ENVIRONMENTAL IMPACT OF MARINE TRANSPORTATION ON THE OGU-BONNY CHANNEL IN ONNE, RIVERS STATE

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CERTIFICATION

I certify that this work "**Environmental Impact of Marine Transportation on the Ogu-Bonny Channel in Onne, Rivers State**" was carried out by **Akeredolu Ayodeji Owojori** (Reg. No: 20075598789) 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 project is dedicated to God Almighty for making the program a huge success, my lovely wife, Pastor (Mrs) Edith A. Akeredolu and my lovely children for their encouragements, endurance and moral supports.

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ABSTRACT

The physicochemical characteristics of the Ogu-Bonny Channel serving the Onne Port, as well as some shipping transport activities that could constitute pollution in the Channel were investigated during the wet season of 2011 at three sampling locations. *In situ* measurements were made for water temperature, turbidity, conductivity, salinity, and dissolved oxygen (DO) with HORIBA U-10 Water Quality Checker and for total dissolved solids (TDS) with HACH conductivity/TDS meter. Water samples were collected in replicates with 2 litres plastic container 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 product moment correlation coefficient (r) to explore the interrelationship between the parameters and shipping transport activities. Water temperature varied between 28.50-28.90 (28.68 ± 0.07) °C, turbidity between 69.00-92.50 (81.16 ± 4.83) NTU, and salinity between 35.20-36.72 (36.13 ± 0.25) ‰. DO varied between 0.85 and 1.84 (1.21 ± 0.18), BOD between 2.05 and 3.61 (3.21 ± 0.30), PO_4^{2-} between 0.002 and 1.050 (0.378 ± 0.227), SO_4^{2-} between 21.70 and 100.00 (76.78 ± 14.31), and NO_3^- between 2.10 and 3.60 (2.89 ± 0.28) mg/L. However, the trace metals (Fe, Pb, Zn, Hg and Cu) varied between 0.60-3.07 (1.71 ± 0.55), 0.00-0.02 (0.01 ± 0.003), 0.02-0.40 (0.14 ± 0.07), 0.000-0.002 (0.002 ± 0.000), and 0.02-0.16 (0.06 ± 0.03) mg/L, respectively. Fe, Zn and Cu levels were outside permissible limits for aquatic life by the Federal Ministry of Environment. Sampling location B recorded highest concentrations in several of the variables, though there was spatial homogeneity [$F_{(1.73)} < F_{crit(3.92)}$] at P<0.05. Of the shipping transportation activities, garbage generation on board accounted for the highest waste volume (97.13%), even as bilging significantly influenced hardness (r=0.992; P<0.01), and bunkering influenced Pb level (r=0.948), accidental dumping of effluents influenced water temperature (r=0.881), and fish trawling and deliberate dumping of effluents influenced DO (r=0.896 and 0.957, respectively) at P<0.05. It is recommended that regulatory agencies should enforce environmental laws to prevent the Port from getting seriously polluted.

Key words: Ogu-Bonny Channel, transportation, pollution, water quality, regulation

CHAPTER ONE

1.0 INTRODUCTION

1.1. Overview

Nigeria has about 8,600km of inland waterways, with the longest being the Niger River and its tributaries (Egborge, 1994). The Benue River is another long waterway of the country. However, of these, the most used, especially for commerce and larger powered boats are those in the Delta region; from the Lagos lagoon to Cross Rivers in the Nigerian Delta. In 2004 for example, this commercial region housed 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), the body responsible for managing the ports established along these waterways is established in Lagos, and Port Harcourt. The Lagos Port, which consists of separate facilities at Apapa and Tin Can Island has a rail connection to points inland and handles about 5.75 million tons of cargo each year (NPA, 2000). The Port Harcourt Port, a transshipment port is located about 66 km from the Gulf of Guinea along the Bonny River in the Niger Delta and handles about 815,000 tons of cargo yearly, even as it 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. However, a new port located about 25 km south was constructed in the nearby Port Harcourt. With the ever increasing demand for higher revenues for the country's escalating needs, these ports have become the hubs of international trades. It is expected that by 2020, shipping traffic on these ports to and from United States of America would be doubled. There would also be increases in traffic in the waterways from and to other trade partners by this time.

Unfortunately, these increases in activities at the ocean ports are also associated with environmental pollution directly and indirectly. 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, while 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).

Water pollution is a major problem in the global context. It has been reported that it is the leading worldwide cause of deaths and diseases (Pink, 2006; West, 2006) and that it accounts for the death of more than 14,000 people daily (West, 2006). For example, some 90% of China's cities suffer from some degree of water pollution (Chinadaily, 2005) and in addition to the acute problems of water pollution in developing countries, industrialized countries continue to struggle with pollution problems as well.

In the most recent national report on water quality in the United States, 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).

Water is typically regarded as polluted when it is impaired by humanly introduced contaminants and either does not support a human use, and/or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish.

1.2 **Justification**

According to King and Nkanta (1991), water is an important resource amongst the natural environmental gifts of nature. Various activities such as fishing, irrigation practice, recreation, swimming, boating, shipping, and waste disposal have created different requirements for water quality (Adesiyan, 2005), and so, water quality management was originally geared towards protecting the intended uses of a water body.

Like other ports in world, the Nigeria Ports Authority (NPA) in Port Harcourt located in the Niger Delta area of Nigeria 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, various contaminants associated with the goods and services rendered could impair the quality of the waterways and thus, constitute threats to the resident biodiversity in the aquatic ecosystem. Such pollutants could emanate from ballast waster, exhaust emissions from vessels, oil spills, as well as domestic and human wastes generated aboard.

The Port Harcourt Ports consist of two separate port facilities; The Port Harcourt Quays along Primerose Creek/Dockyard arm of the Bonny River and the Onne Port at the Ogu-Bonny Channel. These ports have been in operation for over 40 years now, and shipments have been on the increase. Though several researches have been conducted in other aquatic ecosystems in the Niger Delta area, no groundtruthing research has been carried out to ascertain the specific effects brought about by the Port's activities. It is in view of this gap that the current study, to investigate the impacts of transportation of goods and services along the waterways on the quality/regimen of the Ogu-Bonny River serving the Onne Port is attempted.

1.3 Aim

The aim of this research is to determine the water quality regimen of the Ogu-Bonny waterway serving the Onne Port impacted by marine transportation.

1.4 Objectives

The aim was achieved with the following objectives

- Determination of the physicochemical parameters of the channel
- Determination of spatial variation in the physicochemical variables of the channel.
- Identification of the transport activities that constitute pollution in the channel.
- Determination of the interactions of the physicochemical variables of the channel, as well as the transport activities that constitute pollution.

- Comparison of the levels of the physicochemical variables with regulatory standards

1.5 Scope and Delimitation

The study covered some physicochemical variables of the Port Channel, including surface water temperature, pH, electrical conductivity, dissolved oxygen, alkalinity, sulphate, chloride, nitrate, phosphate, calcium hardness, magnesium hardness, and trace metals (Fe, Pb, Zn, Hg, Cu). The study also covered incidents of some pollution arising from Ports transport activities. The study was limited to the Port Harcourt Ports Authority in the southern part of Nigeria, only. It covered the Ogu-Bonny Channel, serving the Port in the area.

1.6 Significance of Study

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

- Create awareness on the extent or severity of pollution of the Port Harcourt Port waterway
- It will create awareness on the compliance levels of the indicator parameters measured.

- It will increase the databank of limnological studies in the Niger Delta area of Nigeria
- It could also incite strict regulations by the requisite agencies
- Above all, it will provide baseline information on the water quality regime of the waterway, and provide extrapolations to other sea ports in the country.

1.7 Definition of terms

Ballast water: This is weight loaded to make worthy when a ship has to proceed to sea without cargo. It could be any solid or liquid that is brought on board of a vessel to increase the draft, change the trim, and regulate the stability or to maintain stress loads within acceptable limit.

Bilges water: This is carbonaceous mixture with oil, as the waste product of an internal combustion engine. This may contain solid wastes and pollutants having high amounts of oxygen-demanding materials, oil and other chemicals.

Gray water: This is wastewater from the sinks, showers, galleys, laundry, and cleaning activities aboard a ship.

Black water: This is sewage wastewater from toilets and medical facilities which contain harmful bacteria, pathogens, diseases, viruses, intestinal parasites, and harmful nutrients.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Water pollution

Water pollution is a large set of adverse effects upon water bodies (lakes, rivers, oceans, groundwater) caused by human activities. Although natural phenomena such as volcanoes, storms, earthquakes etc also cause major changes in water quality and the ecological status of water, these are not deemed to be pollution (Iwuchukwu, 2006). Water pollution has many causes and characteristics. For example, increases in nutrient loading may lead to eutrophication, organic wastes such as sewage and farm wastes could impose high oxygen demands on the receiving water leading to oxygen depletion with potentially severe impacts on the whole eco-system, and industries discharge a variety of pollutants in their wastewater including heavy metals, organic toxins, oils, nutrients, and solids.

Discharges can also have thermal effects, especially those from power stations, and these too reduce the available oxygen. Silt-bearing runoff 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). Pollutants in water include a wide spectrum of chemicals, pathogens, and physical chemistry or sensory changes. Many of the chemical substances are toxic or even carcinogenic (Okoli *et al.*, 2011). Pathogens can obviously produce waterborne diseases in either human or animal hosts. Alteration of water's physical chemistry includes acidity, conductivity, temperature, and excessive nutrient loading (eutrophication).

Principal sources of water pollution include industrial discharge of chemical wastes and byproducts discharge of poorly-treated or untreated sewage, surface runoff containing pesticides, agricultural wastes, spilled petroleum products, 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.

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

2.2. Development and water pollution

As human population increases with attendant socio-economic development activities in mostly the developing countries, there is always a 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. However, 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. He therefore argued that pollution of surface waters only results when the natural ability of surface water to dilute and disperse waste materials is undermined.

Surface water pollution therefore is 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 impact on the on intended use of water (Bhatia, 2003; Jonnalagadda and Mhere, 2001).

In many cases of a large river, the upstream discharge of one settlement may become the downstream abstraction of another.

Precisely, 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.

2.3. Sources of water Pollution

The sources of water 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. These sources are discrete and identifiable and therefore relatively easy to monitor and regulate (Rashed, 2001).

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

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 (Singh, 2006). 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).

In many industrialized countries, streams are so polluted 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). Consequent upon 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.

On the other hand, 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 are from 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. The impurities in road-grade salt can contribute to water quality deterioration (Sincero and Sincero, 2006).

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

Municipal wastes includes solid and liquid waste materials from residential areas, schools, restaurants, hospitals, offices and other commercial areas that find their way into surface waters (Viessman and Hammer, 1999). 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. Waste waters from laundry washings add hard detergent that will cause foam on surface water (Okpokwasili and Olisa, 1991; Ademoroti, 1996).

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. Industries within municipal areas ordinary discharge their waste water to city's sewer systems (Sincero and Sincero, 2006; Uchegbu, 2002a&b).

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 (Adesiyan, 2005; Mukherjee *et al.*, 2006).

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).

Uncontrolled and excessive use fertilizer, pesticides and herbicides have long-term effect on water resources (Ademoroti, 1996; Adesiyan, 2005). 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). When the compounds formed gets into surface water, they could induce pollutions with great consequences on human health (Alozie, 2000; Deswal and Deswal, 2007).

Natural sources of surface water pollution include volcanic eruptions, earthquakes, and oil spillages at the sea bed rock and through natural seepage (Presad, 2008; Jain and Rao, 2008). 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, runoff from natural drainage basin (natural areas and forest) supplies organic waste and soil sediments into surface waters (Adakole *et al*., 2003).

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,

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

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

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

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). Also nitrogen (IV) oxide reacts with OH to form trioxonitrate (V) acisd during thundering (Oghenejoboh, 2005).

$$NO_2 + OH \longrightarrow HNO_3 \text{..........................iv}$$

2.4. Effects of water pollutants on aquatic ecosystems

According to Suter *et al. (*2009), the wide range of pollutants effects on surface water are grouped into broad classes as mentioned above (point sources and non-point source). 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. Industrial and domestic wastes add large amount of organic and inorganic substances into aquatic system (Peter and Gunten, 2008) that could produces turbidity. It has been reported by Adakole *et al.* (2003) 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 clog the gills of fishes. Egborge (1994) reports that it also lowers the temperature of surface waters.

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. Basically the above statement is characterized by multiple discharges possibly from combination of urban and agricultural runoff into water bodies. Oxygen demanding materials (usually biodegradable organic matter), also constitute pollution, and so do certain inorganic compounds in water bodies (Wood, 1995; Bhatia, 2003; Deswal and Deswal, 2007). 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. The effect on species diversity and abundance could also be severe, whereby there could be complete elimination of biotypes (Ogbuagu and Ayoade, 2011b). Viessman and Hammer (1999) argue that dissolve oxygen does not drop to zero and that the stream recovers without a period of anaerobiosis.

The two common nutrients of primary concern- nitrogen and phosphorus are considered pollutants when their concentrations become very high (eutrophication) (Adesiyan, 2005). 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. These are added to the water through natural and anthropogenic activities.

Pathogenic organisms are micro-organism found in industrial and domestic wastes, as well as human faeces; including bacteria, viruses and protozoa excreted by diseased persons or animals. When discharged into surface waters, they make the water unfit for drinking. 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, decreased light penetration (Ogbuagu and Ayoade, 2011a), 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.

Although 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, increase in water temperature negatively affects surface water microorganism, and the rate of oxygen depletion increase (Chapman and Kimstach, 1992). 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. Excessively high water temperature or abnormal temperature fluctuation during egg development have been observed to cause a genetically male embryo to develop functioning female sex organs (Ademoroti, 1996; Deswal and Deswal, 2007).

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. Heavy metals may be toxic to fish as well as harmful to human health as indicated by Spaak and Bauchrowitz (2010). 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. Fertilizers add nutrients to water, which causes eutrophication (Adesiyan, 2005).

2.5. Water resources management

The turning point for water resources development and management in Nigeria 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.

One should emphasize here 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. It also seriously disrupts river navigation (FME, 2001).

2.6. 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.

2.6.1. Inland 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.

2.6.2. Ocean water transport: 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.

2.7. Ballast water

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.

2.8. Air pollution associated with Ports operations

Since 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 pollution loadings. 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).

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 ports, 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). School absenteeism due to respiratory symptoms has also been linked to PM pollution (Park *et al*., 2002).

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. 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 (CARB, 1998).

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). In fact, people with allergies or asthma have far stronger reactions to common allergens, such as pollen, when they are also exposed to NOx (Davies *et al*., 1998).

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).

Burning 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. SOx 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 asthmatics (Nicolai, 1999).

In addition to the pollutants discussed above, there are other air pollutants that threaten public health that are not discussed in this report, including carbon (II) (CO), formaldehyde, heavy metals, dioxins, and pesticides used to fumigate produce.

Generally, 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).

Many 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.

Although 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 (NRDC, 2011). 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). And the 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).

2.9. Water pollution from Ports operations

Ports operations can cause significant damage to water quality and subsequently to marine life and ecosystems, as well as human health. 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 (The Ocean Conservancy, 2002). Major water quality concerns at ports include wastewater and leaking of toxic substances from ships, stormwater runoff, and dredging (NRDC, 2011).

The primary threats to water quality include bilge. 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. This oily wastewater, combined with other ship wastes such as sewage and wastewater from other onboard uses, is a serious threat to marine life (The Ocean Conservancy, 2002).

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 (INA, 1999). While toxic antifouling additives are slowly being phased out of use, these toxic pollutants persist in the marine environment. Alternatives to TBT are in ample supply.

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. In fact, 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 (US EPA, 2000). 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. This process, called eutrophication, has been identified by the National Research Council as the most serious pollution problem facing estuaries in the United States (US EPA, 2002). As major sources of NOx, 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. 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 (USCG, 2001).

In the year 2000, 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.

2.10. Pollution associated with cruise ships

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 (Fig. 2.1). 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

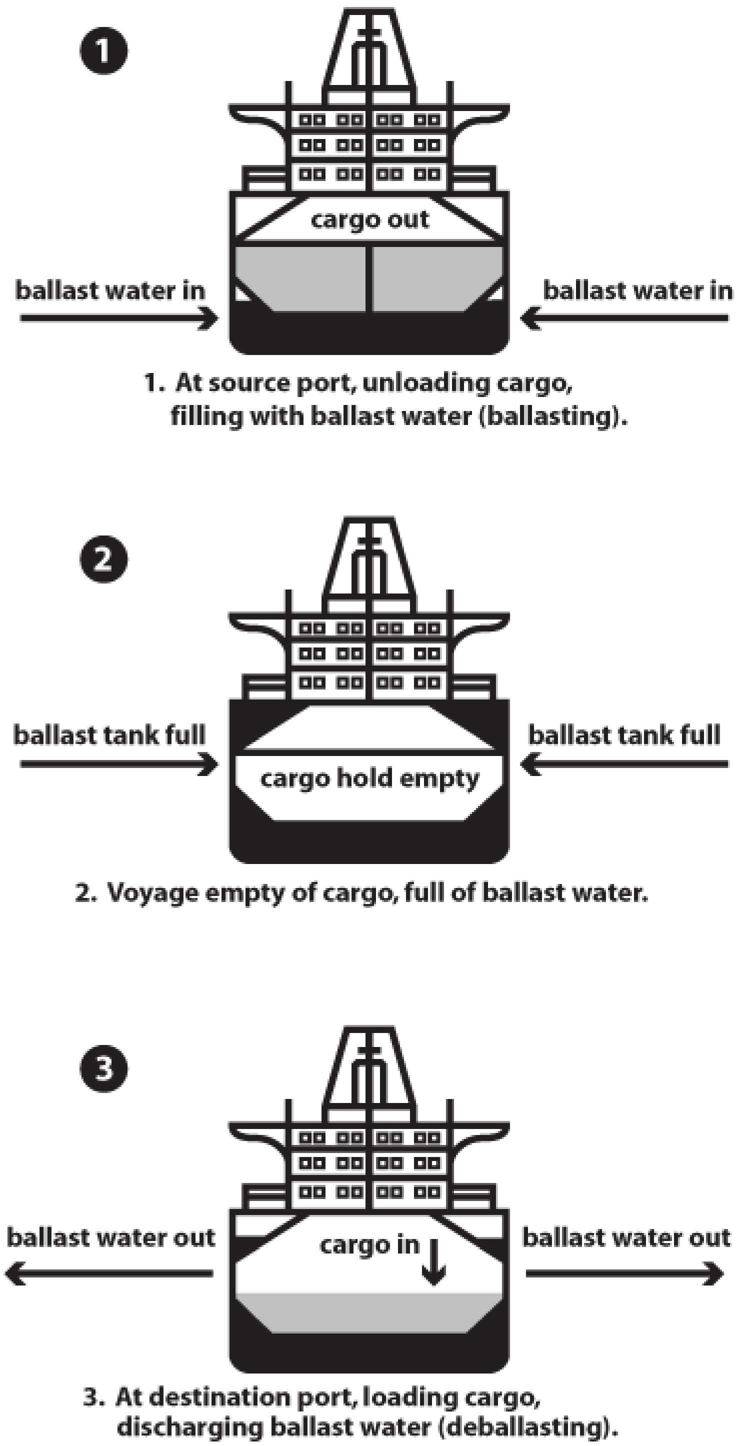

Fig. 2.1. Mechanism of Ballasting in ships/vessels

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.

2.11. Land use problems at Ports

The highly industrialized operations at ports are often in close proximity to residential areas, creating nuisances and hazards for nearby communities. Ports have several available options to avoid developing new terminals near residential areas. They can develop property previously used in an industrial capacity, or they can increase efficiency of land use at existing terminals. The land use patterns at U.S. ports, for example, suggest much room for efficiency improvements. Of the 10 largest U.S. ports, even those that are most efficient in terms of land use, Long Beach and Houston, are four times less efficient than the Port of Singapore, a model of land-use efficiency.

One positive approach to land use is for ports to focus their expansion efforts on brownfields, or tracts of land that have been developed for industrial purposes, polluted, and then abandoned (US EPA, 2003). The potential costs of cleaning up brownfield sites makes them less appealing to companies looking to locate or expand, and as a result, new industrial operations are often sited on pristine, undeveloped "greenfield" land. This often leads to a loss of habitat and wildlife, increases in air and water pollution, and urbanization of open space valuable for its recreational and aesthetic qualities (NRDC, 1999). However, developing brownfields offers many advantages to business, communities, and the environment. Businesses benefit from locating on sites near existing transportation infrastructure, and with a utility infrastructure already in place, while cleaning up contamination that poses a danger to both the community and the environment (VDEQ, 2003).

2.12. Ports-community relations

Ports can be very bad neighbors. In addition to the air and water pollution problems they create, they can be loud, ugly, brightly lit at night, and a cause of traffic jams. These problems can go beyond simple annoyance to cause serious negative health effects. For example, noise pollution has been linked to hearing impairment, hypertension (high blood pressure), sleep deprivation, reduced performance, and even aggressive behavior (WHO, 1999).

Sound pollution caused by shipping and other human enterprises has increased in recent history. The noise produced by ships can travel long distances, and marine species that may rely on sound for their orientation, communication, and feeding, can be harmed by this sound pollution.

At ports bordering residential neighborhoods, bright lights at night and the flashing lights of straddle carriers and forklifts can affect nearby residents, disrupting biological rhythms and causing stress and annoyance (INA, 1999; HCN, 2000).

In addition to the negative effects experienced by people, noise from ship engines may disturb marine mammal hearing and behavior patterns, as well as bird feeding and nesting sites (HSUS, 2003; INA, 1999). Similarly, artificial lights at ports, sometimes burning 24 hours a day, can have negative effects on wildlife, including disorientation, confusion of biological rhythms that are adapted to a day-night alternation, and a general degradation of habitat quality.

This pollution can cause high mortality in animal populations, particularly to birds attracted to brightly lit buildings and towers and that circle these structures until they die of exhaustion or run head on into them (IDA, 2002; Guynup, 2003).

Ports can also be bad neighbors by ignoring residents of the communities living next door, or making little or no effort to solicit community input into port operational decisions that will directly affect the life of the community and its residents. Many local and international ports have developed decidedly hostile relations with their neighbors, not just because of the pollution the ports produce, but because they have consistently ignored residents of nearby communities, refusing sometimes even to share critical information about possible effects of port operations. The hostilities existing in the Niger Delta region of Nigeria could be traced to a combination of factors related to industrial negligence over the years.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Study Area

The Port Harcourt Port Complex is located in both Port Harcourt and Onne, all in Rivers State. It is one of the country's Ports under the Nigerian Port Authority (NPA); the first to be established in the then eastern region before Calabar Port. It is the third largest among the nation's Sea Ports, after Lagos Ports at Apapa and Tin Can Island. Its distance from the Fairway Buoy is 27 nautical miles (NPA, 2000).

The Port was opened for organized shipping activities in 1913 by the then Colonial Governor Fredrick Lugard. It 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 coastline, between the east, north-eastern Nigeria, and to some extent, 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 expansion in 1962 and post-Nigerian civil war (1970-1974) second National Development Plan, the Port had 8 berths in 2000. The total quay length is approximately 12,000 m. the average draught along the quays is 8.97 m. Vessels up to 15,000 metric tone dead-weight can be berthed (NPA, 2000).

The ports complex 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). 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.

3.1.1. 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 and decreases to 45% in dry season. Ambient air temperature ranges from 24.5^0C to 32^0C in wet season and from 25^0C to 36^0C in dry season.

The climate types as marked by high relative humidity are 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 or riparian regime, which is comparatively uniform throughout the proximity of

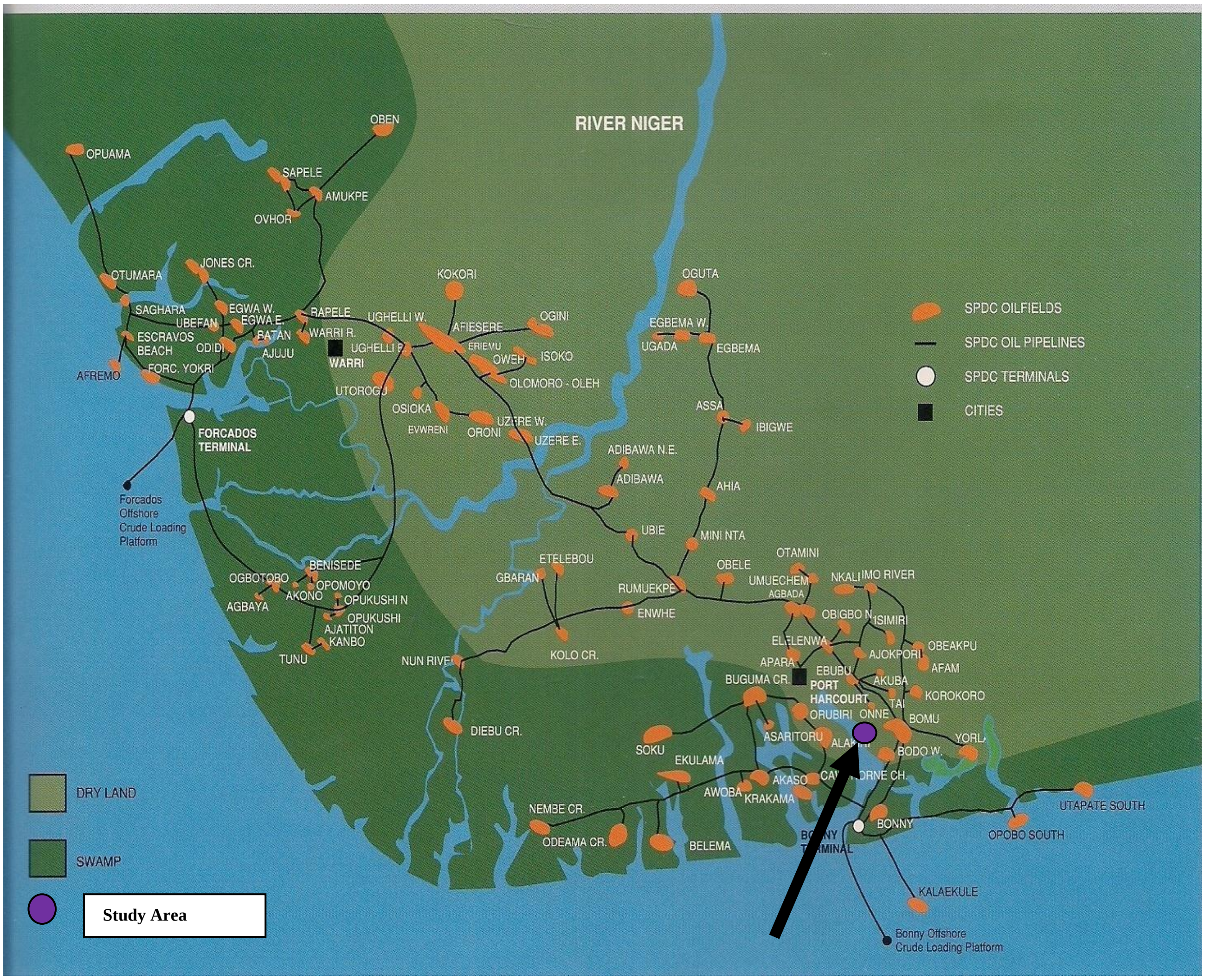

Fig. 3.1. Map of the Niger Delta showing Onne, the study area in Rivers State

the region to the Atlantic Ocean. The other vegetation type is the farmland/fallowing mosaic modified kind. 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 area of study.

3.1.2. Population and Economic Activities

The total population of the port complex coverage 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 crops grown include yam, cocoa yam, cassava, plantain.

The Port is well located to serve the economic interests of the eastern States and beyond. The proximal Port Harcourt city and its environs have thus become beehives of economic activities. 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. These combine to underscore the relevance of the Port to the business successes of the catchment states it is meant to serve.

3.2 Sources of Data

The data used in this research were obtained from both primary and secondary sources.

3.2.1 Primary Data

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

3.2.2 Secondary Data

Secondary data includes all published materials used in this study. These 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 on three different days at three sampling locations between 07:00-11:00 am in June, 2011. The study comprised field sampling and laboratory analyses.

3.4. Sampling locations

Three sampling locations were established; with two located at the highest points of marine transportation activities nearest land, and the third, located upstream, away from areas of intense activities and to serve as control, all in the navigational channel along the Ogu-Bonny River serving the Port route.

The three sampling locations were sited about 200m from each other. Sampling locations A and B were located at the Federal Ocean Terminal (FOT). Associated Port transport activities such bilging, garbage dumping, balasting, banking as well as deliberate discharge of effluents were rift at these locations than in C.

3.5. Field sampling

3.5.1. *In situ* measurements

In situ measurements for water temperature, turbidity, electrical conductivity, salinity, and dissolved oxygen were made with a 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. The probe was immersed in water and the TDS value 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. All samples were properly labeled.

3.6. Laboratory analysis

3.6.1. 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,

$$BOD_5\ (mg/L) = \frac{DO_1 - DO_2}{P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..v$$

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:

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

3.6.7. Total Hardness (Calcium and Magnesium)

The ASTM D807-52 (Titrimetric) method was used.

Apparatus: Burette, Beaker, conical flask, measuring cylinder etc.

Reagents: Eriochrome black T indicator, standard EDTA titrant 0.01ml, standard calcium solution, sodium hydroxide (NaOH), Ureoxide indicator, buffer solution.

Procedure: Mg hardness:

- 25ml of the sample was dilute to about 50ml in a conical flask.
- 2ml of buffer solution was added
- 2 drops of indicator solution (Eriochrome Black T) was added.
- The standard EDTA titrant in the burette was titrated against the mixture from red to blue as end point and the volume recorded.

Ca hardness:

- 25ml of the sample was diluted to 50ml in a conical flask
- 2ml of 0.1N NaOH was added
- 1ml of mureoxide indicator was also added and mixture stirred for proper mixing.
- The standard EDTA titrant in the burette was titrated against the mixture and volume used was recorded.

NB: Magnesium is obtained by subtracting Ca^{2+} titre from hardness titre.

Calculations:

Hardness $MgCaCO_3$/L = $\frac{\text{Titre value X 0.4 X 2.5 X 100}}{\text{Volume of sample}}$

Ca, Mg $CaCO_{3/}$L =

$$\frac{\text{Titre value X Normality of EDTA X } \frac{1}{2} \text{ Molar mass of Ca X 1000}}{\text{Volume of sample}}$$

Mg, $MgCaCO_3$/L =

$$\frac{\text{Titre value X Normality of EDTA X } \frac{1}{2} \text{ Molar mass of Mg X 1000}}{\text{Volume of sample}}$$

3.6.8. Trace metals (Fe, Pb, Zn, Hg, Cu)

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.
- Ten mL 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. Transport activities

Data on transport activities and frequency of occurrence of associated pollutions were obtained from the Environmental Pollution Monitoring Department of the Nigerian Ports Authority (NPA), Port Harcourt.

3.8. Statistical Analysis

Descriptive statistics was explored to obtain means, standard error, range, and graphical representations of ensuing data. The interrelationships existing between the physicochemical variables and pollution related transport activities in the Port was explored using the Pearson product moment 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).

CHAPTER FOUR

4.0. RESULTS

4.1. Variation in physicochemical parameters

Appendix 1 shows values of the physicochemical characteristics of the Ogu-Bonny Channel during the study period. Both narrow and wide variations were observed in the parameters measured. Conductivity, sulphate, chloride ions and total hardness showed wide variations, while the other parameters showed narrow variations. Temperature ranged between 28.50 and 28.90 (28.68 ± 0.07) °C, turbidity between 69.00 and 92.50 (81.16 ± 4.83) NTU, TDS between 28.10 and 58.00 (42.47 ± 6.30) mg/L, and salinity between 35.20 and 36.72 (36.13 ± 0.25) ‰ (Table 4.1). Conductivity ranged between 500.00 and 25000.00, with mean of 9574.00 ± 5517.65 µS/cm, DO between 0.85 and 1.84 (1.21 ± 0.18) mg/L, BOD between 2.05 and 3.61 (3.21 ± 0.30) mg/L, and phosphate between 0.002 and 1.050 (0.378 ± 0.227) mg/L.

However, sulphate varied between 21.70 and 100.00 (76.78 ± 14.31), nitrate between 2.10 and 3.60 (2.89 ± 0.28), chloride between 95.10 and 150.00 (117.62 ± 10.04), alkalinity between 12.20 and 21.50 (15.86 ± 2.02), and total hardness between 75.80 and 5000.00 (1099.40 ± 975.48) mg/L. The trace metals- Fe, Pb, Zn, Hg and Cu ranged from 0.6-23.07 (1.71 ± 0.55), 0.00-0.02

Table 4.1. Variations in physicochemical parameters of Ogu-Bonny Channel

Parameters	Minimum	Maximum	Range	Mean	SE	FME
Temperature (°C)	28.50	28.90	0.40	28.68	0.07	20-33
Turbidity (NTU)	69.00	92.50	23.50	81.16	4.83	NS
TDS (mg/L)	28.10	58.00	29.90	42.47	6.30	NS
Salinity (‰)	35.20	36.72	1.52	36.13	0.25	NS
Conductivity (µS/cm)	500.00	25000.00	24500.00	9574.00	5517.65	NS
DO (mg/L)	0.85	1.84	0.99	1.21	0.18	6.8
BOD (mg/L)	2.05	3.61	1.56	3.21	0.30	4.0
PO_4^{2-} (mg/L)	0.002	1.050	1.050	0.378	0.227	NS
SO_4^{2-} (mg/L)	21.70	100.00	78.30	76.78	14.31	NS
NO_3^- (mg/L)	2.10	3.60	1.50	2.89	0.28	NS
Alkalinity (mg/L)	12.20	21.50	9.30	15.86	2.02	NS
Cl^- (mg/L)	95.10	150.00	54.90	117.62	10.04	NS
Hardness (mg/L)	75.80	5000.00	4924.20	1099.40	975.48	NS
Fe (mg/L)	0.60	3.07	2.47	1.71	0.55	1.0
Pb (mg/L)	0.00	0.02	0.02	0.01	0.003	NS
Zn (mg/L)	0.02	0.40	0.38	0.14	0.07	0.03
Hg (mg/L)	0.000	0.002	0.002	0.002	0.000	NS
Cu (mg/L)	0.02	0.16	0.15	0.06	0.03	2.0-4.0

SE = standard error of mean, FME=Federal Ministry of Environment, NS=Not Specified

(0.01 ± 0.003), 0.02-0.40 (0.14 ± 0.07), 0.000-0.002 (0.002 ± 0.000), and 0.02-0.16 (0.06 ± 0.03) mg/L, respectively. Several of the physicochemical characteristics measured were within the Federal Ministry of Environment's permissible limits for aquatic life (Appendix 2). However, mean Fe (1.71 ± 0.55 mg/L) and Zn concentrations (0.14 ± 0.07

mg/L) were above the regulatory limits of 1.0 and 0.03 mg/L, respectively.

Also, the range of Cu recorded in the study (0.02-0.16 mg/L) was totally outside the recommended range of 2.0-4.0 mg/L.

4.2. Spatial variation in physicochemical parameters

Longitudinal spatial variations were observed in the physicochemical parameters measured, with sampling location B recording higher levels of several of the variables than the other locations. Mean maximum temperature, phosphate, and Fe contents of 28.85 °C, 0.9256, and 3.03 mg/L, respectively were recorded in sampling location A (Figs. 4.1, 4.6, and 4.4). However, the control location recorded mean maximum DO of 1.84 mg/L (Fig. 4.5).

Mean maximum turbidity (92.05 NTU) and TDS (57.6 mg/L) (Fig. 4.1), conductivity (23000 µS/cm), chloride content (140.25 mg/L), and hardness (2610.25 mg/L) (Fig. 4.2), and salinity (36.28 ‰), alkalinity (20.75 mg/L), and SO_4^{2-} (99.21 mg/L) (Fig. 4.3) were recorded in sampling location B. Also, mean maximum NO_3^- content of 3.49 mg/L (Fig. 4.4), BOD of 3.60 mg/L (Fig. 4.5), Pb content of 0.017 mg/L (Fig. 4.6), Zn content of 0.305 mg/L, and Cu content of 0.123 mg/L (Fig. 4.7) were recorded in location B. Albeit, mean maximum Hg content of 0.0021 mg/L was recorded in sampling locations A and B (Fig. 4.7).

A test of homogeneity in mean variance of the physicochemical variables across the sampling locations revealed spatial equality as $F_{(1.73)} < F_{crit(3.92)}$ at $P<0.05$ ($P=0.19$) (Appendix 3).

4.3. Incidents of pollution associated with transport activities

Of the seven ports transport activities that were studied, garbage generation on board accounted for the highest source of pollution (2120.9; 97.13%) during the study period (Table 4.2.). However, bunkering, accidental discharge, deliberate discharge, dumping at port, and fishing activities contributed minor pollutions of 0.62, 0.26, 0.33, 0.38, and 0.25%, respectively. Bilging contributed about 1.03% pollution incidents.

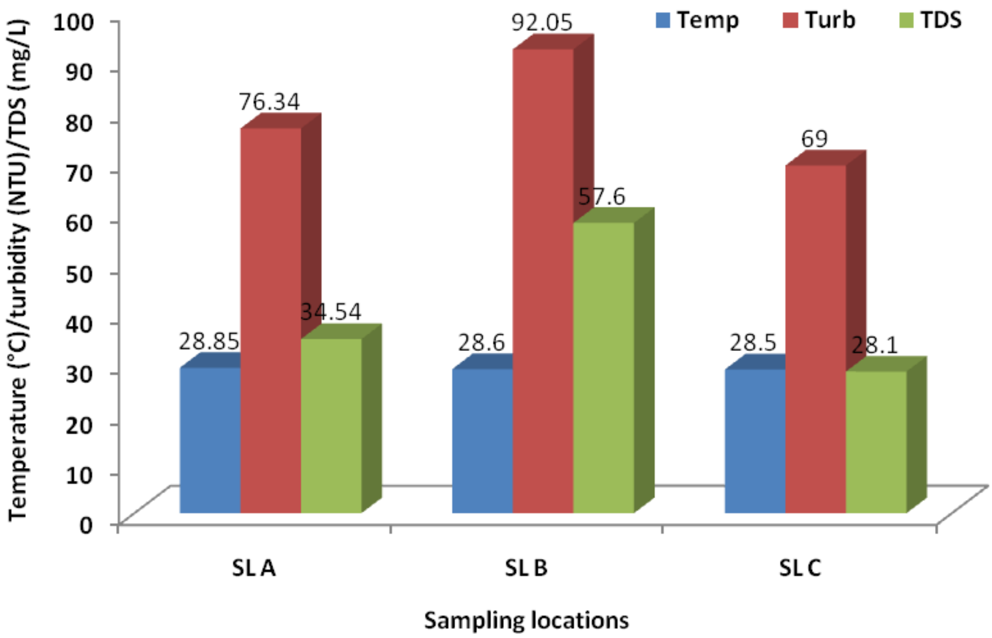

Fig. 4.1. Spatial variation in temperature, turbidity and total dissolved solids of Ogu-Bonny Channel

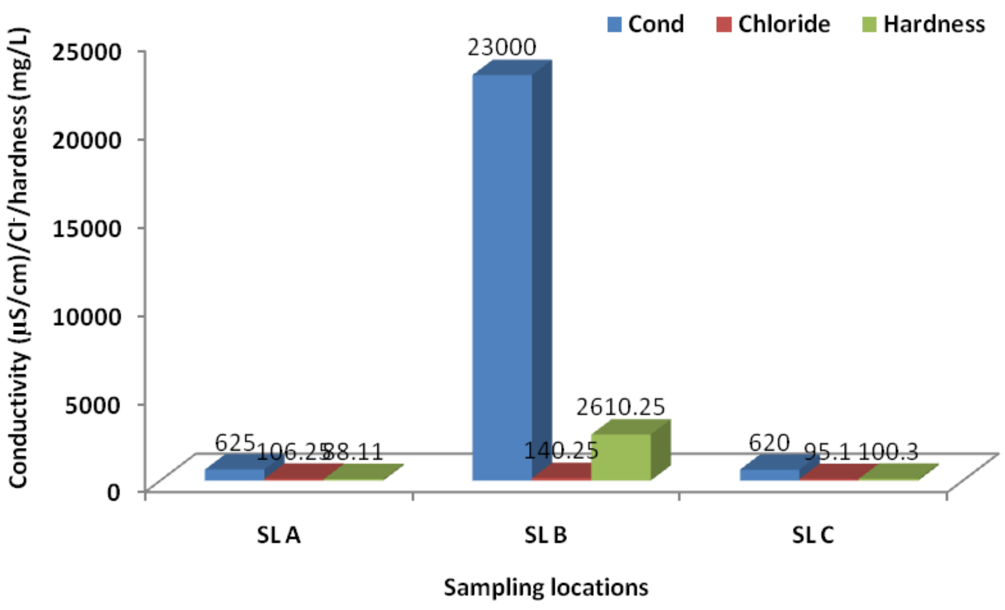

Fig.4.2. Spatial variation in conductivity, chloride ions and hardness of Ogu-Bonny Channel

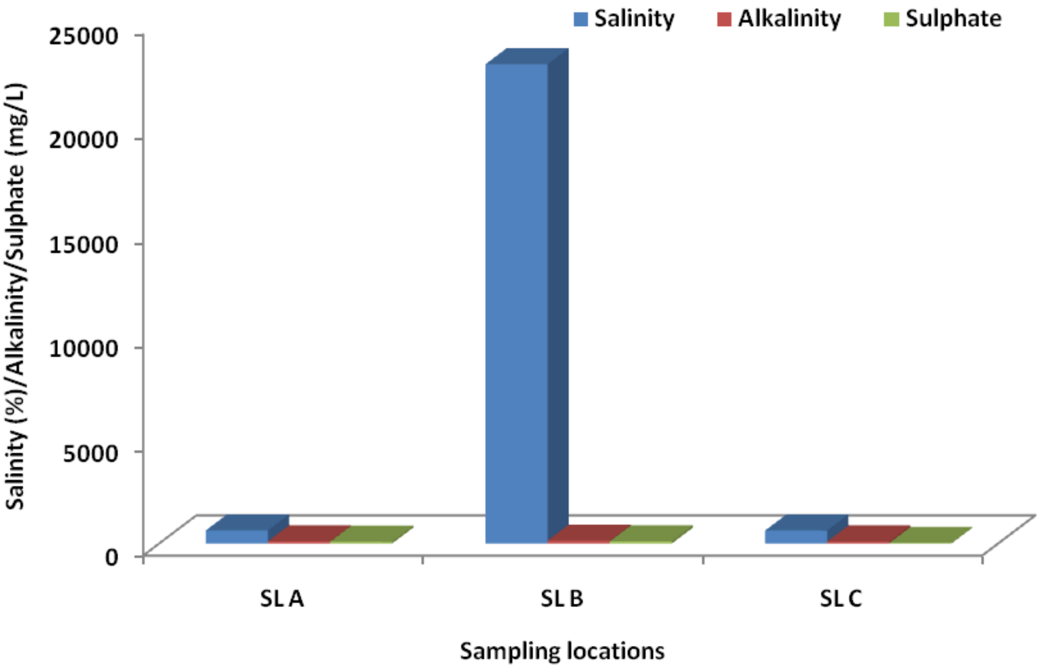

Fig. 4.3. Spatial variation in salinity, alkalinity and sulphate contents of Ogu-Bonny Channel

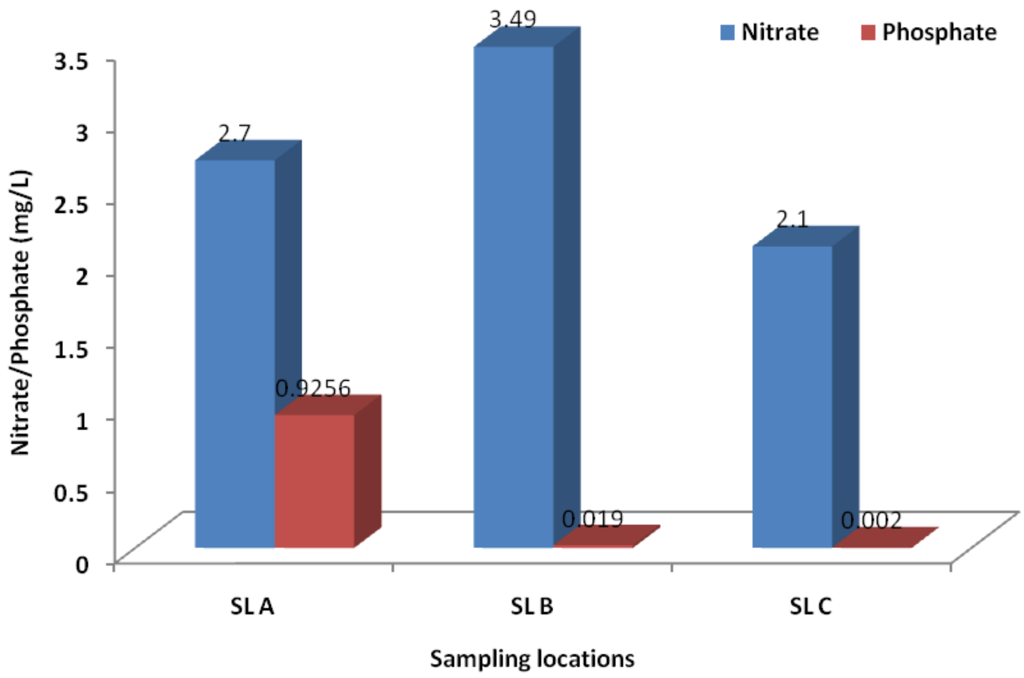

Fig. 4.4. Spatial variation in nitrate and phosphate contents of Ogu-Bonny Channel

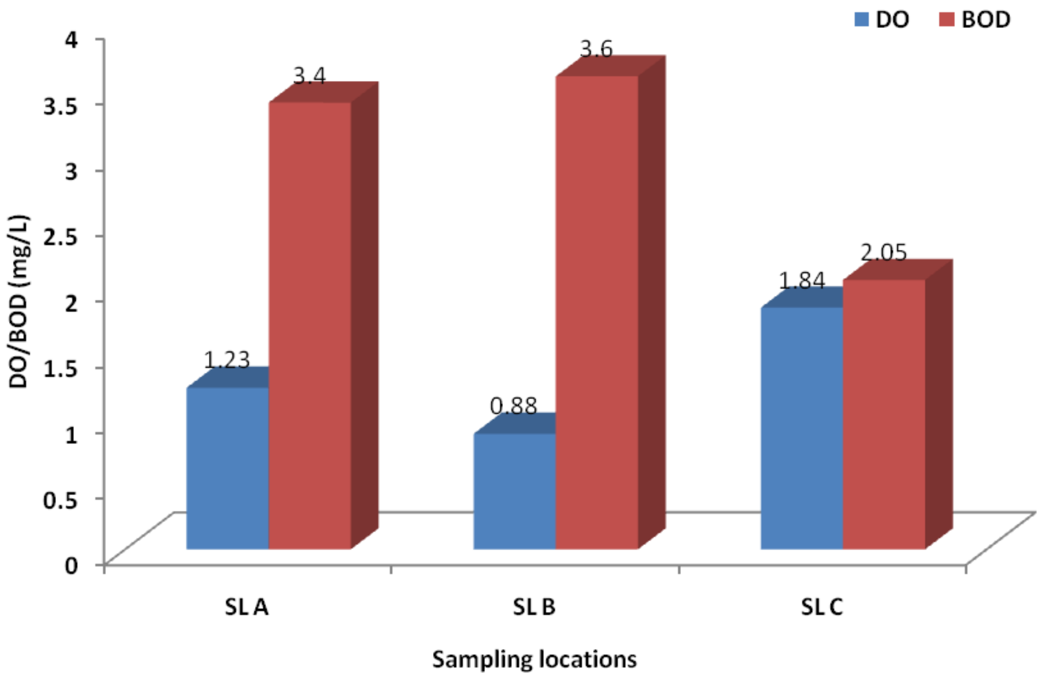

Fig. 4.5. Spatial variations in dissolved oxygen and biological oxygen demand of Ogu-Bonny Channel

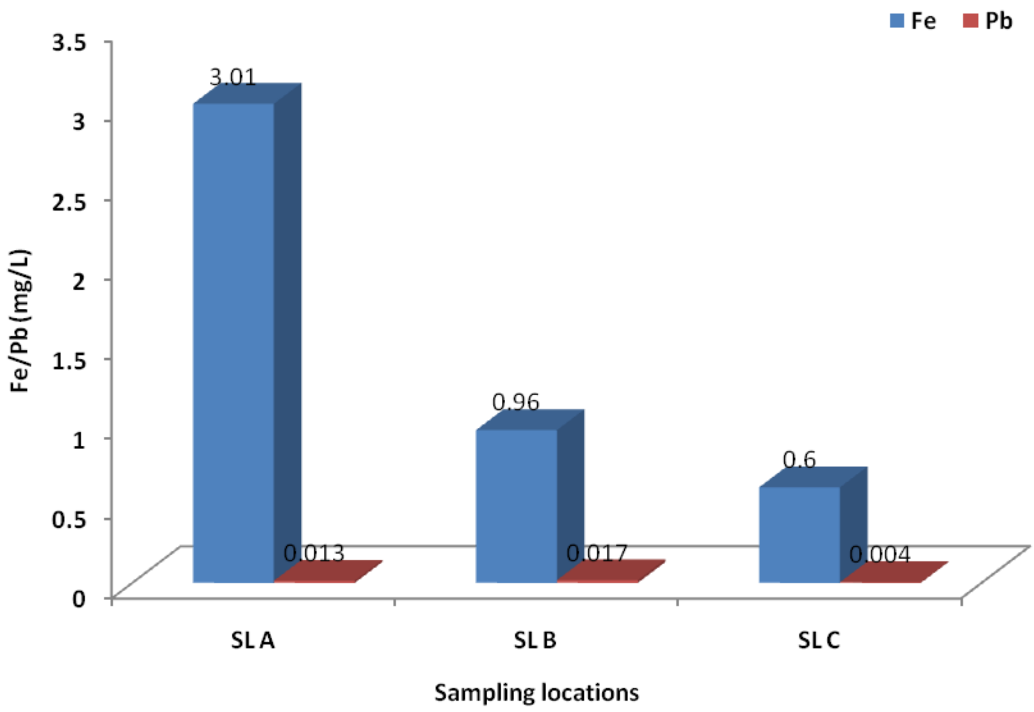

Fig. 4.6. Spatial variations in iron and lead contents of Ogu-Bonny Channel

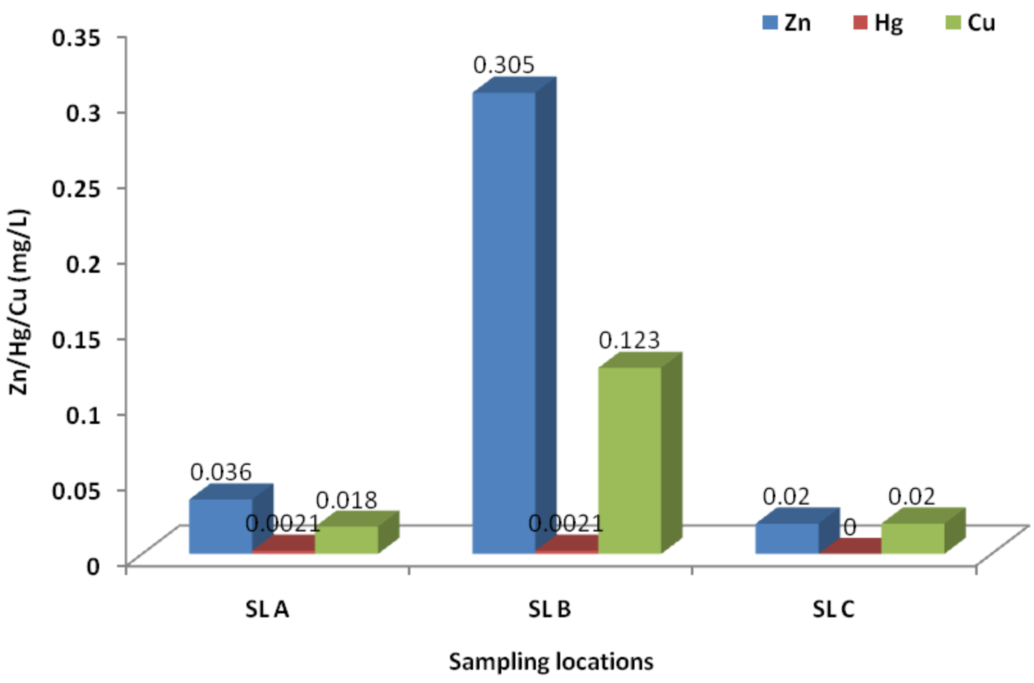

Fig. 4.7. Spatial variations in zinc, mercury and copper contents of Ogu-Bonny Channel

Table 4.2. Transport activities and incidents of pollution in Ogu-Bonny Channel

Transport activities	Associated pollutants	Mean occurrence (±SE)
Bunkering	Oil, sludge	13.6 ± 1.1
Accidental discharge of ship effluents	Oil, Bilge water	5.6 ± 0.5
Deliberate discharge of ship effluents	Oily ballast water	7.2 ± 0.6
Dumping	Garbage, plastic nylon	8.2 ± 0.6
Fishing trawlers	Fishing chemicals, oil	5.4 ± 0.5
Domestics	Garbage, nylon, etc	2120.9 ± 350.7
Bilging	Oil, heat	22.5 ± 6.8

SE = standard error of mean

4.4. Relationships between physicochemical parameters and Ports transport activities

Of the ports activities investigated, bunkering, accidental discharge of effluents, deliberate discharge of effluents, fish trawling, garbage, and bilging had significant influences on the physicochemical parameters measured (Table 4.3). At $P<0.01$, deliberate dumping of effluents correlated negatively with turbidity (r= -0.978), fisheries trawling correlated negatively with nitrate (r= -0.959), and garbage generations correlated negatively with BOD (r= -0.976). However, bilging correlated positively with total hardness (r= 0.992).

At $P<0.05$, bunkering correlated positively with Pb (r= 0.948), accidental dumping of effluents correlated with temperature (r= 0.881), deliberate dumping of effluents with DO (r= 0.957), and fisheries trawling activities correlated with DO (r= 0.896). However, deliberate dumping of effluents correlated negatively with TDS (r= -0.896) and sulphate (r= -0.906), while garbage generation correlated with sulphate (r= -0.948).

Table 4.3. Correlation (r) matrix of the physicochemical parameters and transport activities in Ogu-Bonny Channel

	Temp	Turb	TDS	Salinity	Cond	DO	BOD	PO_4^{2-}	SO_4^{2-}	NO_3^-	Cl^-	Alkal	Hard	Fe	Pb	Zn	Hg	Cu
Banking	0.227	0.469	0.636	0.451	0.463	-0.632	0.591	0.047	0.642	0.658	0.813	0.638	-0.119	-0.058	0.948*	0.748	0.515	0.732
ADofE	0.881*	0.081	0.112	0.112	-0.113	-0.480	0.668	0.770	0.622	0.317	0.245	0.020	-0.292	0.713	0.675	0.094	0.731	0.050
DDofE	0.023	-0.978**	-0.896*	0.149	-0.833	0.957*	-0.876	0.241	-0.906*	-0.862	-0.832	-0.845	-0.529	0.102	-0.735	-0.780	-0.776	-0.749
Dumping	-0.560	-0.436	-0.257	0.347	-0.199	0.642	-0.760	-0.445	-0.708	-0.444	-0.085	-0.105	-0.506	-0.649	-0.201	0.067	-0.839	0.118
FTrawl	-0.214	-0.737	-0.818	-0.378	-0.754	0.896*	-0.807	0.013	-0.870	-0.959**	-0.718	-0.721	-0.696	-0.101	-0.639	-0.557	-0.802	-0.527
Garbage	-0.643	-0.599	-0.529	0.101	-0.361	0.873	-0.976**	-0.453	-0.948*	-0.685	-0.520	-0.410	-0.228	-0.544	-0.748	-0.368	-0.992**	-0.315
Bilge	-0.370	0.667	0.666	0.155	0.782	-0.542	0.346	-0.502	0.424	0.682	0.417	0.612	0.992**	-0.300	0.028	0.354	0.320	0.350

***= Significant at P<0.05, **= Significant at P<0.01, Turb= turbidity, Cond= conductivity, Alkal= alkalinity, Hard= hardness, ADofE= accidental discharge of effluents, DDofE= deliberate discharge of effluents, FTrawl= fishing trawlers**

CHAPTER FIVE

5.0 DISCUSSION, SUMMARY AND CONCLUSION

5.1 Discussion

According to Adakole *et al.* (2003), the quality of any water body is governed by its physicochemical factors. The monitoring of these factors therefore is vital for both long and short term environmental management (Wood, 1995). The distribution and productivity levels of organisms are largely determined by physicochemical factors in aquatic ecosystems (Adakole *et al.*, 1998). Consequent upon this, Spaak and Bauchrowitz (2010) asserts that anthropogenic environmental changes affect natural biodiversity. Accordingly, several authors have investigated 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).

According to the UNEP GEMS (2006), 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 is important in aquatic systems because it can cause mortality and can also influence the solubility of dissolved oxygen and other materials in the water column (e.g. ammonia). The narrow variation recorded in temperature of this study is suitable for aquatic organisms, since they have narrow temperature tolerance, even as the temperature range is similar to many other waters of the Niger Delta area (NADECO, 1980; SPDC, 1998). 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 (UNEP GEMS, 2006).

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 municipal, agricultural, and industrial discharges into the Channel may have contributed further ions to the receiving Port.

The wide variation recorded for SO_4^{2-} is attributed to increased inputs 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 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), where increased nutrient concentrations lead to increased primary productivity (Ogbuagu and Ayoade, 2011a).

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). Albeit, the alkalinity recorded in the current study were below permissible limits and so do not pose significant regulatory concerns, in the least. Recorded values for alkalinity were similar to those observed in tropical waters by Ombu (1987), Hart (1994), Yakubu *et al.* (1996), Mansi (1997), and Ikoma (1999).

Dissolved oxygen (DO) is one of the most important components of aquatic systems. This is because oxygen 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. Many aquatic ecosystems rely heavily on external subsidies of organic matter to sustain production. However, 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 on its part reflects the degree of organic matter pollution of a water body. 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. Albeit, the DO and BOD of the current study did not indicate pollution of the Channel during the study period.

Turbidity refers to water clarity. 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. High turbidity could reduce primary production by the autotrophic algae, and thus, reduce the biotic diversity and abundance through trophic impairments (Ogbuagu and Ayoade, 2011b). Though turbidity was not specified by the FME for aquatic life, comparatively high values in this study could impair aquatic productivity of resident biotypes.

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 Fe and Zn, as well as concentrations of Cu that is outside regulatory limits portends grave consequences to public consumers of sea foods from this Channel and its surrounding water bodies.

The chloride ion contents in water supplies could indicate salt water intrusion, sewage or other pollution. The chloride ion contents of surface and well waters ranges usually from 5 to 200mg/l, while sea water content is about 19,000mg/l (UNEP GEMS, 2006). Drinking water supplies should not contain more than 250 mg/L chloride ion. 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.

Hardness is caused by the presence of calcium and magnesium salts in the water. Polyvalent metals ions (aluminum, iron, manganese, strontium and zinc) may be included in the hardness. According to Chapman (1992), hardness variation in natural waters reaches lowest value during high flow condition e.g. river action. As results show here, mean value of hardness of 1099.40 mg/L places the Ogu-Bonny Channel as very hard.

The observed relative higher concentrations of the parameters in sampling location B indicates accumulative pollution from catchment or adjoining areas, unlike the more pristine location C. However, the observed equality in spatial variation of the physicochemical parameters indicates non-existence of microhabitats along the gradient of the Channel under lotic influences that encourage mixing effects. The stretch of the Channel is exposed to various activities such as the introduction of varying domestic and industrial wastes, as well as runoffs from dumpsites in the area. Other atmospheric and urban wastes are also introduced at different segments of the Port. According to the UNEP GEMS (2006), water quality is neither a static condition of a system, nor can it be defined by the measurement of only one parameter. Rather, it is variable in both time and space and requires routine monitoring to detect spatial patterns and changes over time.

The Ports transport activities that showed significant correlations have also been previously associated with pollution (NRDC, 2011; CARB, 2000; The Ocean Conservancy, 2002; Mitchell, 2001). The observed direct correlation between bilging and hardness indicates that the ports activity introduced carbonates of Ca^{+} and Mg^{+} ions. That between bunkering and Pb indicates that this activity introduced the trace metal, even as accidental dumping of effluents introduced hot effluents capable of elevating the temperature of the water. Deliberate dumping of effluents also introduced sulphate ions, though garbage did not encourage the presence of the same ions. Albeit, results rightly indicate that ports transport activities could pollute waterways.

5.2. Summary and Conclusion

The Ogu-Bonny Channel serving the Port Harcourt Ports revealed wide variations in conductivity, sulphate and chloride ions, as well as total hardness during the sampling period. However, narrow variations were observed in temperature, salinity, DO, BOD, and the nutrients. 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 Fe, Zn, and Cu, the other physicochemical variables measured fell within recommended limits of water for aquatic life by the Federal Ministry of Environment.

There was no significant spatial variation in the physicochemical parameters of the Channel. Bilging, bunkering, accidental and deliberate dumping of effluents, and bilging contributed to pollution of the waterway. While bilging and banking encouraged total hardness and presence of Pb in the water column, accidental dumping of effluents and fish trawling/deliberate dumping of effluents encouraged elevated temperature and DO, respectively. BOD values recorded in the study indicates some degree of organic pollution of the waterway.

5.3. Recommendations

Sequel to the research finding of the current study, the following recommendations are made:

1. The Environmental Pollution Monitoring Department of the NPA should enforce compliance to reductions in bilging, bunkering, deliberate and accidental dumping of refuse from Vessels.
2. The State environmental protection agencies (SEPA) should develop practicable standards and regulations for the protection of the waterways.
3. SEPA should mount regular surveillance to prevent further pollution of the Channel.
4. Current approaches by the Pollution Control Department of the Nigerian Ports Authority (NPA) aimed at reducing significant pollution should be maintained.
5. Further studies should include microbiological and plankton enumerations, as well sediment chemistry to properly assess the current status of the waterway.
6. Basic personal and environmental hygiene should be made known to the people to safeguard their health as well as the environmental resources.

7. The companies involved in polluting the river either through effluent discharge or waste dump at coastlines should ensure adequate treatment with best available technology (BAT) to permissible limits before discharging.

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APPENDIXES

Appendix 1: Physicochemical characteristics of Ogu-Bonny Channel in Onne during the sampling period

Parameters	Sampling Locations				
	SL A		SL B		SL C (control)
	1	2	1	2	
Temperature (°C)	28.8	28.9	28.6	28.6	28.5
Turbidity (NTU)	80.51	72.17	92.50	91.60	69.00
Total dissolved solids (TDS) (mg/L)	33.40	35.67	57.20	58.00	28.10
Salinity (%0)	35.20	36.72	36.30	36.25	36.20
Conductivity (µS/cm)	500	750	25000	21000	620
Dissolved oxygen (DO) (mg/L)	1.25	1.20	0.85	0.90	1.84
Biological oxygen demand (BOD) (mg/L)	3.50	3.30	3.61	3.60	2.05
Phospahte (PO_4^{2-}) (mg/L)	0.801	1.050	0.020	0.017	0.002
Sulphate (SO_4^{2-}) (mg/L)	83.20	80.60	100.00	98.42	21.70
Nitrate (mg/L)	2.50	2.90	3.60	3.37	2.10
Chloride (Cl^-) (mg/L)	102.00	110.50	130.50	150.00	95.10
Alkalinity (mg/L)	12.50	13.10	20.00	21.50	12.20
Total hardness (mg/L)	75.80	100.41	5000.00	220.50	100.30
Iron (Fe) (mg/L)	2.95	3.07	1.30	0.61	0.60
Lead (Pb) (mg/L)	0.011	0.014	0.012	0.021	0.004
Zinc (Zn) (mg/L)	0.032	0.040	0.210	0.400	0.020
Mercury (Hg) (mg/L)	0.0021	0.0020	0.0022	0.0019	0.0000
Copper (Cu) (mg/L)	0.015	0.020	0.086	0.160	0.020

Appendix 2. Standards for water quality: Aquatic life

Parameter	Permissible Limit Standard
Temperature (ºC)	20-33ºC
Turbidity (NTU)	NS
Total dissolved solids (TDS) (mg/L)	NS
Salinity (‰)	NS
Conductivity (µS/cm)	NS
Dissolved oxygen (DO) (mg/L)	6.8
Biological oxygen demand (BOD) (mg/L)	4.0
Phosphate (mg/L)	NS
Sulphate (mg/L)	NS
Nitrate (mg/L)	NS
Chloride (mg/L)	NS
Alkalinity (mg/L)	NS
Hardness (mg/L)	NS
Iron (Fe) (mg/L)	1.0
Lead (Pb) (µg/L)	
Zinc (Zn) (mg/L)	0.03
Mercury (Hg) (mg/L)	NS
Copper (Cu) (µg/L)	2.0-4.0
BOD at 20-25 ºC (mg/L)	0
DO at 20-25 ºC (mg/l)	7.5

(Source: FME, 2001), NS = No specification

Appendix 3: Test of homogeneity of variance using single factor ANOVA

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	60	30496.04	508.2673	8885479
Column 2	60	120	2	0.677966

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7689197	1	7689197	1.730733	0.190868	3.921478
Within Groups	5.24E+08	118	4442740			
Total	5.32E+08	119				