could be detrimental to aquatic lives and even human beings if discharged untreated. pH and TSS were higher in the dry season than in the rainy season while TS and TDS were higher in the rainy season in all the effluents monitored. TSS contribute to high turbidity of water bodies into which these effluents are discharged and will prevent sunlight from reaching aquatic plants and animals, thus adversely effecting their growth and reproduction rates.

Two sample paired t-test showed that pH, TS, TDS and TSS were highly significant ($p<0.05$) between rainy and dry seasons. Again, the Analysis of Variance (ANOVA) also indicated that there were significant difference ($p<0.05$) in the levels of pH, TS and TDS (except TSS) among the various effluents monitored. In as much as the values obtained for physicochemical parameters were either within or below the FMENV effluent limits, continued discharge of these wastes into the environment without proper treatment could result in severe accumulation of the toxicants, which could endanger crop yields, aquatic lives and human health. In that case, careless disposal of these waste waters by the food processing industries should be discouraged if a healthy environment is to be achieved in the nearest future.

To ascertain the level of pollution occasioned by the physicochemical parameters monitored in these effluents, pollution index was calculated. From the results obtained, Golden effluent had the highest pollution index in the rainy season while KP effluent had the least value in the same season. In the dry season, it was Obisco effluent that had the highest pollution index with Savana effluent having the least index. Pollution index of the effluents in both seasons showed that the trend of pollution in the industries was Golden>RIMCO>Obisco>Life>KP>Savana respectively. This finding clearly showed that physicochemical characteristics of the effluents were not involved in the pollution observed in the food industries monitored since values obtained for the index were less than one (pi < 1.000).

Counts of the Most Probably Number (MPN) of organisms showed higher values in the rainy season than in the dry season in all the effluent samples monitored. This could be as a result of high humidity during this period that favoured the growth and reproduction of these microbes. High counts of coliform organisms were observed in the effluent samples from Obisco (22MPN/100ml and 20MPN/100ml) for both rainy and dry seasons at point 1 (P_I) and 30MPN/100ml and 35MPN/100ml at 15 and 30 meters away from the point of discharge for the rainy and dry season counts respectively. Nevertheless, there was no evidence of coliform organisms in the effluent samples from RIMCO and Life breweries in both seasons.

In as much as these counts were higher in the rainy season than that of dry season, they were still below the limit allowed by the Federal Ministry of Environment in industrial effluent, though higher than the limit set by the World Health Organization in drinking water. Observation showed that coliform accumulation was higher at 15 and 30 meters away (P_2 and P_3) than at the point of discharge (P_1), which could be as a result of flow velocity factor leading to boundary effect. Organisms isolated from the effluents were *Escherichia coli*, *Bacillus cereus* and *Enterobacter aerogens* whose presence could lead to risk of waterborne diseases if the effluents are discharged directly into receiving water bodies without proper treatment. This could be the source of frequent cholera outbreak in certain parts of the country of recent, which have killed many lives especially children as a result of drinking polluted water or washing food items with contaminated water especially those food items that are eaten raw.

The major organic pollutants in Life breweries effluent samples were alkyl benzenes, alkane compounds, alkanoic acids, benzyl phthalates and phenolic compounds. These pollutants could come from the laboratory analar reagents used in the industry or from soil and air pollution of the surrounding petroleum industries. Some of these organics could react in the environment to form Poly Aromatic Hydrocarbons (PAHs) and become toxicants to receiving water bodies and soils. Benzonitrates, phenolic compounds and diols were the organics in Savana effluents. The benzonitrates might react in the environment forming PAHS that are not easily biodegradable. In KP effluents, the pollutants were substituted benzene compounds, alkanoic acids among others which are easily biodegradable though care should be taken in the discharge of these effluents. Obisco effluents had the following major pollutants: alkanoic acids, substituted phenol, diol and substituted benzene compounds. Though these compounds are biodegradable, but could still pose problems to the soil microbes and aquatic health since they might accumulate to toxic levels.

In Golden effluents, the organics were phenolic compounds, alkanoic acids and substituted benzene compounds which are easily biodegradable but the presence of alkanoic acids was evident in low pH obtained in the effluent sample from this particular industry in both seasons. This was also the case with RIMCO effluent that had mainly alkanoic acids as its organic pollutant. High pH of these effluents could lead to an increase in the acidity of receiving water bodies that might lead to the death of aquatic ecosystem.

Exposure to these organic pollutants can cause reduced reproductive success, birth defects, behavioural changes and death. This is because they are suspected carcinogens and disrupt the immune and endocrine systems.

These findings implied that consumption of polluted water by animals or human beings and even consumption of aquatic organisms that have accumulated these pollutants could be hazardous. Moreover, soil contaminated by these effluents might produce unhealthy crops as heavy metals can enter the food chain and thus be consumed by human beings. For instance, the mean concentrations of lead from the polluted effluents which was found to be above the permissible level could exert toxic effects on human beings if consumed from the water or irrigated agricultural products. These effluents, therefore need to be appropriately treated with respect to these toxic metallic elements before being discharged into the environment or surface water bodies.

5.2 Recommendation

From the conclusions highlighted above, it can be said that industrial pollution in the state poses a serious threat to human beings and needs to be tackled from every angle simultaneously using industrial technology, legal measures and environmental awareness education. It will be disastrous to nature as well as to mankind if this thoughtless interference with the environment is continued.

It is recommended that:

1. Regulatory bodies should be put in place, to guide waste disposal in order to prevent health dangers for aquatic, plant, animal and human lives.
2. Regulation and standard must be identified, this can help in eradicating environmental pollution, and hence terminate the hazards caused so far by its effects.

3. More research is recommended as regards the receiving waterbodies of these effluents, the soil around the industries and also the crops growing within the vicinity of these industries to ascertain their level of pollution by these wastewaters being discharged carelessly into the environment.

   Moreover, there is need for conservation, together with efficient wastewater treatment processes so that the cycle between ‘used’ water and its reuse can be shortened. The more water we use, the more wastewater we generate. And the more wastewater, the more its cost to clean it up; and the more it costs, the more we cannot pay the full cost. Equally, the more we don’t pay the full cost of water, the less money we invest in waste and sewage treatment. Also, the less we invest in waste and sewage treatment; the more pollution we generate.

There is also the need to give incentives or to recognize any food industry that adhere strictly to the industrial effluent limits. This will encourage the particular industry to further continue in the right direction, while at the same time, make others that are deviating/defaulting in their wastewater disposal operation to try and maintain the effluent limit allowed by the regulatory body. In effect, careless disposal of the wastes should be discouraged and if possible, there is need for all the manufacturing industries to install a treatment plant for all the industrial wastes so that they are properly treated before being discharged into the environment.

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