ASSESSMENT OF WATER QUALITY OF THE OGU CREEK IMPACTED BY SEAPORT ACTIVITIES IN ONNE, NEAR PORT HARCOURT, RIVERS STATE

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CERTIFICATION

I certify that this work "**Assessment of Water Quality of the Ogu Creek impacted by *Seaport activities in Onne, near Port Harcourt*, Rivers State**" was carried out by **Agbonikhena, Asuenime Nasiru** (Reg. No: 20075589839) in partial fulfillment for the award of the Master of Technology (M.TECH) degree in Environmental Technology in the Department of Environmental Technology of the Federal University of Technology, Owerri

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DEDICATION

This thesis is dedicated to the Almighty God

and my beloved family- Mrs. Emilomoh Agbonikhena, Jemiola Agbonikhena and Ohitolagbonta Agbonikhena

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ABSTRACT

The physicochemical parameters of the Ogu Creek serving the Onne Port of the Nigerian Ports Authority in Port Harcourt, which is impacted by Port transport activities were investigated in September 2011 at 6 sampling points. *In situ* measurements were made for water temperature, pH, salinity, dissolved oxygen (DO), turbidity, and conductivity using HORIBA U-10 Water Quality Checker and for total dissolved solids (TDS) with HACH conductivity/TDS meter. Other parameters were determined using standard methods of APHA. Water samples were collected in replicates with 2 litres plastic containers and transferred to the laboratory in iced-coolers for analysis. The test of homogeneity in mean variance was used to determine spatial variation in the physicochemical variables, and the Pearson correlation coefficient (r) used to explore the interrelationship existing between the parameters. Mean parameters were observed as follows: temperature 28.25 ± 0.12 °C, pH 6.02 ± 0.20, salinity 36.32 ± 0.12 ‰, DO 3.38 ± 0.14 mg/L, BOD 1.74 ± 0.21 mg/L, TSS 25.05 ± 2.45 mg/L, TDS 53.60 ± 5.75 mg/L, turbidity 81.23 ± 5.22 NTU, alkalinity 17.92 ± 1.61 mg/L, conductivity 1815.00 ± 238.24 µS/cm, total petroleum hydrocarbons 2.10 ± 0.15 mg/L, NO_3^- 3.62 ± 0.36 mg/L, PO_4^{2-} 2.59 ± 0.38 mg/L, SO_4^{2-} 78.07 ± 8.70 mg/L, Cl^- 95.55 ± 16.66 mg/L, Al 0.95 ± 0.08 mg/L, Cd 0.022 ± 0.011 mg/L, Cr 0.05 ± 0.01 mg/L, Cu 0.08 ± 0.01 mg/L, Fe 2.67 ± 0.38 mg/L and Pb 0.030 ± 0.009 mg/L. The lower ranges of pH, the upper ranges of Al and Fe, and Cd and Cu levels were outside permissible limits of the Federal Ministry of Environment for aquatic life. The control sampling location recorded highest concentrations in several of the variables, even as there was marked spatial heterogeneity [$F_{(8.41)}<F_{crit(3.88)}$] at P<0.05, with conductivity being most responsible for the observed difference. TDS correlated positively with NO_3^- (r=0.883) and PO_4^{2-} (r=0.881), and conductivity with SO_4^{2-} (r=0.825) at P<0.05, while TDS correlated with turbidity (r=0.923), and conductivity with NO_3^- ion (r=0.928) at P<0.01. However, pH correlated negatively with Cu ions (r=-0.946) at P<0.01. It is recommended that environmental regulatory agencies should enforce laws and standards in order to save the Port from further pollution.

Key words: Ogu Creek, Nigerian Ports, pollution, water quality, environmental regulation

CHAPTER ONE

1.0 INTRODUCTION

1.1. Background to Study

Marine pollution includes a range of threats arising from land-based sources, oil spills, untreated sewage, heavy siltation, eutrophication (nutrient enrichment), invasive species, persistent organic pollutants (POPs), heavy metals from mine tailings and other sources, acidification, radioactive substances, marine litter, overfishing and destruction of coastal and marine habitats (Ajao and Anurigwo, 2002). Water pollution almost always means that some damage has been done to an ocean, river, lake, or other water source. A 1971 United Nations report defined ocean pollution as:

> ***The introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities, including fishing, impairment of quality for use of sea water and reduction of amenities.***

Of the about 8,600km Nigerian inland waterways, the longest is noted to be the Niger River and its tributaries, followed by the Benue River waterway. However, of these, the most used, especially for commerce and larger powered boats are those in the Delta regions- covering from the Lagos lagoon through Cross Rivers to Port Harcourt in the Nigerian Delta. This Delta region has within it about 105 km of pipelines for transportation of petroleum condensates, 1,896 km for natural gas, 3,638 km for crude oil, and 3,626 km for refined petroleum products (NPA, 2000).

The Nigerian Ports Authority (NPA) situated in Lagos and Port Harcourt is the body responsible for managing the ports established along these waterways. The Lagos Port has separate facilities at Apapa and Tin Can Island, with a rail connection to points further inland. This port handles about 5.75 million tons of cargo each year (NPA, 2000). The Port Harcourt port, on the other hand is a transshipment port located about 66 km from the Gulf of Guinea along the Bonny River in the Niger Delta. The port handles about 815,000 tons of cargo yearly, and also has a railway connection. Both ports are not only responsible for the country's sea borne trades, but also serve neighbouring inland countries like Niger and Chad Republics.

With increasing regional and national economic demands targeted at higher revenue generation, these ports have become the hubs of international trades. According to an NPA estimate, it is expected that by 2020, shipping traffic on these ports to and from the United States of America alone would be doubled.

There would also be remarkable increases in traffic along these waterways from and to other trade partners by this time.

Though these increases in the ocean ports would create credit on the regional and national balance sheets, they would also be associated with direct and indirect environmental pollutions. For example, ships pollute the waterways and oceans in many ways. Spills of oil and chemicals, emissions of the oxides of sulphur, nitrogen and carbon from the exhaust fumes of cargo vessels and discharge of cargo residues from bulk carriers can pollute Ports, waterways, and oceans (Mitchell, 2001; The Ocean Conservancy, 2002; US EPA, 2000; CARB, 2000; Brunekreef *et al*., 1997; Ciccone *et al*., 1998; Duhme *et al*., 1996). Ships also create noise pollution and wrecked abandoned tanks could spread harmful algae and other invasive species (US EPA, 2000). In many instances, vessels intentionally discharge illegal wastes directly into the waterways. Others discharge ballast waters into the Open Ocean and waterways (NRDC, 2011). Additionally, crude and refined oil spills could also occur, thereby contaminating the waterways with both aliphatic and alicyclic hydrocarbons which are noted for their mutagenic and carcinogenic potentials (Okoli *et al*., 2011). Additionally, ancillary and services companies to the Ports activities could contribute pollution, thus increasing pollutants loading on the waterways.

The problem of water pollution in the global context has been suggested to be a leading worldwide cause of deaths and diseases by Pink (2006) and West (2006), and that it accounts for the death of more than 14,000 people daily (West, 2006). For example, The Chinadaily (2005) reported that some 90% of China's cities suffer from some degree of water pollution, and that in addition to the acute problems of water pollution in developing countries, industrialized countries also struggle with pollution problems as well. In a recent national report on water quality in the United States of America, 45% of assessed stream miles, 47% of assessed lake acres, and 32% of assessed bay and estuarine square miles were classified as polluted (US EPA, 2007).

1.2 Justification

For years now, the Port Harcourt Ports with its beehive of activities has attracted the presence of several service companies in and around the coastal city. The range of pollutants that could be introduced by these companies include domestic wastes (from catering and on-board services), through inorganic and organic chemicals, to oil and gas chemicals (eg oil, gasoline, cleaning solvents, detergents, etc). These pollutants could impairs the quality, and so use value of the water such as fishing, irrigation practices, recreation, swimming, boating, shipping, transportation, and the health of the entire biodiversity.

Like other ports in world, the Nigeria Ports Authority (NPA) in Port Harcourt witnesses several transportation activities associated with the seas. The Port is a trans-shipment location that handles about 815,000 tons of cargo ever year, in addition to the presence of railway connection to facilitate transportation of goods. During the processes of shipment alone, various contaminants associated with the goods and services delivered could impact the quality of the waterways negatively and thus, constitute threats to the resident biodiversity in the aquatic ecosystem. Such pollutants could emanate from ballast waters, exhaust emissions from vessels, oil spills, as well as domestic and human wastes generated aboard. The concomitant contribution of these pollutants could further exacerbate the pollution load of the waterways.

Though the Port Harcourt Port has been in operation for over 40 years now, and shipments have been on the increase since then, and though several researches have been conducted in the aquatic ecosystem and others in the Niger Delta area, few ground-truthing research has been carried out to ascertain the specific effects brought about by the Port's activities on the waterway. This research therefore attempts to fill this gap, through the investigation of the impacts of ports activities, especially in the Ogu Creek serving the Onne Seaport of the Nigerian Ports Authority in Port Harcourt.

1.3 Aim

This research aims at determining water quality regime of the Ogu Creek serving the Port Harcourt Ports Waterway in Onne, Rivers State impacted by marine transportation and ancillary activities, as a contribution to baseline data.

1.4 Objectives

The following were the objectives of the study. They include:

1. Determination of the physicochemical parameters of the Ogu Creek of the Onne Ports/Waterway.
2. Determination of variability contributions by the physicochemical parameters measured along the Creek.
3. Determination of spatial variation in the physicochemical variables of the Waterway.
4. Determination of the interactions of the physicochemical variables of the Waterway.
5. Comparison of the levels of the physicochemical variables with regulatory standards

1.5 Scope and Delimitation

The study covered 21 physicochemical parameters (temperature, pH, salinity, dissolved oxygen, biological oxygen demand, total suspended solids, total dissolved solids, turbidity, alkalinity, conductivity, total petroleum hydrocarbons, nitrate, phosphate, sulphate, chloride, trace elements- Al, Cd, Cr, Cu, Fe and Pb) measured along the Port Waterway. The study was conducted around the Port Harcourt Ports Authority in Onne, Rivers State, Nigeria.

1.6 Significance of Study

Water chemistry study is basic to the knowledge of the multi-dimensional aspects of aquatic environmental studies involves sources, composition, reactions and transport of pollutant loadings. The research therefore will among other things,

1. Create awareness on the extent or severity of pollution of the Port Harcourt Ports Waterway.
2. Create awareness on the relationship between the quality of the Waterway and regulatory standards.
3. Increase the databank of limnology in the Niger Delta area of Nigeria.
4. Stimulate strict regulations by the requisite agencies.

5. Provide baseline information on the water quality regime of the Waterway, and so provide extrapolations to other sea ports in the country.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. The Niger Delta and Resources

The Niger Delta is a vast floodplain built up by the accumulation of sedimentary deposits washed down the Niger and Benue rivers (Moffat and Linden, 1995). It is one of the World's wetlands, encompassing about 20,000 Km^2 in Southeastern Nigeria (Ajao and Anurigwo, 2002). According to Egborge (1994), the operational hub of the petroleum industry in Nigeria is concentrated in the Niger Delta, between Latitude 4º-6º N and Longitude 4º-8º E. This area includes the Atlantic Ocean coastal waters and the mangrove and freshwater swamps of Ondo, Delta, Edo, Rivers, Imo, Abia, Akwa Ibom and Cross River States. In Rivers State, four major multinational oil companies (Shell Petroleum Development Company of Nigeria Limited- SPDC, National Agip Oil Company- NAOC, Chevron Nigeria Limited and Elf Petroleum Nigeria Limited- EPNL) and a major gas company (Nigeria Liquefied Natural Gas Limited- NLNG) are present in the coastal city of Port Harcourt and its suburbs. Aside from these major companies, there are also several other service oil and gas industries that litter the region.

Additionally, there is the Port Harcourt Ports, one of the two major seaports of the country's Nigerian Ports Authority (NPA), with its beehive of activities in the areas of transportation and seafaring. There are well over 80 services and ancillary companies to this Ports Authority. The presence of these companies has not failed to establish a great deal of environmental consequences over time in the Ports Channels. The concomitant environmental degradation arising from the operations of these industries are fingerprinted in the immense stress on this large and ecologically sensitive region (Okpokwasili and Amanchukwu, 1988).

Being a wetland, the most fragile component of the Niger Delta area that is prone to environmental perturbations is the aquatic ecosystem. This ecosystem, which serves economic, domestic and recreational purposes is also home to fin and shellfish. Accordingly, the following damages caused by environmental pollution of the aquatic ecosystems have been identified by Ogundipe (2006):

- Destruction of wildlife habitats,
- Killing of seabirds and fish,
- Injury or killing of large animals such as seals and whales in seawaters,
- Destruction of plankton and subsequent destruction of aquatic food chain,
- Destruction of breeding and feeding grounds of sea animals such as oysters and shrimps, and

- Damage to beaches and rocky shores due to oil coats, and as such, affect holiday resorts at these locations.

2.2. Nigeria and Water Resources Management and Development

Water resources management and development was initially not accorded the priority attention it deserved in Nigeria. The turning point only occurred after the severe drought of the 1960s. The government response to the catastrophe was the initiation of strategies for co-ordinated and effective water resources development, culminating in the mid–1970s in the creation of the Federal Ministry of Water Resources and the River Basin Development Authorities. The activities of these institutions were further strengthened in 1981 by the establishment of the National Committee on Water Resources, and the Water Boards at the state level. These bodies were charged with taking an inventory, and ensuring rational and systematic planned management and conservation of the country's water resources. In the 1970's and early 1980's, water resources management in Nigeria was faced with a lot of problems which slowed down the development of the resource. Some of these problems included the deficiency of the resource in it, unnecessary duplication and overlap in organizations, structures and functions of the relevant bodies, the ill-defined and uncoordinated roles of the federal, state, and local government agencies responsible for water resources development, failure to recognize the inter-relationship between surface and ground waters and between water resources and land use, and lack of effective water and environmental protection laws, and the means to enforce the already existing ones.

In the late 1980s, Nigeria began to make serious efforts to address these problems. A national body was created to coordinate all environmental protection activities in the country. A comprehensive National Environmental Policy was formulated which, among other things, addressed the issue of water resources, and the Hazardous Waste Decree was promulgated with the intention of discouraging reckless and illegal dumping of hazardous and harmful wastes on land and into water courses.

The implementation of the Nigerian National Policy on Environment depends on specific actions directed towards major sectors and towards problem areas of the environment (FME, 2001). The management approach adopted in the policy is based on an integrated, holistic and systematic view of environmental issues. The programme activities of this policy are expected to establish and strengthen legal, institutional, regulatory, research, monitoring, evaluation, public information and other relevant mechanisms for ensuring the attainment of the specific goals and targets of the policy.

An understanding of these considerations will help water managers and policy makers implement environmental control and protection strategies, invest in monitoring and science, and develop future environmental policies, standards and guidelines.

Emphasis should be placed here on the invasion of the water hyacinth (*Eichornia crassipes*), which was first noticed in Nigeria in 1984. It is believed to have entered the country through Porto Novo Creeks, via Badagery creek *en route* to Lagos Lagoon. The weed covers a substantial portion of our surface water and a considerable distance along the south-western coast including Lagos, Ogun, Ondo, Edo, Delta state and recently has been introduced into Bayelsa State, *en route* from River Nule. It is spreading fast to new areas. Water hyacinth is a menace which displaces and kills other aquatic organisms. According to the FME (2001), it also seriously disrupts river navigation.

2.3. Aquatic Pollution

Aquatic pollution implies a large set of adverse effects upon lakes, rivers, oceans, groundwater, etc, largely caused by human activities. According to Wikipedia

(2011) report, though natural phenomena such as volcanoes, storms, earthquakes etc also cause major changes in water quality and the ecological status of water, these are not usually deemed to be pollution. Aquatic pollution has many causes and characteristics, including increases in nutrient loading which may lead to eutrophication, organic wastes such as sewage and farm wastes which could impose high oxygen demands on the receiving water leading to oxygen depletion with potentially severe impacts on the whole eco-system, and industrial discharges of a variety of pollutants in their wastewater including heavy metals, organic toxins, oils, nutrients, and solids.

Industrial pollution discharges can also have thermal effects, especially those from power stations, and these too reduce the available oxygen. Runoff containing silt from many activities including construction sites, forestry and farms can inhibit the penetration of sunlight through the water column, thus, restricting photosynthesis and causing blanketing of the lake or river bed which in turns damages the ecology (Ogbuagu and Ayoade, 2011a).

Aquatic pollutants therefore include a wide spectrum of chemicals, pathogens, and physical chemistry or sensory changes. Many of these chemical substances have been noted to be toxic or even carcinogenic to organisms (Okoli *et al.*, 2011). Pathogens on the other hand can produce waterborne diseases in either human or animal hosts. Alteration of water's physical chemistry could result in acidity, elevated conductivity and temperature, as well as excessive nutrient loading (eutrophication).

The major sources of water pollution include industrial discharge of chemical wastes and by-products discharge of poorly-treated or untreated sewage, surface runoff containing pesticides, agricultural wastes and spilled petroleum products. Other major sources include surface runoff from construction sites, farms, or paved and other impervious surfaces (e.g. silt discharge of contaminated and/or heated water used for industrial processes), acid rain caused by industrial discharge of sulfur (IV) oxide (by burning high-sulfur fossil fuels), excess nutrients added by runoff containing detergents or fertilizers, and underground storage tank leakage leading to soil contamination, thence aquifer contamination through soil seepages.

Aquatic pollution is such a serious problem in the global context that it has been suggested the leading cause of death and disease worldwide by the WHO (1984) and EPA (2003).

2.4. Man, Development and Water Pollution

With increasing socio-economic development activities that are often associated with growing human populations, there is also an equivalent growing pressure on the environmental resources. According to Adesiyan (2005), surface water is subjected to pollution mainly by the activities of human beings. It has been argued by Nath (1999) and Obunwo *et al.* (2004) that it is difficult to maintain unpolluted water of stream, rivers and lakes in a highly polluted and industrialized society. Though Ademoroti (1996) stated that receiving water can assimilate wastes to some extent, depending on their natural self-purification capacity, problem arises when pollutant load exceeds this capacity. Ademoroti therefore argued that pollution of surface waters only results when the natural ability of surface water to dilute and disperse waste materials is undermined.

The Federal Ministry of Environment therefore views surface water pollution as the addition of undesirable foreign substances into surface water that deteriorate its quality. In order words, surface water pollution is the presence of impurities in the water in such a quantity and of such nature as to impair the use of water for a stated purpose (FME, 2001; Johnson *et al.*, 2008). By this definition, pollution exerts a direct negative or noxious impact on the intended use of water (Bhatia, 2003; Jonnalagadda and Mhere, 2001) or its resources. This effect could be disperse in action as in many cases of a large river, the upstream discharge of one pollutant in a settlement may become the downstream abstraction of another.

Generally therefore, humans have always been polluting water since the early days of civilization. This is because we have been attracted to live by river environment where a continuous supply of water for drinking and farming activities such as irrigation and watering of animals exist.

2.5. Sources of Aquatic Pollution

Aquatic pollution can be from domestic sewage, industrial wastes, agricultural runoff, marine activities, deliberate and accidental discharge by ship, volatile compounds, as well as particulates from the air, and dumping of assorted types of metallic and non-organic materials (such as rusted motor parts and others) into our natural sources of water supply (Salem *et al.*, 2000). These sources of water pollutants are generally grouped under point and non-point sources. Point sources of water pollutants are specific location e.g. drains, pipes, ditches, sewer outfall etc from which pollutant materials enter water bodies. According to Rashed (2001), these sources are discrete and identifiable and therefore relatively easy to monitor and regulate.

Non-point sources are scattered or diffused, having no particular location whereby discharge into a particular body of water is observed. According to Obunwo *et* al. (2004), agriculture is the leading non-point source of pollutants such as nutrients, fertilizer and pesticide. The areas of concern in aquatic pollutants are numerous, but the major sources include industries, municipal, agriculture and natural origins.

Singh (2006) stated that the rapid growth of technology, exploration and exploitation of natural resources from the earth crust, as well as various other anthropogenic activities generate pollutants capable of causing serious problems in the environment. According to Uchegbu (2002a), the range of pollutants is vast, depending on the nature of the industrial activities and what gets "thrown down the drain". Most untreated industrial waste waters are often discharged into surface water. Some substances or impurities that form the discharge mixture includes traces of heavy metals, solvents, salts, organic and inorganic compounds; many of which could be toxic when they occur in high enough concentrations (Ademoroti, 1996).

Streams are so polluted in many industrialized countries that they are becoming progressively unsuitable as a source of water supply without people of catchment cities spending a prohibitive amount of money needed to purify them sufficiently for human consumption (Viessman and Hammer, 1999). As a result of this, it is now being recognized in most countries that it is the responsibility of the industries to treat their trade wastes in such a way that they do not deteriorates the quality of receiving waters which otherwise would make the utilization of such water very difficult or costly for downstream settlers.

Conversely, the major sources of municipal pollution are urban storm water run-off discharged through road drains or combined sewer outfalls, through surface water drainage systems (including spills of chemicals and oil and refuse or solid waste drainage). Other sources of municipal pollutants include traffic and maintenance operations. Traffic generates pollutants from vehicle emissions, including volatile solids, polynuclear aromatic hydrocarbon (PAHs) derived from unburned fuel (Okoli *et al*., 2011), load compounds and hydrocarbons on main roads, and leaks from lubrication systems (Ademoroti, 1996; Iwuchukwu, 2006). Abrasion of tyres during normal wear also releases zinc, lead and hydrocarbons (Ademoroti, 1996). Research work carried out in Germany has indicated that tyre abrasion ion motorways can release typically 572 gha(a) lead, 120 gha(a) chromium and 115 gha(a) Nickel (Rashed, 2001). Corrosion of vehicle also contributes quantities of metals e.g. chromium and lead in the surface water through run-off. Road maintenance, particularly de-icing is an important source of pollution e.g. salt and urea. Accordingly, Sincero and Sincero (2006) observed that the impurities in road-grade salt can contribute to water quality deterioration.

Adakole *et al.* (1998) observed that animal wastes, rich in bacteria can also accumulate and contribute to high levels of micro-organisms found in some waters. Additionally, Prasad (2008) observed that oil pollution associated with vehicle maintenance are also a specific problem in many surface water areas.

Viessman and hammer (1999) observed that municipal wastes, including solid and liquid waste materials from residential areas, schools, restaurants, hospitals, offices and other commercial areas can find their ways into surface waters. Human wastes from residential areas, schools, offices, etc. and waste water arising from personal washing, cleaning, etc dumped directly into the surface waters many add intestinal bacteria (coliform), along with other pathogens to the water. Okpokwasili and Olisa (1991) and Ademoroti (1996) observed that wastewaters from laundry washings add hard detergent that causes foam on surface waters.

The coliforms are the most widely used indicators of feacal contamination of waters. This is because they are present in large numbers in faeces and sewage and can be isolated in small volumes of water. However the direct detection of specific pathogens in contaminated water is a possible task. It is however practicable to isolated and identify these pathogens as a routing practice with expertise (Jimoh, 2003). Coliform in general are not necessarily all of feacal origins. Nevertheless, Okpokwasili and Olisa (1991) state that since they are not indigenous to water, their presence in water should cast suspicion on the water and should indicate pollution in the widest sense.

Sanitary sewers from residential and commercial areas carry surplus of oxygen demanding wastes and solids into surface water. Sincero and Sincero (2006) and Uchegbu (2002a&b) observed that industries within municipal areas ordinarily discharge their wastewaters into city's sewer systems.

According to Adesiyan (2005) and Mukherjee *et al.* (2006), the major causes of concern associated with agricultural pollution are organic matter (which often leads to nutrient enrichment of water bodies), including the disposal of solid organic wastes and slurries from livestock, effluents from silage clamps, and in some situations, domestic effluents from farmstead septic tanks, pesticides and fertilizers, and from soil erosion.

A lesser known activity (but one which can be classified as agricultural) is fish farming. In some countries, this activity is now an important source of food and its development can give rise to diffuse pollution problems. For example, in Norway the problem has become sufficiently important for the state pollution control authorities to issue instruments and guidance to minimize pollution from such activities (Khitoliza, 2004). The World Health Organization (W.H.O) in 1977 adopted control of nutrients throughout much of the world, both from public health perspective and to keep natural waters free from eutrophication. The most widely used water quality standard for nitrate is the 50mg/l limit adopted by WHO to safeguard babies from the risks of contracting methaemoglobinaemia.

Obunwo *et al.* (2004) are of the view that eutrophication problem is universally dependent on the control of nitrate and phosphate sources. According to Wood (1995), ploughing of grassland and other crops, particularly during autumn, leads to the release of large quantities of soil nitrogen and therefore, a general move towards permanent pasture regimes assists in lowering nitrate leaching. And as a result excessive nitrates are washed downstream during storm.

Kemdirim (1993) states that other relevant human agricultural activities that constitute pollution in surface water are laundry, fermenting of cassava tubers, washing of melon etc. Agricultural activities also result in excessive soil erosion, thereby increasing sediments loads. Animal wastes washed from fields and orchards into streams and rivers, as well as pesticides have been demonstrated to persist in the environment, causing serious problems (Adesiyan, 2005).

According to Ademoroti (1996) and Adesiyan (2005), uncontrolled and excessive use fertilizer, pesticides and herbicides have long-term effect on water resources. Feed lots where large numbers of animals are penned in relatively small space are usually located near slaughter houses and thus, near cities. Feed lots provide an extremely high potential for water pollution (Bhatia, 2003). Aquaculture has a similar problem because wastes are concentrated in a relatively small space (Kemdirim, 1993).

Scientists, mostly geophysicists and astronomers believe that the expanding universe is as a result of an enormous and powerful explosion called the big bang.

This theory assumes that during radioactive activity of the star (Sun), precisely through the process of nuclear fission and fusion, reactions produced plasma pull-down by gravitational force after due accumulation of mass energy (Lowrie, 1997). According to Alozie (2000) and Deswal and Deswal (2007), when the compounds formed gets into surface water, they could induce pollutions with great consequences on human health.

Presad (2008) Jain and Rao (2008) therefore state that natural sources of surface water pollution include volcanic eruptions, earthquakes, and oil spillages at the sea bed rock and through natural seepage. The aspect of dead organic matters arising from plants and animals are other sources of surface water pollution. Dead plants (leaves, branches etc) fall into the surface water and decay in them.

According to Ademoroti (1996), the decaying plant material give rise to fungal growths, while the decaying animal yield bacteria. Following this, Adakole *et al*. (2003) observed that runoff from natural drainage basin (natural areas and forest) supplies organic wastes and soil sediments into surface waters.

Chemistry in cloud droplets through the process of hydrolysis and oxidation leading to the formation of acid rain is another phenomenon or medium whereby surface water could be polluted (Oghenejoboh, 2005). When clouds are present, the loss rate of SO_2 is faster than can be explained by gas phase chemistry alone. Sulfur (IV) oxide dissolves in water and then, like carbon (IV) oxide, hydrolyses in a series of equilibrium reactions as follows,

$$\mathbf{SO_{2(g)} + H_2O \rightleftharpoons SO_2.H_2O} \text{ ……………………i}$$

$$\mathbf{SO_2 + H_2O \longrightarrow H^+ + HSO_3^-} \text{ …………………ii}$$

$$\mathbf{HSO_3 \longrightarrow H^+ + SO_3^{2-}} \text{ …………………..iii}$$

There a large number of aqueous reactions that oxidize sulfur from S (IV) to S (VI), leading to the formation of tetraoxosulphate (VI) acid. The most important oxidation reactions are with ozone, hydrogen peroxide and oxygen (reactions with oxygen are catalyzed by iron and manganese in the cloud droplets). Oghenejoboh (2005) explains that nitrogen (IV) oxide also reacts with OH to form trioxonitrate (V) acid during thundering.

$$\mathbf{NO_2 + OH \longrightarrow HNO_3} \text{ ……………………………iv}$$

2.6. Effects of Pollutants on Aquatic Ecosystems

Suter *et al. (*2009) state that a wide range of pollutants that affects surface water are grouped into broad classes as point and non-point sources. Domestic sewage and industrial wastes are called point sources because of their nature of collection by a network of pipes or channel and conveyance to a single point of discharge into the receiving water. Peter and Gunten (2008) state that both industrial and domestic wastes add large amount of organic and inorganic substances into aquatic system that could produces turbidity. Accordingly, Adakole *et al.* (2003) reported that small amounts of suspended matter may affect the life history of fishes at spawning sites and that high concentrations of suspended solids reduce transparency and photosynthesis, and may even clog the gills of fishes. Further, Egborge (1994) reports that it also lowers the temperature of surface waters.

Sequel to these, Alozie (2000), Duggal (2004) and Davies and Susan (2004) report that much of non-point source pollution occurs during rainstorms or spring snowmelt, resulting in large flow rates that make treatment even more difficult. The statement above is characterized by multiple discharges possibly from combination of urban and agricultural runoff into water bodies. Wood (1995), Bhatia (2003) and Deswal and Deswal (2007) report that oxygen demanding materials (usually biodegradable organic matter) also constitute pollution, and so do certain inorganic compounds in aquatic ecosystems. The consumption of dissolved oxygen poses threat to fish and other forms of aquatic lives that must have oxygen to live (Adakole *et al.*, 2003). The impact of dissolved oxygen depletion on aquatic ecosystem includes toxicity to water biota, public health and aesthetics. The toxicity may either be acute or chronic, depending on the prevailing circumstance. Ogbuagu and Ayoade, (2011b) therefore observed that the effect on species diversity and abundance could also be severe, whereby there could be complete elimination of biotypes. Viessman and Hammer (1999) argue that dissolve oxygen does not drop to zero and that the stream recovers without a period of anaerobiosis.

Adesiyan (2005) observed that the two common nutrients of primary concern (nitrogen and phosphorus) are considered pollutants when their concentrations become very high (eutrophication). The nutrients naturally support the growth of living things, but in excess could lead to large growths of alga; referred to as algal bloom, which in turn become oxygen-demanding material and when they die, they settle at the bottom. Through natural and anthropogenic activities, these are added to the aquatic system.

Pathogenic organisms, which are micro-organisms found in industrial and domestic wastes, as well as human faeces (including bacteria, viruses and protozoa excreted by diseased persons or animals) make the water unfit for drinking when discharged into surface waters. Also when the concentration of the pathogen is sufficiently high, the water may even be unsafe for swimming and fishing.

Organic and inorganic particles that are carried by waste water into receiving water are termed suspended solids. These suspended solids could be impurities and exist in the form of suspended, colloidal, dissolved and sedimented particles. The presence of these materials poses problem to water body, thereby altering surface water quality. The effects are increase in turbidity, which according to Ogbuagu and Ayoade, (2011a) decrease light penetration, and increased bacterial population and solid deposit on the bottom of the water body, thereby destroying the habitat of many benthic organisms (Ogbuagu and Ayoade, 2011b). For example salmon eggs can only develop and hatch in stream beds of loose gravel. As the pores between the pebbles are filled with sediments, the eggs suffocate and the salmon population is reduced. Endocrine disrupting chemicals (EDCs) include the polychlorinated biphenyls, commonly used pesticide such atrazine and other triazine chemicals, and the phthalates (Schirmer, 2009; Wittmer and Burkhardt, 2009). EDCs in water can mimic estrogens, androgen, or thyroid hormones or their antagonists. Their presence in surface water also interferes with the regulation of reproductive and development processes in mammals, birds, reptiles and fish. The chemical can also alter the normal physiological function of the endocrine system and can affect the synthesis of hormones in the body and the tissues.

Though heat is not often recognized as a pollutant, those in the electric power industry are well aware of the problems of disposing of water heat. In some environments, increase in water temperature can be beneficial. For example production of clams and oysters can be increased in some areas by warming the water. On the other hand, according to Chapman and Kimstach, (1992), increase in water temperature negatively affects surface water microorganism, and the rate of oxygen depletion increase. Heat is being theorized as one of the potential causes of the feminization of genetically male Chinook salmon in the Columbia River near Hanford Washington. Ademoroti (1996) and Deswal and Deswal (2007) observed that excessively high water temperature or abnormal temperature fluctuation during egg development caused a genetically male embryo to develop functioning female sex organs.

Aquatic pollution also reduces the surface tension of stream and introduces heavy metals such as Pb, Zn, As, Cu, Hg and Cd are often deposited in water bodies from the air near emitting facilities. These elements also enter water ways from runoff from pipes, drainage, industrial effluents and mining activities, as well as from oil spillages. Effluents from electroplating contain a number of heavy metal constituents. Spaak and Bauchrowitz (2010) have observed that heavy metals may be toxic to fish as well as harmful to human health. Hazardous, synthetic and carcinogenic organic and inorganic compounds are important surface contaminants from petrochemical and radioactive discharge effluents, agricultural runoff which contains pesticides and fertilizer residues. Adesiyan (2005) observed that fertilizers add nutrients to water, which could cause eutrophication.

2.7. Overview of Ports Transportation

Ports transportation refers to movement of goods (cargo) and people (passengers) on waterways by using various means like boats, steamers, launches, ships, etc. Sea or water transport has been the largest carrier of freight throughout recorded history. Although the importance of sea travel for passenger has decreased due to aviation, it is effective for short trips and pleasure cruises. Transport by water is cheaper than transport by air. It may be for commercial, recreational or military purposes. Virtually, any material can be moved by water. However, water transport becomes impractical when material delivery is highly time–critical. General Cargo is goods packaged in boxes, cases, pallets and barrels. Water Transport can be over any distance by boat, ship, sail boat, or barge over lakes and oceans, through canals in Ports or along rivers. With the help of these means, cargo and passengers are carried to different places, both within as well as outside the country. Within the country, rivers and canals facilitate the movement of boats, launches, etc. Since the goods and passengers move inside the country, this type of transport is called inland water transport. When the different means of transport are used to carry goods and passengers on the sea route, it is termed ocean water transport.

Inland water transport use boats, launches, barges, steamers, etc, to carry goods and passengers on river and canal routes. These routes are called inland waterways and are used in domestic or home trades to carry bulky goods.

Ocean transport is referred to as movement of goods and passengers with the help of ships through sea or ocean waterways. It plays an important role in the development of international trade and is also used for the transporting goods and passengers in the coastal areas. Ocean transport has its fixed route which links to almost all the countries of the world through Ports. Sea transport may be of the following types:

1. **Coastal shipping**: In this transport, ships ply between the main ports of a country. This helps in home trade and also in carrying passengers within the country.
2. **Overseas shipping**: In this transport, ships ply between different countries separated by sea or ocean. It is mainly used for promotion and development

of international trade. It is an economical means of transport to carry heavy machineries and goods in bulk. Overseas transport is carried out on fixed routes, which connect almost all the countries. In ocean transport, different types of ships are used to carry passengers and goods.

2.8. Ports Effluent Composition

The quality and quantity of port effluent can fluctuate significantly as it reflects the various, different processes that take place within the port complex. They include raw materials, work preparations, fermentation and filtration packaging wastes, among others. The amount of wastewaters produced is related to the specific water consumption, usually expressed as lil water. A part of this water is usually disposed from the vessels and ancillary manufacturing industries.

Organic components in ports effluents, often expressed as chemical oxygen demand (COD) are generally easily biodegradable as these mainly consist of gingers, soluble starch, ethanol, volatile fatty acids, etc. this is illustrated by the relatively high biological oxygen demand (BOD)/COD ratio of 0.6-0.7. The ports solids, usually expressed as total suspended solids (TSS) mainly consist of spent grains, waste yeast, hot tub, etc. Ports effluents pH levels are mostly determined by the amount and type of chemicals used at the various units (eg caustic soda, phosphoric acid, nitric acid, sulphuric acid, etc).

Nitrogen and phosphorus levels are mainly dependent on the handling of raw materials and the amount of oil spills present in the effluent. Elevated phosphorus levels can also be as a result of phosphorus containing chemicals used at the various units.

2.9. Ballasting in Ports Operations

A ship at sea is a massive structure which though floatable, requires stability to sail through the waters safely. For this reason, sea water is taken into the bottom of the ship in specially made compartments. As water is easily and abundantly available, it is used to provide the required stability and trim to the ship. This water is known as ballast water, and the process of taking ballast water into the ship is known as ballasting. The tanks in ships where the ballast water is filled are known as ballast tanks. Ships are designed to move through water carrying cargo, such as oil, grains, containers, machineries and people. If the ship is travelling without cargo or has discharged some cargo in one port and is on route to its next port, ballast may be taken on board to achieve the required safe operating stability which may as well cause adverse contamination in the environment due to migration.

2.10. Ports operations and Associated Air Pollution

Owing to the fact that water is a sink for both air and land pollutions, elucidation of air pollutions associated with Ports activities is useful for the indirect estimation of water pollutant loadings that could have adverse effects on the ecosystem. The diesel engines at ports, which power ships, trucks, trains, and cargo-handling equipment, create vast amounts of air pollution that affect the health of workers and people living in nearby communities and contribute significantly to regional air pollution. More than 30 human epidemiological studies have found that diesel exhaust increases cancer risks, and a California study found that diesel exhaust is responsible for 70 percent of the cancer risk from air pollution (CARB, 2000). A more recent study (Pandya *et al.*, 2002) have linked diesel exhaust with asthma. Major air pollutants from diesel engines at ports that can affect human health include particulate matter (PM), volatile organic compounds (VOCs), oxides of nitrogen (NOx), and sulfur (SOx).

Air-borne particulate matter pollution, or PM, ranges from coarse dust kicked up from dirt roads to tiny sooty particles formed when wood, gasoline or diesel is burned. At seaports, construction and daily operations often create coarse PM, but it is the tiniest PM that causes the greatest health hazards. Much of this fine PM, so small it is invisible to the eye, comes from diesel engine exhaust. Less than 1.20 the diameter of a human hair, fine PM can travel deep into the lungs, landing in the delicate air sacs where oxygen exchange normally occurs (Bagley, 1996). Numerous studies have found that these fine particles impair lung function, aggravate such respiratory illnesses as bronchitis and emphysema, and are associated with premature deaths (Pope, 1995). Dozens of studies link airborne fine-particle concentrations to increased hospital admissions for asthma attacks, chronic obstructive lung disease, pneumonia, and heart disease, including an increased risk of heart attacks (Peter *et al*., 2001). Park *et al.* (2002) have linked school absenteeism due to respiratory symptoms to particulate matter pollution.

Volatile organic compounds (VOCs) are often toxic, and when they evaporate into the air, they can react with other pollutants to form ground-level ozone, commonly referred to as smog. According to CARB (1998), common VOCs produced by diesel engines include benzene, 1,3-butadiene, formaldehyde, and toluene, each of which poses significant health risks, including cancer and birth defects.

Oxides of nitrogen (NOx) are a family of chemicals, including nitrogen (IV) oxide, trioxonitrate (V) acid, nitrogen (II) oxide, nitrates, and other related compounds. They can cause a wide variety of health problems, including respiratory distress, and react with VOCs in the atmosphere to create ozone. A number of studies have found that NOx can have a toxic effect on the airways, leading to inflammation and asthmatic reactions (Davies *et al*., 1997). According to Davies *et al*. (1998), people with allergies or asthma have far stronger reactions to common allergens, such as pollen, when they are also exposed to NOx.

Additionally, ozone, also known as smog, is a reactive gas produced when VOCs and NOx interact in sunlight and split apart oxygen molecules in the air. The layer of brown haze it produces is not just an eyesore, but also is a source of serious illnesses. Ozone is extremely irritating to the airways and the lungs, causing serious damage to the delicate cells lining the airways. It contributes to decreased lung function, increased respiratory symptoms, asthma, emergency room visits, and hospital admissions (US EPA, 1996a). Ozone can cause irreversible changes in lung structure, eventually leading to chronic respiratory illnesses, such as emphysema and chronic bronchitis (US EPA, 1996b).

Combustion of fuels that contain sulfur, such as diesel and especially marine diesel fuels that have high sulfur content produce oxides of sulfur (SOx). Oxides of sulfur include sulfur (IV) oxide and a range of related chemical air pollutants. Nicolai (1999) observed that oxides of sulphur react with water vapor in the air to create acids that irritate the airways, sometimes causing discomfort and coughing in healthy people, and often causing severe respiratory symptoms in asthmatic patients.

On a general note, the health effects of pollution from ports may include asthma, other respiratory diseases, cardiovascular disease, lung cancer, and premature death. In children, these pollutants have been linked with asthma and bronchitis, and high levels of the pollutants have been associated with increases in school absenteeism and emergency room visits. In fact, numerous studies have shown that children living near busy diesel trucking routes are more likely to suffer from decreased lung function, wheezing, bronchitis, and allergies (Brunekreef *et al.* 1997; Ciccone *et al.*, 1998; Duhme *et al.*, 1996).

Several major ports operate virtually next door to residential neighborhoods, schools, and playgrounds. Due to close proximity to ports, nearby communities face extraordinarily high health risks from associated air pollution. Many of these areas are low income communities of colour, a fact that raises environmental justice concerns.

According to NRCE (2011), though cars, power plants, and refineries are all large and well-known sources of pollution, it has been demonstrated that the air pollution from ports rivals or exceeds these sources. In the Los Angeles area for example, oceangoing ships, harbor tugs, and commercial boats such as passenger ferries emit many times more smog-forming pollutants than all power plants in the Southern California region combined (Mitchell, 2001). Latest growth forecasts predicting trade to approximately triple by 2025 in the Los Angeles region mean that smog-forming emissions and diesel particulate pollution could severely increase in an area already burdened by the worst air quality in the nation. This situation could be similar to the Nigerian case, where Ports activities are also on the increase due to economic demands. The larger contribution of port sources to air pollution can be attributed to the fact that pollution from cars, power plants, and refineries is somewhat controlled, whereas port pollution has continued to grow with almost no regulatory control (NRDC, 2011).

2.11. Ports Operations and Aquatic Pollution

Ports operations portend significant damage to water quality and subsequently to marine life and ecosystems, as well as human health. According to The Ocean

Conservancy (2002), these effects may include bacterial and viral contamination of commercial fish and shellfish, depletion of oxygen in water, and bioaccumulation of certain toxins in fish. NRDC (2011) states that major water quality concerns at ports include wastewater and leaking of toxic substances from ships, stormwater runoff, and dredging.

A primary threat to water quality from ports operations includes bilging. Bilge is water collected at the bottom of the hull of a ship; water that is often contaminated with oil leaking from machinery. Bilge water must be emptied periodically to maintain a ship's stability and to prevent the accumulation of hazardous vapors. The Ocean Conservancy (2002) states that this oily wastewater, combined with other ship wastes such as sewage and wastewater from other onboard uses, is a serious threat to marine life.

According to INA (1999), antifouling additives are often added to the paint used on ships to prevent the growth of barnacles and other marine organisms on ship surfaces. Some of these additives contain tributyltin (TBT), a toxic chemical that can leach into water. Though toxic antifouling additives are slowly being phased out of use, these toxic pollutants persist in the marine environment.

Stormwater runoff is precipitation that travels across paved surfaces. It can accumulate deposits of air pollution, automotive fluids, sediments, nutrients, pesticides, metals, and other pollutants. According to the US EPA (2000), urban stormwater runoff from all sources, including marine ports, is the largest source of impairment in U.S. coastal waters and the second-largest source of water pollution in U.S. estuaries. The case may not differ in the Nigerian situation with several pavements running into canals serving Ports Authorities. Virtually all of the land at a port terminal is paved, and therefore impervious to water. When water bodies are overloaded with nitrogen, algae and plankton can rapidly increase in numbers, forming "blooms" which are sometimes called red or brown tides. The US EPA (2000) also state that this process, called eutrophication, has been identified by the National Research Council as the most serious pollution problem facing estuaries in the United States. As major sources of NOx therefore, ports are major contributors to eutrophication.

The water pumped into a ship's ballast tank contains numerous aquatic organisms including viruses, bacteria, algae, jelly fish, crabs, molluscs, and fish. If the organisms within a ship's ballast water survive the trip to the next destination, they may be released with the ballast water into waters in which they do not naturally occur. If these non-native organisms survive and spread throughout their new environment, they may become invasive species. In this way, ballast water can introduce micro algae and other organisms into the environment.

The most commonly associated with ship pollution are oil spills. While less frequent than the pollution that occurs from daily operations, oil spills have devastating effects. While being toxic to marine life, polycyclic aromatic hydrocarbons (PAHs), the components in crude oil are very difficult to clean up, and lasts for years in the sediments and marine environment. According to the USCG (2001), marine species constantly exposed to PAHs can exhibits developmental problems, susceptibility to disease and abnormal reproductive cycles. One of the more widely known spill was Exxon Valdez incident in Alaska.

The USCG (2001) reports that in 2000, about 8,354 oil spills were reported in U.S. waters, accounting for more than 1.4 million gallons of spilled oil. The majority of these spills occurred in internal and headlands waters, including the harbors and waterways upon which ports rely (USCG, 2001). A large share of oil contamination is the result of "chronic" pollution from such sources as port runoff, unloading and loading of oil tankers, and the removal of bilge water- resulting in up to three times as much oil contamination as tanker accidents (AAPA, 2001). However, large, "catastrophic" spills also have a significant impact. Unfortunately, there are no documented information on the Nigerian case, even as these incidents are also frequent in our Ports.

Dredging is a routine activity of ports to remove sediment that builds up in ship channels from erosion and silt deposition. Dredging also creates new channels and deepens existing ones. Each year, more than 300 million cubic yards of sediment in waterways and harbors are dredged to allow ships to pass through (CARB, 2000). About 5 to 10 % of dredged sediment is contaminated with toxic chemicals, including polychlorinated biphenyls (PCBs), mercury and other heavy metals, polycyclic aromatic hydrocarbons (PAHs), and pesticides- all of which can cause water contamination and complicate sediment disposal (AAPA, 2001). Dredging may also increase water turbidity (cloudiness/murkiness), harm habitat, and disturb or kill threatened and endangered species. It may also risk stirring up and releasing buried contaminants.

These various forms of water pollution cause a broad range of environmental problems, including loss of critical wetlands areas, water sedimentation that harms important habitat (sea grass beds, in particular), collisions involving boats and marine mammals, and marine life exposure to debris, including plastic bags, netting, and plastic pellets.

2.12. Cruise Ships and Aquatic Pollution

Cruise ships generate a number of waste streams that can result in discharges to the marine environment, including sewage, gray water, hazardous wastes, oily bilge water, ballast water, solid waste, sound pollution, exhaust emissions, black water, and oil spills. They also emit air pollutants to the air and water. These wastes, if not properly treated and disposed of, can be significant source of pathogens, nutrients, and toxic substances with the potential to threaten human health and damage aquatic lives. It is important, however, to keep these discharges in some perspective, because cruise ships represent a small– although highly visible-portion of the international shipping industry, and the waste streams described here are not unique to cruise ships. However, particular types of wastes, such as sewage, gray water, and solid waste, may be of greater concern for cruise ships relative to other sea going vessels, because of the large numbers of passengers and crew that cruise ships carry and the large volumes of wastes that they produce (US EPA, 2007).

Furthermore, because cruise ships tend to concentrate their activities in specific coastal areas and visit the same ports repeatedly (especially Florida, California, New York, Galveston, Seattle, and the waters of Alaska), their cumulative impact on a local scale could be significant, as can impacts of individual large volume releases (either accidental or intentional).

The cruise line industry dumps 255,000 gallons of gray water and 30,000 gallons of black water into the sea every day. Black water is sewage, wastewater from toilets and medical facilities, which can contain harmful bacteria, pathogens, viruses, intestinal parasites, and harmful nutrients. Discharges of untreated or inadequately treated. Sewage can cause bacterial and viral contamination of fisheries and shellfish beds, producing risks to public health. Nutrients in sewage, such as nitrogen and phosphorous, promote excessive algal blooms, which consumes oxygen in the water and can lead to fish kills and destruction of aquatic life. A large cruise ship (3000 passengers and crew) generates an estimated 55,000 to 110,000 litres per day of black waterwaste.

Gray water; which is waste water from the sinks, showers, galleys, laundry, and cleaning activities aboard a ship can contain a variety of pollutants, including fecal coliform bacteria, detergents, oil and grease, metals, organics, petroleum hydrocarbons, nutrients, food wastes, and medical and dental wastes. For example, sampling done by EPA and the state of Alaska found that untreated gray water from cruise ships can contain pollutants at variable strengths and that it can contain levels of fecal coliform bacteria several times greater than typically found in untreated domestic wastewater. Gray water has potential to cause adverse environmental effects because of concentrations of nutrients and other oxygen-demanding materials, in particular. Gray water is typically the largest source of liquid waste generated by cruise ships (90%-95% of the total).

Cruise ships produce hazardous wastes from a number of on-board activities and produces, including photo processing, dry cleaning, and equipment cleaning. Types of waste include discarded and expired chemicals and medical wastes, batteries, fluorescent lights, spent paints, and thinners, among others. These materials contain a wide range of substances such hydrocarbons, chlorinated hydrocarbons, heavy metals, paint waste, solvents, fluorescent and mercury vapour, light bulbs, various types of batteries, and unused or out-dated pharmaceuticals.

On a ship, oil often leaks from engine and machinery spaces or from engine maintenance activities and mixes with water in the bilge, the lowest part of the hull of the ship. Oil, gasoline, and by-products from the biological break down of petroleum products can harm fish and wildlife and pose threats to human health if ingested. Oil, even in minute concentrations can kill fish or have various sub-lethal chronic effects (Don, 2000).

Oily bilge wastes may contain solid wastes and pollutants containing high amounts of oxygen-demanding material, oil and other chemicals. A typical large cruise ship will generate an average of 8 metric tons of oily bilge water for each 24 hours of operation. To maintain ship stability and eliminate potentially hazardous conditions from oil vapours in these areas, the bilge spaces need to be flushed and periodically pumped dry. However, before a bilge can be cleared out and the water discharged, the oil that has been accumulated needs to be extracted from the bilge water, after which the extracted oil can be reused, incinerated, and/or off-loaded in port. If a separator, which is normally used to extract the oil, is faulty or is deliberately bypassed, untreated oily bilge water could be discharged directly into the ocean, where it can damage marine life. A number of cruise lines have been charged with environmental violations related to this issue in recent years (NRC, 1995).

Ballast water also comes from cruise ships, as in large tankers and bulk cargo carriers in large quantity and is also used to stabilize the vessel during transport. Ballast water is often taken on the coastal waters in one region after ships discharge waste water or unload cargo, and discharged at the next port of call, wherever more cargo is loaded, which reduces the need for compensating ballast. Thus, it is essential to the proper functioning of ships (especially cargo ships), because the water that is taken in compensates for changes in the ship's weight as cargo is loaded or unloaded, and as fuel and supplies are consumed. However, ballast water discharge typically contains a variety of biological materials, including plants, animals, viruses, and bacteria. These materials often include non-native, nuisance, exotic species that can cause extensive ecological and economic damage to aquatic ecosystems (Hazelwood, 2004).

Solid wastes are wastes generated on a ship which include glass, paper, cardboard, aluminium and steel cans, and plastics. It can be either non-hazardous or hazardous in nature. Solid waste that enters the ocean may become marine debris, and it can then pose a threat to marine organisms, humans, coastal communities, and industries that utilize marine waters. Cruise ships typically manage solid waste by combination of source reduction, waste minimization, and recycling. However, as much as 75% of solid waste is incinerated on board, and the ash typically is discharged at sea, although some is landed ashore for disposal or recycling. Marine mammals, fish, sea turtles, and birds can be injured or killed from entanglement with plastics and other solid wastes that may be released or disposed off of cruise ships. On the average, each cruise ship passenger generates at least two pounds of non-hazardous solid waste per day and disposes of two bottles and two cans. With large cruise ships carrying several thousand passengers, the amount of waste generated in a day can be massive (The Ocean Conservancy, 2002).

Black water, which is sewage, wastewater from toilets and medical facilities contains harmful bacteria, pathogens, diseases, viruses, intestinal parasites and harmful nutrients. Discharges of untreated or inadequately treated sewage can cause bacterial and viral contamination of fisheries and shellfish beds, producing risks to public health. Nutrients in sewage, such as nitrogen and phosphorous promote excessive algal growth, which consumes oxygen in the water and can lead to fish kills and destruction of other aquatic life. A large cruise ship (3,000 passengers and crew) generated and estimated 15,000 to 30,000 per day of black water waste.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. The Port Harcourt Ports

The Port Harcourt Ports Complex (PHPC), located in Onne, a suburb of Port Harcourt on the Bonny River estuary covers an area of 2538.175 hectares which was acquired by the Federal Government in 1978 through the Land Act Decree. The Port is located in an area that is naturally low lying and marshy. The natural formation of the Ogu and Bonny Rivers had necessitated the siting of the Onne Ports Complex, which lies within latitude 64 30 North and longitude 07 09 East. The access channel to the Ports Complex from the sea is the Ogu Creek, into the Federal Ocean Terminal (FOT) and the Federal Light Terminal (FLT) via the Bonny River into the Intel Transit Terminal (ITT) base. It is the first of the country's Ports to be established in the then eastern region before the Calabar Port, under the Nigerian Port Authority (NPA).

As the third largest of the nation's sea ports after the Lagos Ports at Apapa and Tin Can Island, the PHPC is 27 nautical miles from the Fairway Buoy (NPA, 2000). Commissioned for organized shipping activities in 1913 by the then Colonial

Governor, Fredrick Lugard, the port took off with four berths, having a total quay length of 506 metres. In 1926, it was provided with wharfage and berthing facilities, to cope with domestic trade along the Niger Delta coastlines, between the east, north-eastern Nigeria, and to some extent, beyond to the Chad Republic. During and after the First and Second World Wars of 1939 and 1945, foreign trade commenced with patronage from America and Europe. With subsequent expansions in 1962 and post-Nigerian civil war (1970-1974) second National Development Plan, the Port had 8 berths in 2000, with a total quay length of approximately 12,000 metres and an average draught along the quays of 8.97 metres; thus, enabling vessels up to 15,000 metric tone dead-weight to be berthed (NPA, 2000).

3.2. Study Area

Onne, near Port Harcourt in Rivers State is located within longitude 6^0 56’ and 7^0 07’ E and latitude 4^0 44’ and 4^0 52’ N (Fig. 3.1) in the Niger Delta region of Nigeria. Rivers State shares boundaries with Bayelsa State on the West, Anambra State in the North, Abia and Imo States in the East, and the Atlantic Ocean in the South.

Fig. 3.1. Map of Port Harcourt environs showing Onne, the study area in Rivers State

Studv Area

(Source: http://maps.google.com.ng/maps?hl=en&q=map+of+port+harcourt&ie=UTF8&hq=&hnear=Port+Har...)

3.2.1. Climate and Vegetation

Weather conditions over the area are governed by the moist tropical maritime currents from the Atlantic Ocean wave fronts and dry wind and dust laden tropical continental air mass from the northern part of Nigeria. Prevalent wind direction in the area is south-westerly, with speed ranging from 0.3 to 4.5m/s and North-easterly, with speed between 0.3–1.5m/s. Relative humidity is usually above 85% in rainy season, but decreases to 45% in dry season. Ambient air temperature ranges from 24.5 to 32^0C in wet season and from 25 to 36^0C in dry season.

Typical climate of the area is marked by high relative humidity spread over the year from 8–10 months (March–November), and sometimes throughout the year. Dry season begins from either late November or early December to February.

The vegetation of the area is predominated by the typical tropical rainforest regime, which is comparatively uniform throughout the proximity of the region to the Atlantic Ocean. The other vegetation type is the farmland/fallowing mosaic regime. The first canopy consists of plants of 40 meter and above, while the middle canopy is between 15 and 40 meters high, and the last the Mangrove shrubs which are about 15m high. Often mixed with woody climbers (lianas), epiphytes and ferns etc, there are thick forest growths with numerous plants of different kinds (e.g. palm trees, raffia palm and other economic, medicinal, and food crops) within the study area.

3.2.2. Population and Economic Activities

The total population of the area is put at approximately 1,864,570 people, with a growth rate of 2.84% and a total land area of about 1900 km^2 (GPHDMP, 2010). The major traditional occupation of the inhabitants is substantive fish farming, agriculture and civil service. Some of the crops grown include yam, cocoa yam, cassava, plantain, banana and pepper.

The Port and her ancillary and services companies are well located to serve the economic interests of the eastern states and beyond. Port Harcourt city and its environs have thus been converted to centres of economic interests in commerce and trade by the presence of these companies. There are two petroleum refineries, a fertilizer plant, Nigeria's premier Liquefied Natural Gas Plant at Finima near Bonny, some 31 nautical miles downstream from the Port. Several oil related activities, other commercial and industrial enterprises are thriving here. These combine to underscore the relevance of the Port to the business interests and successes of the catchment states it is meant to serve.

3.3. Sources of Data

The data used in this research were obtained from both primary and secondary sources, as stated below.

3.3.1 Primary Data

The primary data were the set of data collected from the study area through sampling, and include those derived from observations made during sampling and laboratory results.

3.3.2 Secondary Data

These included all published materials used in this study. They are information and data from text books, monographs, lecture books, journals, periodicals, internet and literatures from other peoples work.

3.3. Sampling Design

Replicate sampling was made during the wet season (June-August) of 2011 between 0700 and 1100 hours. The study involved field sampling and laboratory analyses.

3.4. Sampling Locations

Five sampling locations were established within the vicinity of high marine transportation and other activities, and one other located upstream, away from areas of intense activities as control, all within the Federal Ocean and Light Terminals (FOT & FLT) navigational channel of the Onne Ports, Port Harcourt. Activities such as generation of garbage on board, bilging, bunkering and dumping of effluents were mostly associated with the sampling locations within the high marine transportation area. Marine vessels were also docked at these locations.

3.5. Field sampling

3.5.1. *In situ* measurements

In situ measurements for water temperature, pH, salinity, dissolved oxygen (DO), turbidity, and electrical conductivity were made with the HORIBA U-10 Water

Quality Checker that had been standardized with phthalate auto-calibration solution. Total dissolved solids (TDS) was also determined *in situ* electrometrically with HACH Conductivity meter (Model CO 150) with an inbuilt automatic TDS measuring device. In each case, the probe of the instrument was immersed in water and the parameter values read off directly in mg/L from the LCD display screen.

3.5.2. Collection of Water samples for laboratory analysis

Water samples were collected in 2 litres plastic bottles that had been severally rinsed with the channel water. Samples were then transported to the laboratory in iced coolers to maintain their integrity. However, water samples for the measurement of the 5-days biological oxygen demand (BOD_5) were collected in 250mL BOD bottles while submerged in water. Initial dissolved oxygen content was determined immediately in one of the bottles with the HORIBA U-10 Water Quality Checker. Water samples for trace metals concentration were collected in plastic containers and fixed with conc. HNO_3 in the ratio of 2:500, while those for the determination of total petroleum hydrocarbons (TPH) were fixed with conc. H_2SO_4. All samples were properly labeled.

3.6. Laboratory analysis

3.6.1. 5-Day Biological oxygen demand (BOD_5)

After a 5-day incubation period in a BOD bottle in the laboratory at 20 ± 2 °C in the dark (APHA, 1998), the DO of the sample was determined with the HORIBA U-10 Water Quality Checker. Result was computed to determine BOD_5 according to the equation,

$$\mathbf{BOD_5\ (mg/L) = \frac{DO_1 - DO_2}{P}}$$

where DO_1 = initial dissolved oxygen (on day 1),

DO_2 = dissolved oxygen after incubation (on day 5), and

P = dilution factor

3.6.2. Determination of nitrate (NO_3^-)

The cadmium reduction method (APHA, 1998) was employed in the determination of nitrate levels of the water samples. A cadmium based reagent pillow was added into 25ml of the water sample in a cuvette and shaken for 1 minute and allowed to stand for another 5 minutes for complete reaction to occur. The absorbance and concentration in mg/l was read at 500nm wavelength using HACH DR 2010 UV-visible spectrophotometer.

3.6.3. Determination of sulphate (SO_4^{2-})

The barium chloride (Turbidometric) method (APHA, 1998) was adopted. The barium chloride based powdered reagent pillow was added into 25ml of water sample. The mixture was properly mixed and allowed to stand for 5 minutes for reaction to occur. The absorbance and concentration in mg/l was read at 450nm wavelength using HACH DR 2010 UV-visible spectrophotometer.

3.6.4. Determination of phosphate (PO_4^{2-})

The ascorbic acid method, according to APHA (1998) was adopted for the determination of phosphate level of the river water. Ascorbic acid based reagent powdered pillow was added into 25ml of the water sample in a cuvette. The sample was allowed to stand for 2 minutes for reaction to occur. The absorbance and concentration in mg/l was read at 890nm wavelength using HACH DR 2010 UV-visible spectrophotometer.

3.6.5. Determination of chloride (Cl^-)

In the determination of the chloride content of water samples, the Argentometric method (APHA, 1998) was employed.

Reagents

a. Potassium chromate (K_2CrO_4) indicator solution

Five grams of K_2CrO_4 was added to 10ml-distilled water in a 50ml beaker. Drops of 0.014N $AgNO_3$ solution were added until a definite red precipitation was formed. The precipitate was allowed to stand for 12 hours, after which it was filtered and diluted to 10ml with distilled water.

b. 0.0141N standard silver nitrate

This was prepared by dissolving 0.2395g $AgNO_3$ in 100ml-distilled water.

c. 0.0141N standard sodium chloride

This was prepared by dissolving 82.4mg NaCl (dried at 140°C) in 100ml-distilled water.

Procedure

The pH of 60ml of the sample was first determined to be less than 7 and then adjusted to about 10 by adding drops of 1N NaOH solution. One millilitre of K_2CrO_4 indicator solution was added to 25ml of sample. This was followed with titration with $AgNO_3$ solution to a pinkish-yellow end point. For the standardization of the $AgNO_3$ solution, 25ml of distilled water containing the reagent (reagent blank) was also titrated with the $AgNO_3$ solution.

Calculation

Mg Cl/l = (A-B) x N x 35,450/Ml sample

where A is ml titration for sample,

B is ml titration for blank,

N is normality of $AgNO_3$

Mg NaCl/l = (mg Cl^-/l) x 1.65

3.6.6. Determination of total alkalinity

The potentiometric titration method of APHA (1998) was employed for the determination of total alkalinity of the river water.

Reagents

a. Standard 0.02N H_2SO_4

This was prepared by diluting 30ml of conc. H_2SO_4 (Specific gravity 1.84) with distilled water to make 1 litre, giving approximately 1N stock solution. Of this solution, 20ml was further diluted to make 1 litre, giving 0.02N solution. A quality checks of this solution against 0.02N Na_2CO_3, using methyl orange indicator was conducted.

b. Phenolphthalein indicator

This was formulated by adding 0.5% solution of phenolphthalein in 50% alcohol.

c. Standard 0.02N Na_2CO_3

To prepare this, 5.3g anhydrous and desiccated Na_2CO_3 was dissolved in 1 litre distilled water to make 0.1N Na_2CO_3 stock solution. Fifty millilitres of this solution was diluted to make 250ml, thus giving 0.02N Na_2CO_3.

d. Methyl orange indicator

This was prepared by making out 0.05% aqueous solution of methyl indicator.

Procedure

a. Phenolphthalein alkalinity (P)

Fifty millilitres of the sample was taken in white porcelain container and 2 drops of phenolphthalein indicator added to it. Whenever the sample remained colourless, P alkalinity was taken to be equal to zero. However, when it turned pink, it was titrated with 0.02N H_2SO_4 to a colourless end point.

Calculation

$$P\ (mg/l) = \frac{\text{ml of 0.02N } H_2SO_4 \times 1000}{\text{ml of sample water}}$$

b. Methyl orange alkalinity (M)

Using methyl orange indicator, the titration was continued until a colour change from yellow to faint orange was observed, indicating the end point.

Calculation

$$M\ (mg/l) = \frac{ml\ of\ 0.02N\ H_2SO_4 \times 1000}{ml\ of\ sample\ water}$$

3.6.7. Determination of total suspended solids (TSS)

An aliquot of the sample was filtered through a pre-weighed glass-fibre filter paper, and the filter paper was oven-dried at 105ºC for 3 hours according to ASTM D1888-78 method. The weight of the filter paper was measured with a Mettler H78AR analytical balance. The difference in weight was taken as the TSS in mg/l.

3.6.8. Determination of total petroleum hydrocarbons (THC) content

The water samples were extracted by pouring 20ml carbon tetrachloride in seperatory funnel and shaking the mixture vigorously for 5 minutes with intermittent release of air. This was then allowed to stand as to enable the extracts settle to the bottom of the funnel. The volume of the water was measured with a measuring cylinder and the value recorded. Extract was analyzed in an infrared spectrophotometer. Cuvette measuring 1cm x 1cm was filled with the extract and corked. The extract was treated with silica gel and scanned between $3000cm^{-1}$ and $2700\ cm^{-1}$ wave numbers while placed in the sample compartment of the FTIR.

3.6.9. Determination of trace metals (Al, Cd, Cr, Cu, Fe, Pb) concentrations

Method: The API-RP45–flame atomization method was used.

Apparatus: 400mL conical flask, atomic absorption spectrophotometer (AAS).

Reagent: Conc. Trioxonitrate (V) acid (HNO_3), etc

Procedure: 5ml of concentrated HNO_3 and a few boiling chips of Hengar granules were mixed with 250ml of the sample in a 400ml conical flask.

- The mixture was then boiled slowly and the content evaporated on a hot plate to the lowest volume possible (about 10–30ml) before precipitation occurred.
- Concentrated HNO_3 was added during the heating process. This was done to attain necessary complete digestion indicated by the observation of a light clear solution.
- During digestion, precaution was followed not to allow the sample dry completely.

- 10ml of water was used to rinse the flask and added to the volumetric flask; further allowed to cool, diluted to 50ml mark and mixed thoroughly.
- From the mixture, the concentrations in mg/L of the trace elements in the cooled sample were determined by means of an atomic absorption spectrophotometer.
- The specific metal standards in the linear range of the metals were used to calibrate the equipment.
- The concentrated or digested samples were then aspirated and their actual concentrations obtained by referring to the calibration graph and necessary calculations made.

3.7. Statistical Analysis

Descriptive statistics as provided by the SPSS© Version 17.0 and MS Excel© 2007 were used to obtain means, standard error, range, and graphical representations of ensuing data. The interrelationships existing between the physicochemical variables were explored using the Pearson correlation coefficient (r). The test of homogeneity in mean variances of the variables measured spatially was conducted with the single factor analysis of variance (ANOVA) and post-hoc structure of group means detected with means plots.

CHAPTER FOUR

4.0. RESULTS

4.1. Variation in physicochemical parameters

The variations in physicochemical quality of the Ogu Creek in Onne Port during the study period are shown in Appendix 1. Total dissolved solids (TDS) (Range=37.40 mg/L), turbidity (Range=36.70 mg/L), conductivity (Range=1660.00 µS/cm), sulphate (Range=55.00 mg/L) and chloride ions (Range=98.10 mg/L) recorded comparatively wide variations during the study period. Temperature, pH and salinity varied from 27.80-28.50 (28.25 ± 0.12) °C, 5.28-6.50 (6.02 ± 0.20) and 36.00-36.70 (36.32 ± 0.12) ‰, respectively (Table 4.1). Dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS) and total dissolved solids (TDS) varied between 3.00 and 3.80 (3.38 ± 0.14), 1.20 and 2.50 (1.74 ± 0.21), 18.40 and 35.00 (25.05 ± 2.45), and, 25.60 and 63.00 (53.60 ± 5.75) mg/L, respectively.

Minimum and maximum turbidity, alkalinity, conductivity, chloride and total petroleum hydrocarbons (TPH) were 58.50 and 95.20 (81.23 ± 5.22) NTU, 11.50 and 21.50 (17.92 ± 1.61) mg/L, 840.00 and 2500.00 (1815.00 ± 238.24) µS/cm, 38.40 and 136.50 (95.55 ± 16.66) mg/L, and, 1.60 and 2.60 (2.10 ± 0.15) mg/L,

Table 4.1. Variations in physicochemical parameters of water in Onne Port

Parameters	Minimum	Maximum	Range	Mean	SE	FME
Temperature (°C)	27.80	28.50	0.70	28.25	0.12	20-33
pH	5.28	6.50	1.22	6.02	0.20	6.0-9.0
Salinity (‰)	36.00	36.70	0.70	36.32	0.12	NS
DO (mg/L)	3.00	3.80	0.80	3.38	0.14	6.8
BOD (mg/L)	1.20	2.50	1.30	1.74	0.21	4.00
TSS (mg/L)	18.40	35.00	16.60	25.05	2.45	NS
TDS (mg/L)	25.60	63.00	37.40	53.60	5.75	NS
Turbidity (NTU)	58.50	95.20	36.70	81.23	5.22	NS
Alkalinity (mg/L)	11.50	21.50	10.00	17.92	1.61	NS
Conductivity (μS/cm)	840.00	2500.00	1660.00	1815.00	238.24	NS
TPH (mg/L)	1.60	2.60	1.00	2.10	0.15	NS
NO_3^- (mg/L)	2.00	4.40	2.40	3.62	0.36	0.06
PO_4^{2-} (mg/L)	1.05	3.70	2.65	2.59	0.38	NS
SO_4^{2-} (mg/L)	35.50	90.50	55.00	78.07	8.70	NS
Cl^- (mg/L)	38.40	136.50	98.10	95.55	16.66	NS
Al (mg/L)	0.60	1.20	0.60	0.95	0.08	0.005-1.00
Cd (mg/L)	0.002	0.060	0.058	0.022	0.011	0.2-1.8
Cr (mg/L)	0.02	0.08	0.06	0.05	0.01	0.02-2.00
Cu (mg/L)	0.05	0.12	0.07	0.08	0.01	2.0-4.0
Fe (mg/L)	0.80	3.25	2.45	2.67	0.38	1.00
Pb (mg/L)	0.011	0.060	0.049	0.030	0.009	1.7

SE = standard error of mean, DO=dissolved oxygen, BOD=biological oxygen demand, TSS=total dissolved solids, TDS=total dissolved solids, TPH=total petroleum hydrocarbons, FME=Federal Ministry of Environment 2001, NS=Not specified

respectively. The nutrients- NO_3^-, PO_4^{2-} and SO_4^{2-} varied from 2.00-4.40 (3.62 ± 0.35), 1.05-3.70 (2.59 ± 0.38) and 35.50-90.50 (78.07 ± 8.70) mg/L, respectively. The trace metals (Al, Cd and Cr) varied from 0.60 to 1.20, 0.002 to 0.060, and 0.02 to 0.08 mg/L, with means of 0.95 (±0.08), 0.022 (±0.011) and 0.05 (±0.01) mg/L, respectively. However, Cu, Fe and Pb contents varied from 0.05-0.12 (0.08 ± 0.01), 0.80-3.25 (2.67 ± 0.38), and 0.011-0.060 (0.030 ± 0.009) mg/L, respectively.

Of the parameters measured in this study, the lower limit of pH (5.28), the upper limit of Al (1.20 mg/L), the upper limit of Fe (3.25 mg/L), as well as BOD, Cd, and Cu contents were all outside the recommended limits of 6.0, 0.005-1.000 mg/L, 1.00 mg/L, 0.00 mg/L, 0.2-1.8 mg/L, and 2.0-4.0 mg/L, respectively for aquatic life by the Federal Ministry of Environment.

4.2. Spatial variation in physicochemical parameters

Longitudinal spatial variations were observed in the physicochemical parameters measured, with the control sampling point (SP) recording most of the least concentrations than the others. However, pH and DO recorded maximum levels (6.50 and 3.80 mg/L, respectively) in the control location. Maximum temperature (28.5 °C), pH (6.50) and alkalinity (21.5 mg/L) were recorded in SP 1and Control (Fig. 4.1),

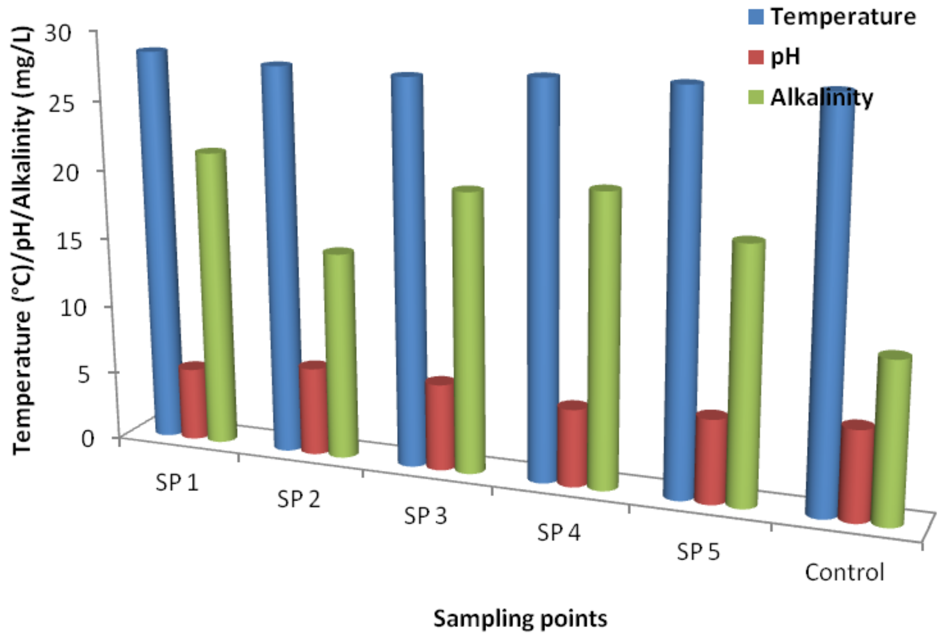

Fig. 4.1. Spatial variations in temperature, pH and alkalinity of Ogu Creek in Onne Ports

Control, and SP1, respectively, while their least values of 27.8 °C, 5.28, and 11.5 mg/L were recorded in SP 3, SP 1, and Control, respectively (Fig. 4.1). Maximum salinity, TSS and TDS contents of 36.7 ‰, 35.0 mg/L, and 63.0 mg/L were recorded in SP 5, SP 5, and SP 4, respectively (Fig. 4.2). Minimum values of 36.0 ‰, 18.4 mg/L, and 25.6 mg/L were recorded in SPs 1&3, Control, and Control locations, respectively.

Figure 4.3 shows that minimum and maximum DO (3.00 and 3.80 mg/L), BOD (1.20 and 2.50 mg/L), and TPH (1.60 and 2.60 mg/L) were recorded in SP 1, SP 3 & Control, Control & SP 4, and Control & SP 5, respectively (Fig. 4.3). Minimum and maximum turbidity (58.5 and 95.2 NTU), conductivity (840 and 2500 µS/cm), and chloride content (38.40 and 136.50 mg/L) were recorded in Control and SP 1, Control and SP 3, and Control and SP 5, respectively (Fig. 4.4). Maximum nitrate, phosphate, and sulphate contents of 2.0, 3.70, and 90.50 mg/L were recorded in SP 5, SP 4, and SP 2, respectively (Fig. 4.5), while minimum contents of 2.0, 1.05, and 35.50 mg/L, respectively were all recorded in the control location.

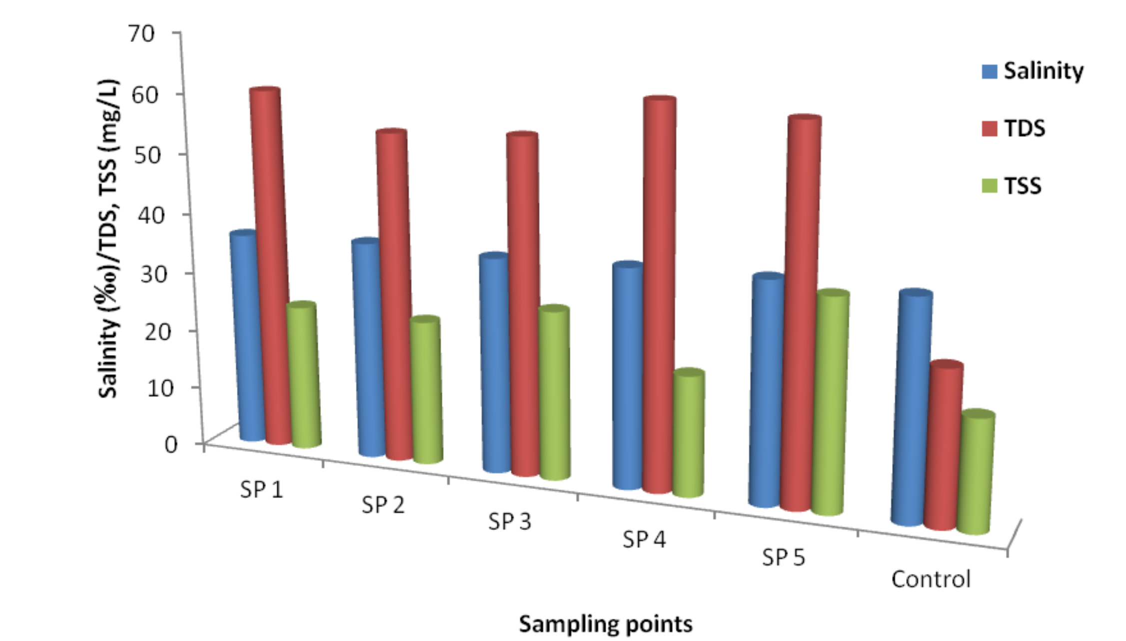

Fig. 4.2. Spatial variations in salinity, total suspended solids and total dissolved solids of Ogu Creek in Onne Ports

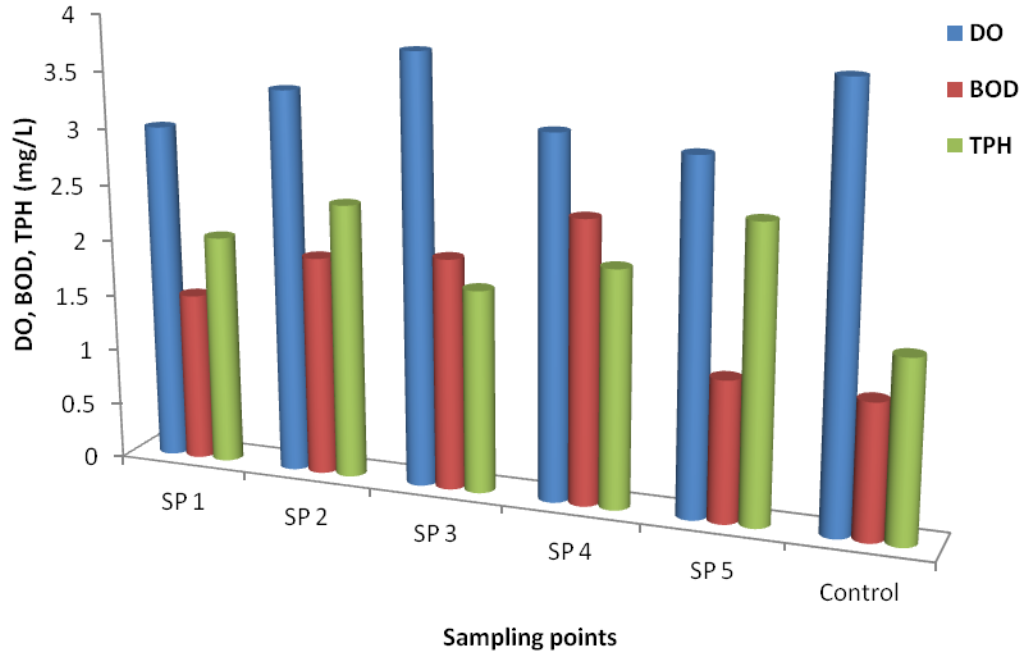

Fig. 4.3. Spatial variations in dissolved oxygen, biological oxygen demand and total petroleum hydrocarbon contents of Ogu Creek in Onne Ports

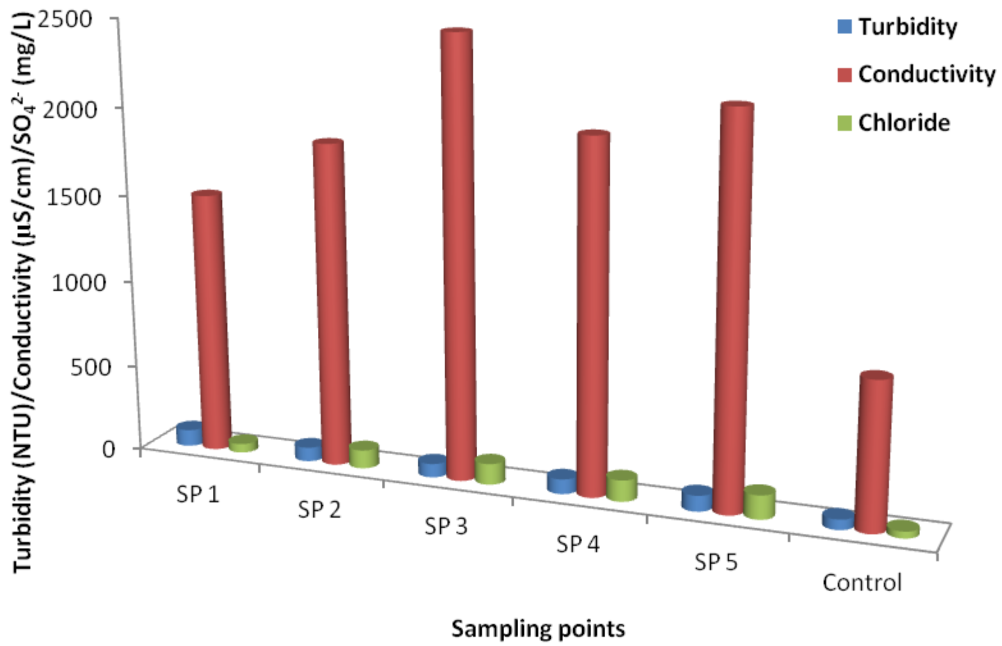

Fig. 4.4. Spatial variations in turbidity, conductivity and chloride contents of Ogu Creek in Onne Ports

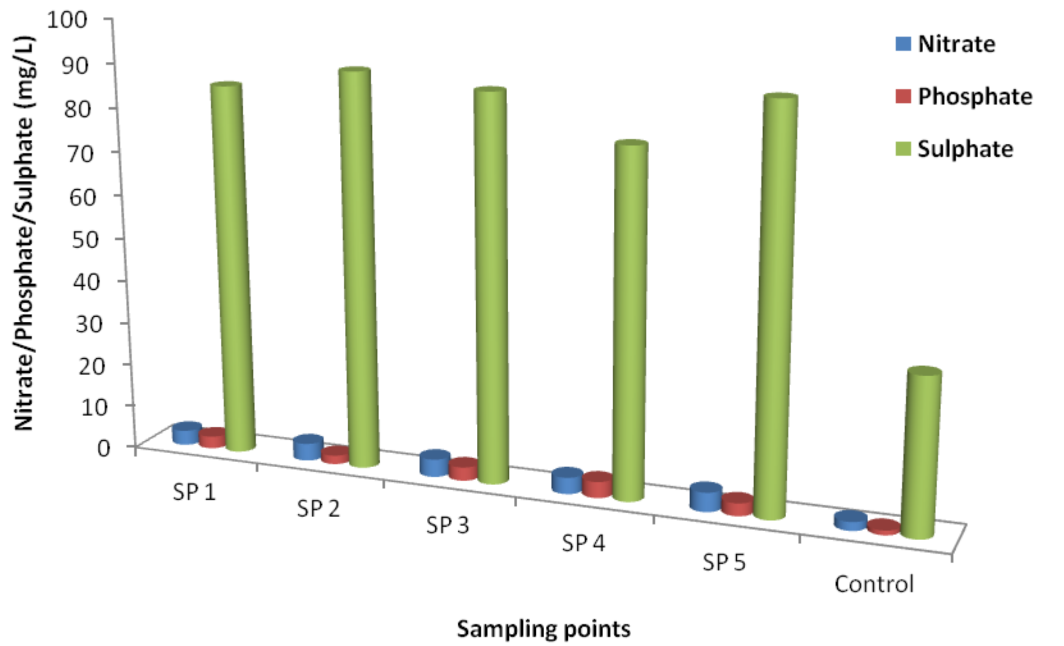

Fig. 4.5. Spatial variations in nitrate, phosphate and sulphate contents of Ogu Creek in Onne Ports

The trace metals (Al, Cu and Fe) contents were highest (1.20, 0.12, and 3.25 mg/L) in SP 5, SP 4, and SP 5, respectively, while their minimum contents (0.60, 0.05, and 0.80 mg/L) were recorded in the control location, SP 2&Control, and control location, respectively (Fig. 4.6). Cd, Cr and Pb recorded minimum and maximum

levels of 0.002 and 0.06, 0.02 and 0.08, and 0.011 and 0.060 mg/L in the Control and SP 5, SP 4&Control and SP 5, and SP 1 and SP 5, respectively (Fig. 4.7).

4.3. Test of Homogeneity in spatial mean variance

The test of homogeneity in mean variance of the physicochemical variables across the sampling points revealed significant inequality as $F_{(8.41)} > F_{crit(3.88)}$ at $P<0.05$ ($P=0.0041$) (Appendix 2). A further structure of group means, using means plots that utilized the control location as predictor variable revealed that electrical conductivity (840.000) was most responsible for the observed heterogeneity in SP 1-SP 5 (Figs. 4.8-4.12).

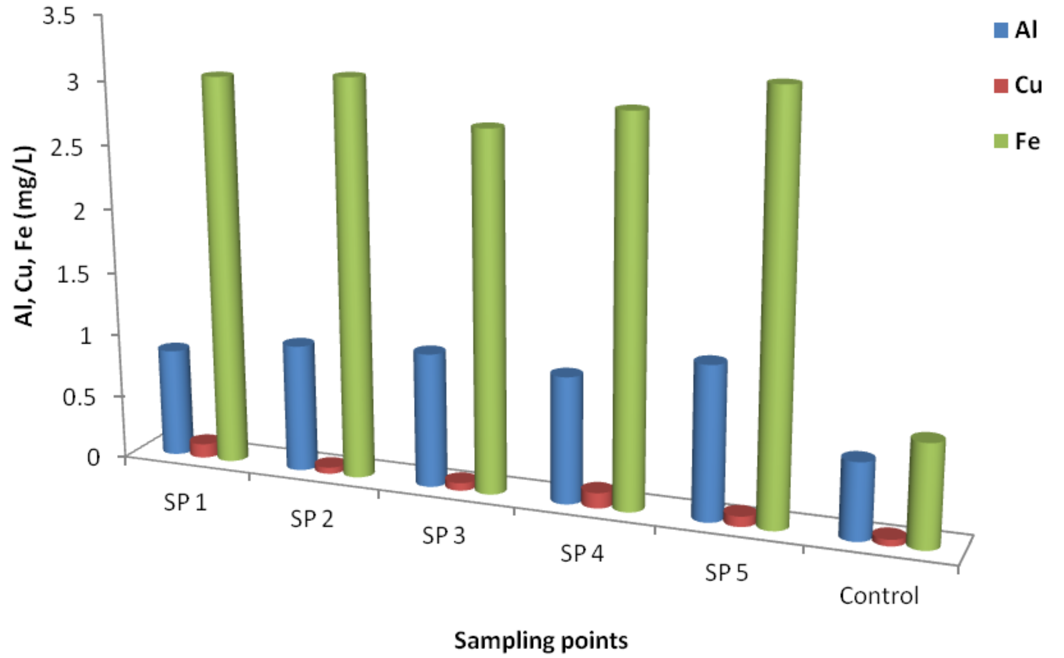

Fig. 4.6. Spatial variations in aluminium, copper and iron contents of Ogu Creek in Onne Ports

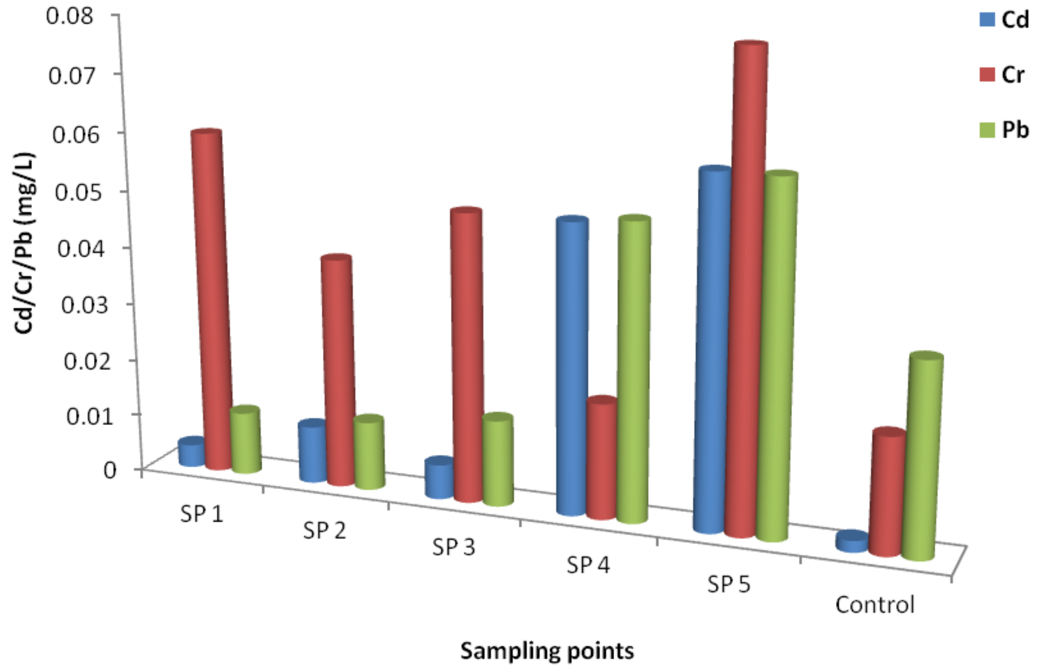

Fig. 4.7. Spatial variations in cadmium, chromium and lead contents of Ogu Creek in Onne Ports

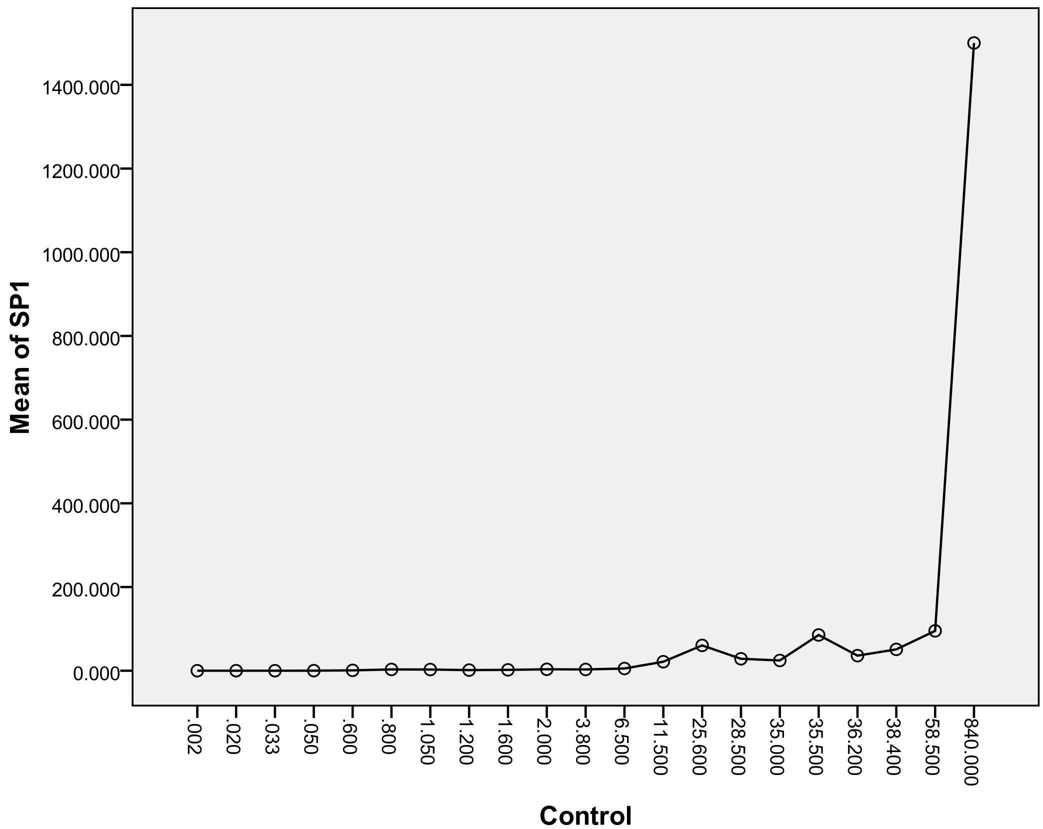

Fig. 4.8. Means plot between the Control location and sampling point 1

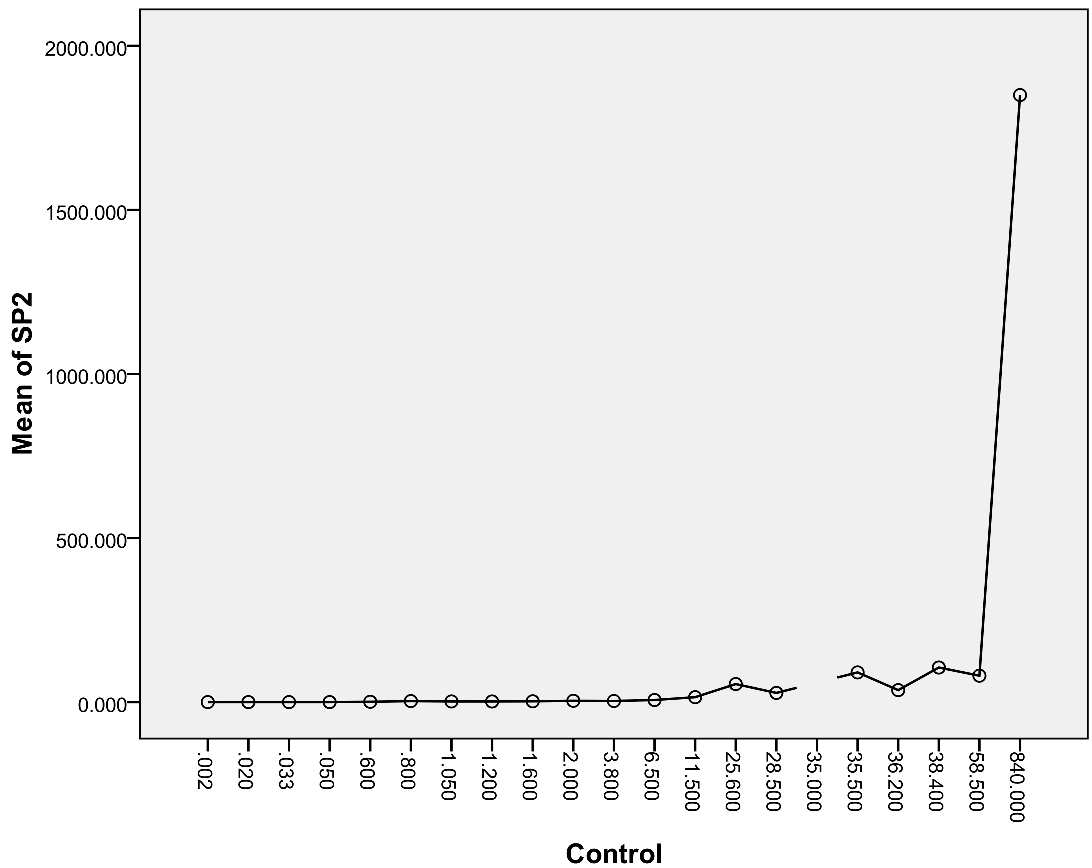

Fig. 4.9. Means plot between the Control location and sampling point 2

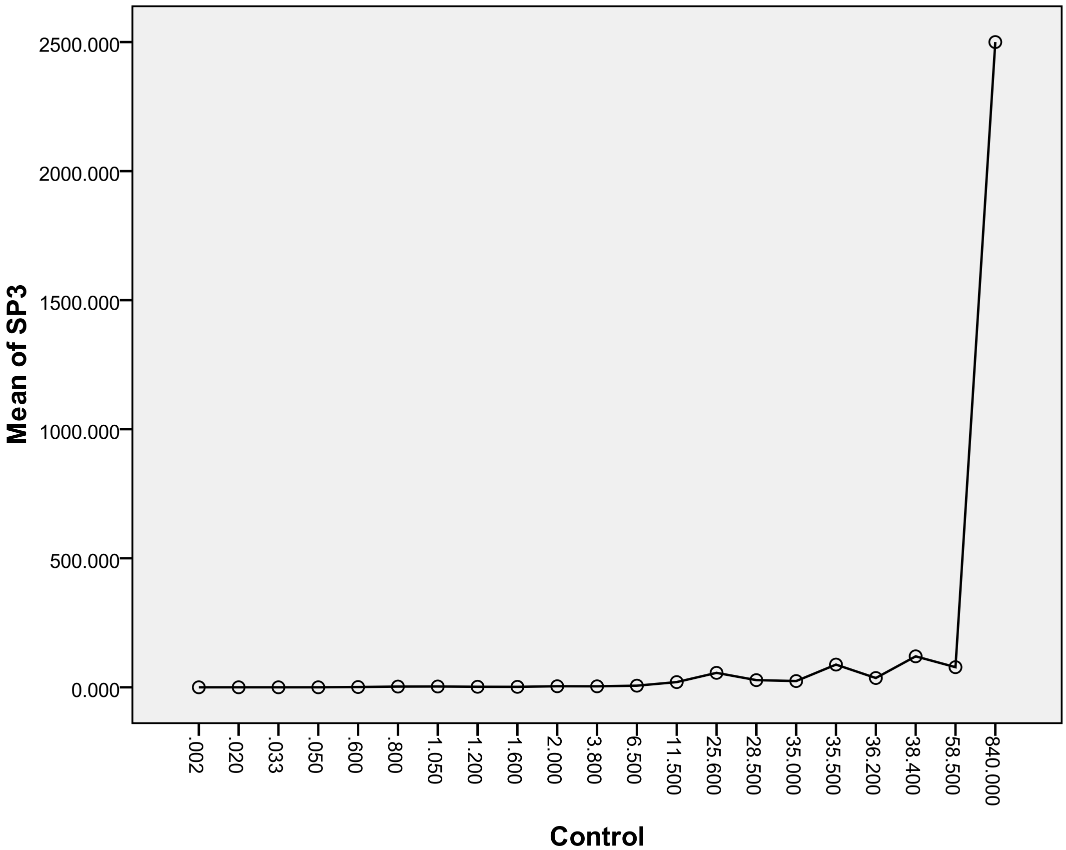

Fig. 4.10. Means plot between the Control location and sampling point 3

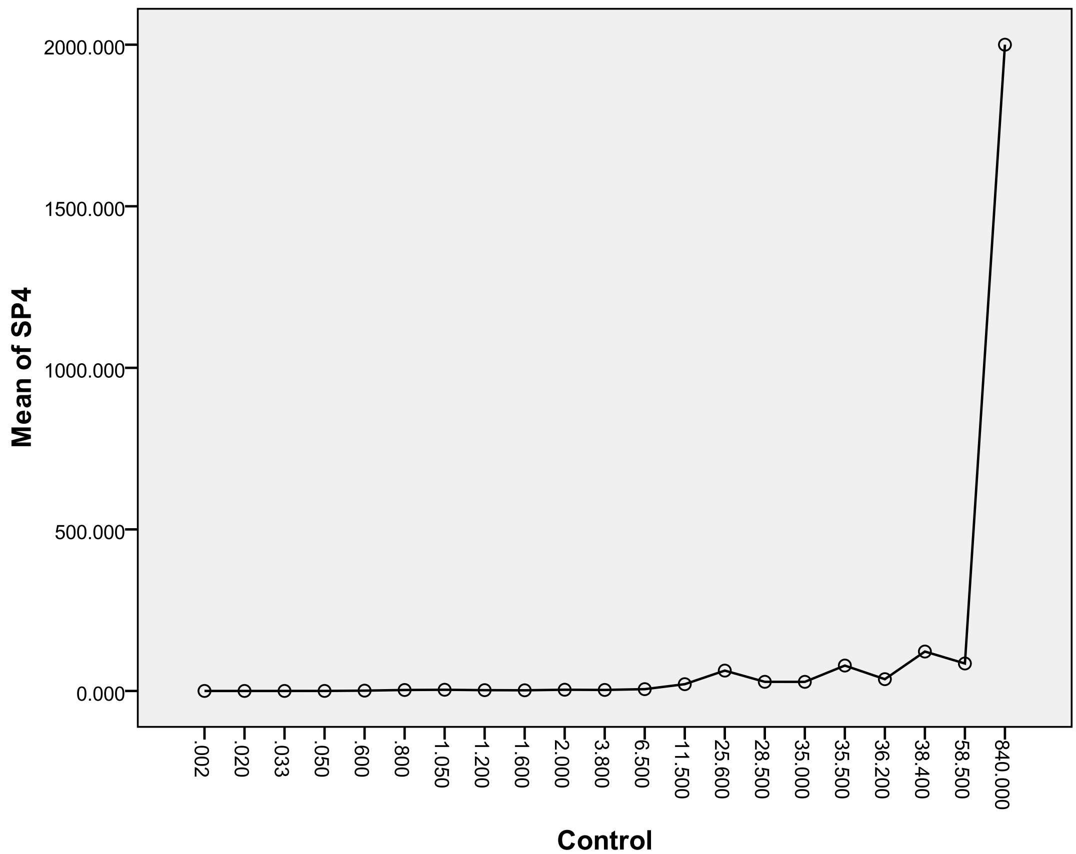

Fig. 4.11. Means plot between the Control location and sampling point 4

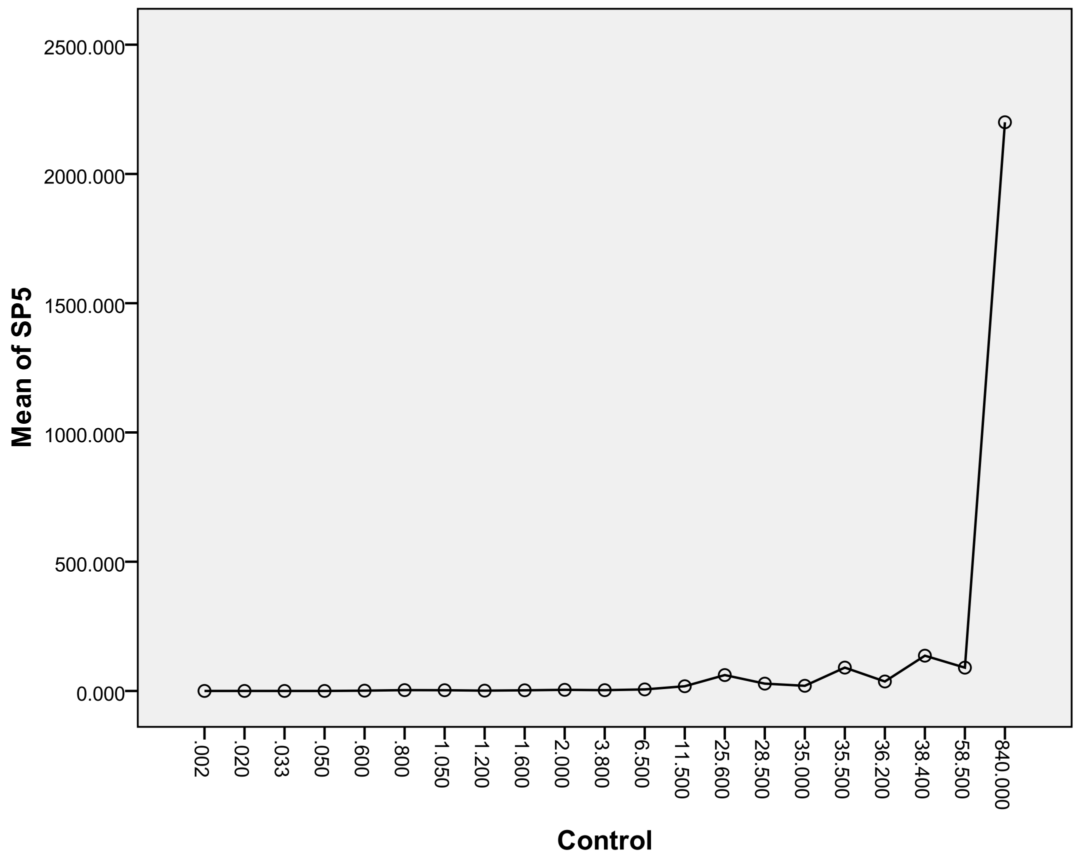

Fig. 4.12. Means plot between the Control location and sampling point 5

4.4. Interactions between the physicochemical parameters

The physicochemical parameters measured showed significant interactions at both the 95 and 99% confidence limits (Table 4.2). At $P<0.05$, TDS correlated positively with alkalinity (r=0.859), nitrate (r=0.883), phosphate (r=0.881) and Al (r=0.818), turbidity correlated with alkalinity (r=0.818), sulphate (r=0.838) and Fe content (r=0.903), conductivity correlated with sulphate (r=0.825), chloride (r=0.903) and Al (r=0.916), nitrate correlated with chloride (r=0.882), sulphate correlated with Al (r=0.867), Al correlated with Fe (r=0.854), while Cd correlated with Pb (r=0.896). However, DO correlated negatively with turbidity (r=0.871) at $P<0.05$.

At $P<0.01$, TSS correlated positively with Cr (r=0.928), TDS correlated with turbidity (r=0.923), sulphate (r=0.924), and Fe (r=0.975), alkalinity correlated with phosphate (r=930), conductivity correlated with nitrate (r=0.928), nitrate correlated with sulphate (r=0.946), Al (r=0.977), and Fe (r=0.926), sulphate correlated with Fe (r=0.977), and chloride correlated with Al (r=0.928). However, pH correlated negatively with Cu (r=-0.946) at $P<0.01$.

Table 4.2. Interactions of the physicochemical parameters of Ogu Creek in Onne Port using correlation coefficient (r)

	Temp	pH	Salinity	DO	BOD	TSS	TDS	Turbidity	Alka	Cond	NO_3^-	TPH	PO_4^{2-}	SO_4^{2-}	Cl^-	Al	Cd	Cr	Cu	Fe	Pb
pH	-0.419																				
Salinity	0.130	0.130																			
DO	-0.468	-0.468	-0.389																		
BOD	-0.574	-0.574	0.041	0.000																	
TSS	-0.204	-0.204	0.306	-0.302	-0.274																
TDS	-0.249	-0.249	0.259	-0.703	0.494	0.521															
Turb	0.053	0.053	0.174	-0.871*	0.191	0.533	0.923**														
Alk	-0.140	-0.140	-0.162	-0.557	0.483	0.327	0.859*	0.818*													
Cond	-0.681	-0.681	0.216	-0.140	0.519	0.668	0.770	0.527	0.637												
NO_3^-	-0.521	-0.521	0.404	-0.426	0.415	0.736	0.883*	0.721	0.618	0.928**											
TPH	-0.023	-0.023	0.768	-0.686	0.016	0.629	0.656	0.660	0.209	0.457	0.740										
PO_4^{2-}	-0.233	-0.233	0.121	-0.498	0.632	0.347	0.881*	0.732	0.930**	0.767	0.727	0.320									
SO_4^{2-}	-0.473	-0.361	0.212	-0.532	0.391	0.657	0.924**	0.838*	0.697	0.825*	0.946**	0.706	0.696								
Cl^-	-0.535	0.058	0.593	-0.180	0.491	0.611	0.675	0.405	0.413	0.903*	0.882*	0.616	0.669	0.688							
Al	-0.443	-0.119	0.512	-0.401	0.311	0.806	0.818**	0.657	0.544	0.916*	0.977**	0.759	0.693	0.867*	0.928**						
Cd	0.209	-0.249	0.808	-0.536	0.156	0.437	0.518	0.429	0.320	0.445	0.529	0.629	0.570	0.324	0.707	0.650					
Cr	0.015	-0.214	0.131	-0.477	-0.429	0.928**	0.515	0.657	0.383	0.464	0.601	0.590	0.277	0.632	0.336	0.636	0.277				
Cu	0.420	-0.946**	0.048	-0.753	0.344	-0.062	0.619	0.684	0.773	0.139	0.214	0.161	0.731	0.290	0.104	0.178	0.469	0.070			
Fe	-0.328	-0.494	0.310	-0.673	0.430	0.589	0.975**	0.903*	0.747	0.774	0.926**	0.755	0.766	0.977**	0.687	0.854*	0.454	0.579	0.457		
Pb	0.418	-0.058	0.722	-0.280	-0.078	0.237	0.106	0.056	0.017	0.122	0.137	0.321	0.272	-0.114	0.442	0.313	0.896*	0.072	0.315	0.017	

*= Significant at P<0.05, **= Significant at P<0.01, Temp=temperature, DO=dissolved oxygen, BOD=biological oxygen demand, TSS=total suspended solids, TDS=total dissolved solids, Turb= turbidity, Alk=alkalinity, Cond= conductivity, TPH=total petroleum hydrocarbons

CHAPTER FIVE

5.0 DISCUSSION, SUMMARY AND CONCLUSION

5.1 Discussion

The quality of any water body is governed by its physicochemical regime (Adakole *et al.*, 2003) and as such, the monitoring of these factors is vital for both long and short term environmental management (Wood, 1995). According to Adakole *et al.* (1998), the distribution and productivity levels of resident organisms are largely determined by these physicochemical factors in aquatic ecosystems. According to Spaak and Bauchrowitz (2010), anthropogenic environmental changes that alter these factors affect overall natural biodiversity. This therefore had prompted several authors to investigate the direct effect of interactions of many frequently measured physicochemical variables on biotic residents of aquatic ecosystems (Jonnalagadda and Mhere, 2001; Kemdirim, 1993; Wood, 1995). The UNEP GEMS (2006) therefore states that temperature affects the speed of chemical reactions, the rate at which algae and aquatic plants photosynthesize, the metabolic rate of other organisms, as well as how pollutants, parasites, and other pathogens interact with aquatic residents. Temperature as an important factor in aquatic systems can cause mortality and can also influence the solubility of dissolved oxygen and other materials in the water column (e.g. NH_3, H_2S, CO_2, etc).

The narrow variation recorded in temperature of this study could make the water suitable for aquatic organisms, since they also have narrow temperature tolerance. Temperature range of this study is also similar to many other waters of the Niger Delta area (NADECO, 1980; SPDC, 1998). The UNEP GEMS (2006) stated that though, water bodies have the ability to buffer against atmospheric temperature extremes, even moderate changes in water temperature can have serious impacts on aquatic life, including bacteria, algae, invertebrates and fish.

The wide variation recorded for TDS, turbidity, conductivity, SO_4^{2-} and Cl^- ions is attributed to increased inputs from the several industrial activities in and around the Port, as well as from catchment lands through runoffs and flooding. Okpokwasili and Olisa (1991) and Odokuma and Okpokwasili (1992) reported that concentrations of sulphate in water bodies could also be contributed by the use of sulphate containing detergents by humans in catchment areas. However, the low nutrients (NO_3^- and PO_4^{2-}) loadings in this study preclude possible eutrophication in the channel. This is because nitrogen and phosphorus are considered to be the primary drivers of eutrophication of aquatic ecosystems (Kiely, 1998), whereby increased nutrient concentrations lead to increased primary productivity (Ogbuagu and Ayoade, 2011a).

According to the UNEP GEMS (2006), the importance of pH in aquatic environment lies in its close link to biological productivity, even as the tolerance of individual species varies. The absence of marked spatial variation in pH at the 6 sampling points of this study indicates stable habitat. According to Grant (2002), the pH of water is affected considerably as photosynthetic activity removes carbon (IV) oxide from water and shifts the carbonate-bicarbonate equilibrium. The slightly acidic pH range of 5.28-6.50 recorded in this study conformed to values previously reported in Niger Delta freshwaters by Ombu (1987), Hart (1994), Yakubu *et al.* (1996), Mansi (1997) and Ikomah (1999). The lower pH range of this study falls outside the FME regulations for aquatic life (6.0-9.0). This lower range makes it quite unsuitable for fish production in the Creek (Adakole and Anunne, 2003; Adakole *et al.*, 2003; Adeniyi, 1986).

The narrow variability in salinity in this study indicates stability in a saline aquatic ecosystem. It is known that salinity is an indication of the concentration of dissolved salts such as Ca^{+}, Mg^{2+}, Na^{+}, and K^{+}, and the major anions such as CO_3^{2-}, HCO_3^{2-}, SO_4^{2-}, and Cl^{-}. The several industrial, municipal and agricultural discharges into the Creek may have contributed further ions to the receiving Creeks serving the Port.

Dissolved oxygen (DO) as one of the most important components of aquatic systems is required for metabolism in aerobic organisms, and it influences inorganic chemical reactions (UNEP GEMS, 2006). Oxygen is often used as an indicator of water quality, such that high concentrations usually indicate good water quality. The amount of DO depends highly on temperature and somewhat on atmospheric pressure (UNEP GEMS, 2006). The amount of any gas, including oxygen, dissolved in water is inversely proportional to the temperature of the water. Decomposition processes consume oxygen from the water by bacterial respiration and many aquatic ecosystems rely heavily on external subsidies of organic matter to sustain production. It has also been observed that excess inputs of organic matter from drainage basin can upset the production balance of an aquatic system and lead to excessive bacterial production and consumption of DO that could compromise the integrity of the ecosystem and lead to favourable conditions for growth of less than ideal species (Spaak and Bauchrowitz, 2010).

BOD reflects the degree of organic matter pollution of a water body, and it is a measure of the amount of oxygen removed from aquatic environments by aerobic microorganisms for their metabolic requirements during the breakdown of organic matter. UNEP GEMS (2006) states that BOD (and COD) is a common measure of water quality that reflect the degree of organic matter pollution of a water body.

Though the BOD of the current study indicates pollution of the Creek serving the Port during the study period, it could still support aquatic life, going by the FME (2002) 4.0 mg/L maximum permissible limit.

Pratt *et al.* (1971) classified waters with TSS of 278 mg/l and above as grossly polluted. The high solvating nature of water makes it an excellent medium for several substances in the environment to dissolve in. Since many of these solutes could be pollutants in the aquatic environment, TDS levels have thus been used to evaluate the purity of water. In the present study, TDS values fairly followed the same trend as TSS; indicating that suspended particulate matter eventually gets dissolved in water.

Turbidity refers to clarity of water, and the greater the amount of suspended solids in water, the murkier it appears, and the higher the measured turbidity. The major sources of this parameter in open water zones is typically plankton, but closer to shore, particulates may also include clays and silts from shoreline erosion, re-suspended bottom sediments, and organic detritus from stream and/or water discharges. According to Ogbuagu and Ayoade (2011b), high turbidity could reduce primary production by the autotrophic algae, and thus, reduce the biotic diversity and abundance through trophic impairments.

The UNEP GEMS (2006) states that alkalinity is a related concept that is commonly used to indicate a system's capacity to buffer against acid impacts. Buffering capacity is the ability of a body of water to resist or dampen changes in pH. Alkaline compounds in water such as bicarbonates, carbonates, and hydroxides remove H^+ ions and lower the acidity of the water (i.e., increase pH).

The high conductivities recorded in the study indicate a saline environment. At low levels of electrical conductivity, major ions may determine the nature of the fauna (Moss, 1993; Adakole *et al.*, 2003). Conductivity values fell outside the maximum acceptable limit of 1000 µS/cm by the CSPI (2009), (which recommended maximum value of 1000 µS/cm for drinking water in Nigeria).

The UNEP GEMS (2006) states that primary producers assimilate inorganic nitrogen as ammonium (NH_4^+) and nitrate (NO_3^-) ions, and organic nitrogen is returned to the inorganic nutrient pool through bacterial decomposition and excretion of NH_4^+ and amino acids by living organisms. This brings to the fore the importance of nitrate in major cellular components of organisms as well as the entire ecosystem. Contributions from industrial activities, as well as those from agricultural practices by inhabitants of the study could constitute nitrates from soils into the water body. Nitrate contents range of 2.0–4.4 mg/L recorded in this study falls above the FME's 0.06 mg/l limit for aquatic life. However, values are comparable to those of earlier works conducted in the Niger Delta water bodies by Amadi *et al.*, (1997) and Edoghotu and Aleleye-Wokoma (2007). Nitrate concentrations did not vary markedly across the sampling points; an indication of homogeneity in its natural and anthropogenic inputs at those locations.

Like other nutrients, the sources of phosphate in aquatic environments have been identified as natural weathering of minerals in the drainage basin, from biological decomposition, and as runoff from human activities in urban and agricultural areas (UNEP GEMS, 2006). Phosphate and nitrate are also important for plankton bloom and eutrophication (Kiely, 1998).

Okpokwasili and Olisa (1991) and Odokuma and Okpokwasili (1992) reported that concentrations of phosphate ions in water bodies could even be contributed by the use of sulphate containing detergents by local inhabitants during washing.

The chloride ion contents in water supplies could indicate salt water intrusion, sewage or other pollution. The chloride ion contents of surface and groundwaters ranges usually from 5 to 200mg/l, while sea water content could be up to 19,000mg/l (UNEP GEMS, 2006). Compounds of chlorine such as polychlorinated biphenyls (PCBs) are very hazardous and persistent in aquatic systems. Thus they can remain in the water and continue to degrade aquatic systems, and subsequently affect human health. It is usually introduced into water by improperly treated sewage, agricultural practice etc. This compound at high level is carcinogenic and tends to magnify through the food chain. Polystyrene plastic foam that contains (PCBs), when broken into pellets, resembling food. When consumed by sea turtles (their buoyancy keeps them from diving), it can clog their systems, causing them to starve to death. In low concentrations, chlorine are added to water supply to control algae growth and help to kill bacterial and other pathogens.

According to UNEP GEMS (2006), total hydrocarbon can have population effects through the destruction of more sensitive juvenile life-stages or through the reduction of prey species. Oil is also capable of causing sub-lethal stress effects, carcinogenic and mutagenic effects, and can affect the behaviour of individual organisms. However, Moore and Moore, (1976) reported that TPH concentration of less than 100 mg/l in the environment (as in the current study) is considered to be of biogenic origin while excess may be due to anthropogenic inputs such as board engines and oil effluents of crude oil pollution. Wake (2005) reported that oil-laden effluents could lead to reductions in diversity and abundance of aquatic fauna.

Trace metals occur naturally and become integrated into aquatic organisms through trophic relationships and water. Certain trace metals such as Hg, Cu, Se, and Zn are essential metabolic components in low concentrations. However, metals tend to bioaccumulate in tissues and prolonged exposure or exposure at higher concentrations can lead to health problems. Elevated concentrations can also have negative consequences on both wildlife and aquatic foods. According to Hering (2008), chronic exposure to chemical contaminants, such as trace metals even at low levels, can cause serious health effects including disfigurement, cancer, and premature death. Metals tend to be strongly associated with sediments in aquatic systems and their release to the surrounding water is largely a function of pH, oxidation-reduction state, and organic matter content of the water (and the same is also true for nutrients and organic compounds) (UNEP GEMS, 2006). The high levels of Al, Fe and Cu that are outside regulatory limits portend grave consequences to public consumers of sea foods from this Creek and its surrounding water bodies.

The observed relative higher concentrations of several parameters in sampling points 1-5 than in the control location indicates proximal inputs from the Ports activities, as well as from other sources in catchment or adjoining areas. However, the observed equality in spatial variation of the physicochemical parameters (except in electrical conductivity) indicates non-existence of microhabitats along the gradient of the Creek. This must have been aided by tidal influences that encourage turbulent and mixing effects. The stretch of the Creek is exposed to various activities such as the introduction of varying domestic and industrial wastes, as well as runoffs from dumpsites in the neighbourhood land areas.

The observed significant positive correlations between TDS and nitrate and phosphate indicate that nitrate and phosphate ions also contributed to the total dissolved solids of the river. The correlation between conductivity and sulphate and chloride ions confirm that electrical conductivity is constituted by dissolved ion species. That between TDS and turbidity indicates that dissolved solids contribute to the murkiness of water column. The negative correlation between pH and Cu ions confirms the established inverse relationship that exists between acidification and bioavailability of trace elements in environmental matrices.

5.2. Summary and Conclusion

The Ogu Creek serving the Onne Ports in Port Harcourt revealed wide variations in TDS, turbidity, conductivity, sulphate and chloride ion contents, and narrow variations in temperature, pH, salinity, DO, BOD_5, TSS, alkalinity, nitrate, total petroleum hydrocarbons, phosphate, Al, Cd, Cr, Cu, Fe and Pb contents. The levels of several of these parameters were similar to those recorded for other inland waters of the Niger Delta area of Nigeria.

Other than the lower levels of pH, upper levels of Al and Fe contents, Cd and Cu contents, the other physicochemical variables measured fell within recommended limits of water for aquatic life by the Federal Ministry of Environment in Nigeria.

The control sampling location recorded most of the least levels of parameters measured. Other than in electrical conductivity, the other parameters measured did not reveal marked spatial variations in the Creek during the study period. This indicated proximal inputs of pollutants from ports activities. Dissolved solids in water column consisted of nitrate, phosphate and chloride ions, which also constituted electrical conductivity. pH had an inverse relationship with Cu ions [in conformity to the established bioavailability of more trace elements in increasingly acidic media by Fleischer *et al.*, (1993)], even as dissolved solids constituted turbidity in water column. BOD values recorded in the study indicates some degree of organic pollution of the Creek.

5.3. Recommendations

Following the findings made in the current study, the following recommendations are made:

1. The Rivers State environmental protection agencies (RSEPA) should develop practicable standards and regulations for the protection of the Creek.
2. In the interim, RSEPA should operate regular surveillance to prevent further pollution of the Creek.
3. Current approaches by the Pollution Control Department of the Nigerian Ports Authority (NPA) aimed at reducing significant pollution should be reviewed and upgraded, as they appear inadequate to prevent pollution of the Creek.
4. Plankton, Microbiological and macrobenthos studies should be carried out in order to properly assess the current status of the Creek.

7. The NPA and their service companies involved in polluting the Creek either through effluent discharge or waste dump at coastlines should ensure adequate treatments with best available technology (BAT) before discharging.

REFERENCES

Adakole, C.E., Mbah, C.E. and Dalla, M.A. (2003) Physicochemical limnology of Lake Kubanni, Zaria-Nigeria. *29th WEDC International Conference: Towards the Millennium Development Goals*, Abuja, Nigeria. p.165-168.

Adakole, J.A., Balogun, J.K. and Lawal, F.A. (1998) The effects of pollution on benthic fauna in Bindare stream, Zaria, Nigeria. *Nigerian Journal of Chemical Research*, 3: 13-16.

Adakole, J.A. and Anunne, P.A. (2003). Benthic macroinvertebrates as indicators of environmental quality of an urban stream, Zaria, Northern Nigeria.*Journal of Aquatic Science* 18(2): 85-92.

Ademoroti, C.M.A. (1996) *Environmental Chemistry and Toxicology*. 1st ed., Foludex Press Ltd., Ibadan, 215pp.

Adeniyi, H.A. (1986). Some limnological precautions for fish farmers.*Kainji Lake Research Institute Annual Report*, pp.54-56.

Adesiyan, S.O. (2005) *Man and his biological environment*. Ibadan University Press, Ibadan, Nigeria. 196pp.

Ajao, E.A. and Anurigwo, S. (2002). Land-based Sources of Pollution in the Niger Delta, Nigeria. *AMBIO* Vol. 31 (5): 442-445.

Alozie, P.I. (2000) *Technology, Science and Environment.* 3rd ed., Rapid Educational Press, Calabar, 269pp.

Amadi, N., Chindah, A.C. and Ugoji, C.C. (1997). The effect of municipal drainage on the microflora of a Black Water stream in Port Harcourt, Nigeria.*Niger Delta Biologia*, 2(1):125-139.

American Association of Port Authorities (AAPA) (2001) Green Ports: Environmental Management and Technology at US Ports. Available online at: www.aapa-ports.org/govrelations/greenports.htm. Last visited on June 25, 2003.

American Public Health Association (APHA) (1998) *Standard Methods for the Examination of Water and Wastewater*. 20th ed. APHA/AWWA/WEF, Washington DC.

Bagley, S.T. (1996) Characterization of fuel and after-treatment device effects of diesel emissions. *Research Report Number 76*. Topsfield Massachussets, Health Effects Institute.

Bhatia, S.C. (2003) *Environmental Chemistry.* 1st ed., CBS Publishers and Distribution, New Delhi, 549pp.

Brunekreef, N.A.A; Hartog, J; Haressema, H; Knape, M. and Vliet, P.V. (1997) Air pollution from truck traffic and lung function in children living near motorways. *Epidemiology*, 8: 298-303.

California Air Resources Board (CARB) (1998) Draft Diesel Exposure Assessment: *A-7*, 1998.

California Air Resources Board (CARB) (2000) Diesel Risk Reduction Plan, October 2000.

Chapman, D. (ed) (1992) *Water Quality Assessments*. London: Chapman and Hall.

Chapman, D. and Kimstach, V. (1992) The selection of water quality variables. Water Quality Assessment: a guide to the use of biota, sediment and water in environmental monitoring. Chapman, D. (Ed.) London: Chapman and Hall, 50-199.

Centre for Science in the Public Interest (CSPI). (2009). *Water Links*. http://www.cspinet.org/nah/water/waterlinks.html. Retrieved Dec. 7, 2009.

Chinadaily (2005) China says water pollution so severe that cities could lack safe supplies. Chinadaily.com.cn

Ciccone, G; Fostastiere, F; Agabati, N; Biggeri, A; Bisanti, L. and Chellini, E. (1998). Road traffic and adverse respiratory effects in children. *Occupational and Environmental Medicine,* 55: 771-778.

Davies, M.L. and Susan, J.M. (2004) *Principles of environmental engineering and science*. McGraw-Hill Companies Inc., New York, 704pp.

Davies, R.J; Rusznak, C. and Devalia, J.L. (1998) Why is allergy increasing? Environmental factors. *Clinical Experiment Allergy,* 28(suppl 6): 8-14.

Davies, R.J; Rusznak, C; Calderon, M.A; Wang, J.H; Abdelaziz, M.M. and Devalia, J.L. (1997) Allergen-irritant interaction and the role of corticosteroids. *Allergy,* 52(suppl 38): 59-65.

Deswal, S. and Deswal, A. (2007) *Biotechnology and environmental Chemistry (A text book for engineering students)*. 1st ed. Rai and Co. Publishers Ltd, New Delhi, 523pp.

Don K. K (2000). Cruise Control; “Cruise Ship Waste Dispersion Analysis Report on the Analysis of Gray water Discharge,” presented to the International Council of Cruise Lines, p. 15.

Duggal, K.N. (2004). *Elements of environmental engineering*. 6th ed., S. Chand and Co. Ltd., New Delhi, 504pp.

Duhme, H; Weiland, S.K; Keil, U; Kraemer, B; Schmid, M; Stender, M. and Chambless, L. (1996). The association between self-reported symptoms of asthma and allergic rhinitis and self-reported traffic density on street of residence in adolescent. *Epidemiology,* 7: 578-582.

Edoghotu, A.J. and Aleleye-Wokoma, I.P. (2007). Seasonal variations in phytoplankton composition and physicochemical properties of Ntawoba Creek, Port Harcourt, Nigeria.*International Journal of Natural and Applied Sciences,* 3(3): 344-348.

Egborge, A.B.M. (1994). Water pollution in Nigeria, Vol. 1: Biodiversity and Chemistry of Warri River. Ben Miller Books Nigeria Limited, 313pp.

Federal Ministry of Environment (2001). National Guidelines and Standards for Water Quality in Nigeria. Rishab Printing Press Production, 114pp.

Fleischer, S., Andersson, G., Brodin, Y., Dickson, W., Herrmann, J. and Muniz, I. (1993). Acid water research in Sweden-knowledge for tomorrow? *Ambio,* 22(5): 258-263.

Grant, I.F. (2002). Aquatic invertebrates.*Ecological Monitoring Methods for the Assessments of Pesticide impact in the Tropics*. Grant, I.F. and Tingle, C.C.D. eds. London: The University of Greenwich. 183-193.

Greater Port Harcourt Development Master Plan (GPHDMP) (2010). Final Report of the GPHDMP, Rivers State Government, Port Harcourt.

Guynup, S. (2003). Light pollution taking toll on wildlife, Eco-groups say. National Geographic Today, April 17, 2003. Available online at: news.nationalgeographic.com/news/2003/04/0417_030417_tvlightpollution.html. Last visited June 20, 2003.

Hart, A.I. (1994). The ecology of the communities of benthic macrofauna in the mangrove swamp of Port Harcourt area of the Niger Delta. Ph.D. Thesis, University of Port Harcourt, Rivers State, Nigeria. xvii+286pp.

Hazelwood C. (2004). Ballast Water Management: "New International Standard and NISA Reauthorization," Hearing, House Transportation and Infrastructure Subcommittee on Water Resources and Environment. 108th Cong., 2nd session.

Health Council of the Netherlands (HCN) (2000). Impact of outdoor lighting on man and nature. The Hague: HCN Publication No. 2000/25E, 2000 from http://www.gr.nl/pdf.php?ID=321 on May 11, 2004.

Hering, J. (2008). Provision of safe drinking water: a critical task for society. *Eawag: Swiss Federal Institute of Aquatic Science and Technology*, 65e: 2.

Ikomah, F.B. (1999). The impact of fertilizer plant effluent on ecology of the littoral benthos of Okrika (NAFCON) Creek. M.Sc. Thesis, Rivers State University of Science and Technology, Port Harcourt, Nigeria. xii+154pp.

International Dark-Sky Association (IDA) (2002). Effects of artificial light at night on wildlife. Available online at: www.darksky.org/infoshts/pdf/is187.pdf. Last visited June 18, 2003.

International Navigation Association (INA) (1999) Environmental Management framework for Ports and related Industries. *Report of Working Group,* 4: 38.

Iwuchukwu, J.J.I. (2006) *Environmental hazards management: Principles and Procedures.* 1st ed., Cel-Bez Printing and Publishing Co., Owerri, 169pp.

Jain, K.R. and Rao, S.S. (2008). *Industrial safety, health and environment management systems*. Ist ed., Khanna Publishers, India, 931pp.

Jimoh, H.I. (2003). *Techniques in environmental studies.* Nat Hadex Publishers, Ilorin, 309pp.

Johnson, A., Abba-spour, K., Amini, M., Bader, H.P., Berg, M., Hoehn, E., Hug, S., Mosler, H.J., Muller, K., Rosenberg, T., Scheidegger, R., Winkel, L., Yang, H. and Zurbrugg, C. (2008). Geogenic contaminants. *Eawag: Swiss Federal Institute of Aquatic Science and Technology*, 65e: 16-19.

Jonnalagadda, S.B. and Mhere, G. (2001). Water quality of the Odzi River in the eastern highlands of Zimbabwe. *Water Research,* 35(10): 2371-2376.

Kemdirim, E.E. (1993). Preliminary studies on the productivity of Pankshin reservoir using physic-chemical characteristics and morpho-edaphic index. *Journal of Aquatic Sciences,* 8:23-31.

Khitoliza, R.K. (2004). *Environmental pollution, management and control for sustainable development.* 1st ed., S. Chand (ed.). S. Chand and Co. Ltd., New Delhi, 309pp.

Kiely, G. (1998). *Environmental Engineering.* International Edition. London, UK: McGraw-Graw Hill International Limited.

King, R.P. and Nkanta, N.A. (1991). The status and seasonality in the physic-chemical hydrology of a Nigerian Rainforest pond. *Japanese Journal of Limnology*, 52(1): 1-12.

Lowrie, W. (1997). *Fundamentals of Geophysics.* Press Sndicate, University of Cambridge, UK.

Mansi, S.E. (1997). An ecological survey of the benthic macroinvertebrate communities after dredging activities in an intertidal mangrove swamp of the Niger Delta. M.Sc. Thesis, University of Port Harcourt. xii+128pp.

Mitchell, D. (2001). Health effects of shipping related air pollutants. *California Air Resources Board*, Presentation of EPA Region 9 Conference on Marine Vessels and Air Quality.

Moffat, D. and Linden, O. (1995). Perception and reality: Assessing priorities for sustainable development in the Niger River Delta. *AMBIO* 24,527-538.

Moore, W.J. and Moore, E.A. (1976). *Environmental Chemistry*. London: Academic Press Inc.

Moss, B. (1993). *Ecology of Freshwaters- man and medium*, 2nd ed. London: Blackwell Scientific Publication. 417pp.

Mukherjee, D., Banerjee, A. and Sen, G.K. (2006). Physico-chemical properties of water and fish availability at the Muriganga Estuary adjoining Bakkhali region of Western India Sunderbans. *Environment and Ecology*, 24(2): 385-388.

NADECO (1980). The Waters of the Niger Delta. Reports of an investigation by the Netherlands Engineering Consultants. The Hague. 210-228.

Nath, D. (1999). Chemical characteristics of riverine ecosystem-an overview: ecology, fisheries and fish stock assessment in India rivers. *CIFRI*, Barrackpore, India.

National Research Council (1995). Committee on Shipboard Waste, clean ships, clean port, clean ocean: controlling garbage and plastic waste at sea. National Academy press. Table 2-3, pp.38-39.

Natural Resources Defense Council (NRDC) (1999). Paving Paradise: Sprawl and the Environment. Retrieved from www.nrdc.org/cities/smartgrowth/rpave.asp on June 16, 2003.

Natural Resources Defense Council (NRDC) (2011). Harboring Pollution: The dirty truth about US ports. Retrieved from http://www.nrdc.org/air/pollution/ports1/overview.asp on July 28, 2011.

Natural Resources Defense Council (NRDC) (2011). Paving Paradise: Sprawl and the Environment. Available online at: www.nrdc.org/cities/smartgrowth/rpave.asp. Last visited on July 27, 2011.

Nicolai, T. (1999). Environmental air pollution and lung disease in children. *Monaldi Arch Chest Dis.*, 54: 475-478.

Nigerian Ports Authority (NPA) (2000). *Brochure: Nigerian Ports Authority, Port Harcourt: The Premier Port East of the Niger Promoting the Nation's Economy*. Corporate Affairs Department, NPA, PH, 23pp.

Obunwo, C.C., Braide, S.A., Izonfuo, W. and Chindah, A.C. (2004). Influence of urban activities on the water quality of a fresh water stream in the Niger

Delta, Nigeria. *Journal of Nigerian Environmental Society (JNES)*, 2(2): 196-209.

Odokuma, L.O. and Okpokwasili, G.C. (1992). Role of composition in degradation of oil spill dispersants. *Waste Management*, 17: 491-496.

Ogbuagu, D.H. and Ayoade, A.A. (2011a) Estimation of primary production along gradients of the middle course of Imo River in Etche, Nigeria. *International Journal of Biosciences*, 1(4): 68-73.

Ogbuagu, D.H. and Ayoade, A.A. (2011b). Trends in macrobenthal biotypes of Imo River in a Nigerian Delta region. *Journal of Biodiversity and Environmental Sciences*, 1(4): 22-28.

Oghenejoboh, K.M. (2005). The impact of acid rain deposition resulting from natural gas flaring on the socio-economic life of the people of Afiesere community in Nigeria's Niger Delta. *Journal of Industrial Pollution and Control*, 21(1): 83-90.

Ogundipe, O. (2006). *Introduction to Environmental Issues: causes, effects, and solutions*. Ikofa Commercial Press Ltd., Ibadan, 88pp.

Okoli, C.G; Ogbuagu, D.H; Gilbert, C.L; Madu, S. and Njoku-Tony, R.F. (2011). Proximal input of polynuclear aromatic hydrocarbons (PAHs) in groundwater sources of Okrika mainland, Nigeria. *Journal of Environmental Protection (JEP)*, 2: 848-854.

Okpokwasili, G.C. and Amanchukwu, S.C. (1988). Petroleum hydrocarbon degradation by *Candida* species. *Environment Int.* 14: 243-247.

Okpokwasili, G.C. and Olisa, A.O. (1991). Biodegradation of surfactants in liquid detergents and shampoos. *Water Resource,* 27: 1425-1429.

Ombu, E.J. (1987). The impact of Okrika oil terminal on the littoral benthos of the Central Bonny Estuary, Nigeria. M.Phil. Thesis, Rivers State University of Science and Technology, Port Harcourt.

Pandya, R.J; Solomon, G.M; Kinner, A. and Balmes, J.R. (2002). Diesel exhaust and asthma: Hypothesis and molecular mechanisms of action. *Environmental Health Perspectives,* 110(suppl 1): 103-112.

Park, H; Lee, B; Ha, E.H; Lee, J.T; Kim, H. and Hong, Y.C. (2002). Association of air pollution with school ansenteeism due to illness. *Arch. Pediatr. Adolesc. Med.*, 156: 1235-1239.

Peter, A. and Gunten, U. (2008). Removing trace organic contaminants. *Eawag: Swiss Federal Institute of Aquatic Science and Technology*, 65e: 24-27.

Peter, A; Dockery, D.W; Muller, J.E. and Mittleman, M.A. (2001). Increased particulate air pollution and the triggering of myocardial infection circulation, 103: 2810-2815.

Pink, D.H. (2006). Investing in tomorrow's liquid gold. Yahoo.http://finance.yahoo.com/columnist/article/trenddesk/3748.

Pope, C.A. (1995). Particulate air pollution as a predictor of mortality in a prospective study of US adults. *American Journal of Respir. Crit. Care Med.*, 151: 669-674.

Prasad, R. (2008). *Petroleum refining technology*. 1st ed., R.C. Khanna (ed.), Khanna Publishers, New Delhi, 402pp.

Pratt, I., Pavanello, R. and Pesakin, P. (1971). Assessment of surface water quality by a single index of pollution.*Water Research* 5: 741-751.

Rashed, M.N. (2001). Monitoring of environmental heavy metals in fish from Nasser Lake. *Environmental International*, 27: 27-33.

Salem, H.M., Eweida, E.A. and Farag, A. (2000). Heavy metals in drinking water and the environmental impact on human health. In: *Proceedings of ICEHM 2000*, Cairo University, Egypt, September 2000. p.542-556.

Schirmer, K. (2009). New challenges in the assessment of chemicals. *Eawag: Swiss Federal Institute of Aquatic Science and Technology*, 67e: 4-7.

Shell Petroleum Development Company of Nigeria Limited (SPDC) (1998). Environmental Impact Assessment of Obigbo Node Associated Gas Gathering Project: Final Report by Tial Trade Limited.

Sincero, A.P. and Sincero, G.A. (2006). *Environmental engineering, a design approach*. A.K. Ghosh (ed). Prentice-Hall, India. 795pp.

Singh, Y.K. (2006). *Environmental Science*. 1st ed., New Age International Publishers Ltd, New Delhi, 310pp.

Spaak, P. and Bauchrowitz, M. (2010). Environmental influences and plankton dynamics. *Eawag: Swiss Federal Institute of Aquatic Science and Technology*, 69e: 25-27.

Suter, M., Behra, R., Eggen, R., Fischer, B., Navarro, E. and Nestler, H. (2009). Interraction of multiple stressors. *Eawag: Swiss Federal Institute of Aquatic Science and Technology*, 67e: 19-21.

The Humane Society of the United States (HSUS) (2003). Noise Pollution and Acoustic Harassment. Available online at: www.hsus.org/ace/12609. Last visited on June 30, 2003.

The Ocean Conservancy (2002). Cruise Control, A Report on How Cruise Ships Affect the Marine Environment, p.13. Hereafter, *Cruise Control.*

Uchegbu, S.N. (2002a). *Environmental management and protection*. 2nd ed., Spotline Publishers, Enugu, 201pp.

Uchegbu, S.N. (2002b). *Issues and strategies in environmental planning and management in Nigeria.* 1st ed., Spotline Publishers, Enugu, 184pp.

United Nations Environmental Programme Global Environment Monitoring System (2006). Water quality for ecosystem and human health. UNEP GEMS/Water Programme.

United States Coast Guard (USCG) (2001). Oil spills in US waters 2000. Retrieved from www.uscg.mil/hq/g-m/nmc/response/stats/chpt2000.pdf. on June 23, 2003.

United States Environmental Protection Agency (EPA) (2003). Effects of Acid Rain.

United States Environmental Protection Agency (US EPA) (1996a). Air quality criteria for ozone and related photochemical oxidants, EPA/600/P-93/004aF. Docket No. A-99-06. Document Nos. II-A-15 to 17. www.epa.gov/ttn/naaqs/standards/ozone/

United States Environmental Protection Agency (US EPA) (2007). Office of Water, "Draft Cruise Ship Discharge Assessment Report," EPA842-R-07-005.

United States Environmental Protection Authority (US EPA) (1996b). Air quality criteria for ozone and related photochemical oxidants, EPA/600/P-93/004aF. Docket No. A-99-06. Document Nos. II-A-15 to 17. www.epa.gov/ttn/naaqs/standards/ozone/s.03.index.html.

United States Environmental Protection Authority (US EPA) (2000). National Water Quality Inventory 2000. *Report, at 39, 29*.

Viessman, W. Jr. and Hammer, M.J. (1999). *Water supply and pollution control*. 6th ed. (International students ed.), Addison Wesley-Longmann Inc., California, 827pp.

Virginia Department of Environmental Quality (VDEQ) (2003). About Brownfields. Available online at: www.deq.state.va.us/brownfieldweb/about.html. Last visited June 17, 2003.

Wake, H. (2005). Oil refineries: a review of their ecological impacts on the aquatic environment. *Estuarine, Coastal and Shelf Science*, 62: 131-140.

West, L. (2006). World Water Day: A billion people worldwide lack safe drinking water. Retrieved from http://environment.about.com/od/environmentalevents/a/waterdayqa.htm.

Wikipedia (2011). What is water pollution? Retrieved from http://answers.yahoo.com/question/index?qid on July 28, 2011.

Wittmer, I. and Burkhardt, M. (2009). *Dynamics of biocide and pesticide input*.

Wood, A. (1995). Constructed wetland in water pollution control fundamental to their understanding. *Water Science and Technology*, 32(3): 21-29.

World Health Organization (1984). *Guidelines for drinking water quality*. WHO, Geneva, 335pp.

World Health Organization (WHO) (1999). *Guidelines for Community Noise*. Berglund, B; Lindvall, T; Schwela, D.H. (Eds.). WHO, 159pp. available online at: www.who.int/peh/noise/guidelines2.html. Last visited June 18, 2003.

Yakubu, A.F., Adeyemo, A.A. and Ayina, D.A. (1996). Effect of deforestation on the abundance and distribution of crab in the Eagle Island mangrove swamp of the Niger Delta. *NIOMR Technical Paper*, 103: 7-9.

APPENDIXES

Appendix 1. Physicochemical parameters of Ogu Creek impacted by Ports activities of the Onne Ports

Parameters	Sampling points						FME (2001)*
	1	2	3	4	5	Control	
Temperature (°C)	28.5	28.0	27.8	28.3	28.4	28.5	20-33 °C
pH	5.28	6.39	6.28	5.60	6.05	6.50	6.0-9.0
Salinity (‰)	36.0	36.5	36.0	36.5	36.7	36.2	-
DO (mg/L)	3.00	3.40	3.80	3.20	3.10	3.80	6.8
BOD (mg/L)	1.50	1.95	2.05	2.50	1.25	1.20	4.00
TSS (mg/L)	24.5	24.2	28.2	20.0	35.0	18.4	-
TDS (mg/L)	60.5	55.0	56.0	63.0	61.5	25.6	-
Turbidity (NTU)	95.2	80.5	78.0	85.0	90.2	58.5	-
Alkalinity (mg/L)	21.5	15.0	20.2	21.0	18.3	11.5	-
Conductivity (µS/cm)	1500	1850	2500	2000	2200	840	-
Nitrate (mg/L)	3.40	4.0	4.1	3.8	4.4	2.0	0.06
TPH (mg/L)	2.05	2.44	1.80	2.10	2.60	1.60	-
Phosphate (mg/L)	2.80	2.00	3.10	3.70	2.90	1.05	-
Sulphate (mg/L)	85.40	90.50	88.00	78.60	90.40	35.50	-
Chloride (mg/L)	51.00	105.40	120.00	122.00	136.50	38.40	-
Al (mg/L)	0.85	1.00	1.05	0.99	1.20	0.60	0.005-1.000
Cd (mg/L)	0.004	0.01	0.006	0.05	0.06	0.002	0.2-1.8
Cr (mg/L)	0.06	0.04	0.05	0.02	0.08	0.02	0.02-2.00
Cu (mg/L)	0.11	0.05	0.06	0.12	0.08	0.05	2.0-4.0
Fe (mg/L)	3.05	3.11	2.80	3.00	3.25	0.80	1.00
Pb (mg/L)	0.011	0.012	0.015	0.051	0.060	0.033	1.7

***Standard for water quality: aquatic life**

Appendix 2. Test of Homogeneity in spatial mean variance using single factor ANOVA

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	126	13525.34	107.344	161567.8
Column 2	126	441	3.5	2.94

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	679365.3	1	679365.3	8.409508	0.004065	3.878924
Within Groups	20196345	250	80785.38			
Total	20875710	251				